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Foreword

Dear readers,

It is my great pleasure to introduce You the research papers of the Eighth Symposium on Graphic Engineering and Design. With this proceeding we continue the works of previous symposiums which have been held biennial since year 2002.

We're delighted that this international symposium has again a great number of the papers and participants coming from many countries.

The papers include the achievements of researches in the field of technology and scientific areas relevant to graphic technology and graphic design. Through the work of the symposium GRID we continued significant scientific cooperation with educational institutions all over the Europe, especially with the neighbouring countries in the region. With them we are continuing good cooperation which is the driving force for the creation and display of new developments, both individual and common.

I want to thank everyone who participated with their paper and presentation in the symposium. Your contribution is significant for the improvement of the Symposium on Graphic Engineering and Design GRID 16. The research achievements here presented are also valuable to the scientific and professional community and are highly appreciated.

Editor

SMART FACTORY: JDF AND XJDF

Thomas Hoffmann-Walbeck
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Abstract: *In this paper the relation between "Industry 4.0" and the metadata formats JDF/XJDF are discussed.*

Key words: JDF, XJDF, PDF, Metadata, Print Production, Industry 4.0

1. INTRODUCTION

Smart Factory is a general research concept concerning automation of industrial production processes. This term is part of the "Industry 4.0" initiative, the future project of the German government. One of the main features is the data exchange between machine interfaces based on internet technologies as discussed in section 2.
To stress the industrial character of print production, we will state some of the results of the Smithers Pira report (Pira, 2016) in section 3.
In section 4 the basics of data structure of the Job Definition Format (JDF) is presented. It will be shown that JDF constitute important parts of industry 4.0 in the Graphical Industry. The demand for production efficiency and market concentrations of print services promoted this metadata.
But nevertheless, it is very likely that JDF will be replaced by a new format in the future, the "XJDF" as it is denoted for the time being. Section 5 will outline the differences between the two formats, the motivations for the redesign of JDF and their relations to "Industry 4.0".

2. SMART FACTORY AND INDUSTRY 4.0

The biggest challenge for the current industrial production is flexibility. In the past the productivity of mass production has been risen by fixed automation solutions. Nowadays, however, the production of many variants of customized products in small series becomes increasingly important. A paradigm shift is now expected - from centralized control toward a flexible, decentralized coordination of autonomous operations. The term "Industry 4.0" defines the vision of such production environments, where customer orders control their individual production, book their production machines and their material and finally organize their delivery to the customer (Spath, 2013). Future, self-organizing and interconnected manufacturing plants might determine and configure their components and tools independently. See e.g. (Spath, 2013) and (CIP, 2013).
This metamorphosis of production methods might be cutting-edge technology for the industry in general, for the Graphic Arts Industry, however, it is not. For most print service providers diversity of variants and short run-lengths are daily routine.

3. THE FUTURE OF GLOBAL PRINTING TO 2020

Some people still consider printing as an art, not as an industrial method. Others believe that the printing sector is suffering because of the rise of electronic media so much that phasing down business is more relevant now than improving the effectiveness of print production. Finally, some people claim that the conventional printing will be dying since in the near future everything will be printed digitally. Thus, is it worth the effort to change conventional production methods these days?
Actually, all statements above do not hold globally as we can learn from Smithers Pira report on Printing (Pira, 2016). According to this source, the worldwide revenue with printed material was 876 billion USD in 2015 and will grow to 876 billion USD in 2020. In comparison, the global sales amount in Mobile App Stores according to the study "Mobile App Market Forecast 2016" (App Annie, 2016), written by the Californian company App Annie, will total to 41 billion USD in 2016. This corresponds to five percent of the printing market.

These results may surprise some people. Had not many printers fell into insolvency in recent years? The resolution of this apparent contradiction lies in the increasing industrialization of the printing processes, which has led to an increase of efficiency and concentration. This is still going on, of course.
The subjective perception that "print is dead", is also influenced by the diverging developments of individual product segments. For example, the analysts from Smithers Pira foresee a decline of 16% in sales for newspapers from 2015 to 2020. These numbers are dramatic and they might concern journalists. For the printing industry as such, they represent a fall from 5 to 4 percent share for the newspaper segment. The global increases in packaging printing will compensate this loss easily. According to the analysts the market shares of the label and packaging production will increase by 6% and reach 53% in 2020.
Another factor for the misconception could be the regional differences in development. Revenues from 2015 to 2020 in Europe will stagnate at a high level (175 billion USD), but there will be a significant market growth in Asia.
Smithers Pira has also analyzed the prospects of different printing technologies. While sales in the product manufacturing with conventional printing methods such as flexographic, offset or gravure will increase only marginally from 703 billion USD in 2015 to 715 billion USD in 2020, the revenue with (so called) digital printing will grow in this period from 120 billion USD to 161 billion USD. Thus, the market share of digital printing in terms of sales will grow from the current 15% to 18%. When the amount of printed surfaces is taken as a basis for the calculation, the global market share of digital printing will increase from 2.5% today to 3.6% in 2020.
Overall, it is clear that the conventional print production will remain a powerful industry in the near future. Of course, in the Graphic Arts industry strong structural changes are taking place currently, like in most other industrial sectors.

4. JOB DEFINITION FORMAT (JDF)

The Job definition format (JDF) (CIP, 2013) has been published in 2001 and formed the basis for the data concept of the smart factory in the printing industry ("Printing 4.0"). To show that, let us summarize the main features.
With JDF one can describe the projected product itself, as well as the processes that are needed to produce the product and its product parts. The processes can be aggregated to "Process Groups". All product (parts), process groups and processes are described by XML nodes with the tag-name "JDF". They are called "JDF nodes". The JDF nodes are structured as a tree, whereas the root typically represents the product itself and the children product parts and/or processes and process group nodes. The processes nodes and/or process group nodes that are descendants of a product node describe the processes concerning the production of the product or product part.
Typically, the MIS initiates writing JDF data and generates the product node and product part nodes for a job order. It can also define processes and process groups, but since the MIS would not know much about the technical details of the required production processes, it only can do that in a superficial manner. During the production, other devices will add the necessary details as well as the results of the process execution (status, used resources and the like). That is, the JDF data enlarges during production. In the end, the JDF will contain all settings of the production workflow, provided all components are JDF savvy.
The JDF workflow representation is based on the "process-resource-model". A process is an activity, while resources are either physical entities (paper, plates, ink…) or electronic data (PDF files, images, profiles, parameter sets…). These resources are either input or output resources for a JDF node. An input node for a process node is an entity that is needed for the execution of the process, an output resource is the outcome of the process. An input resource for a product node is called "intent resource", because it describes the customer's intention of the printed product.
Most resources are referenced by two or more JDF nodes. An output resource of a process node, for example, may be an input resource for another process. The main idea of automation using JDF metadata is that devices can execute processes automatically, if all input resources are available, the device is idle and the production window (time span) is met. But since it is not advisable to have different copies of a resource in the JDF data, a resource can be "anywhere" in the JDF data and is not necessarily placed inside a JDF node that refers to the resource. Inside a JDF node, however, the references of this node must be specified via an unambiguous identifier.
One way to communicate JDF data is that it can be sent (as a file) from device to device. Each device then extracts the information from the file (typically one or more JDF nodes and all resources that are needed)

and adds new entries into the file (e.g. operational data). This linear fashion of passing JDF data around could be enhanced by parallel distribution, since JDF allows locking parts of the data, so that there is no update of JDF data needed from two different devices concerning the same data part.
This architecture is getting close to the ideas of industry 4.0, which has been postulated more than a decade after the specification of JDF. Even plug-and-play features are part of the JDF specification (though still far away from implementation) as well as descriptions of device capabilities.
Sending JDF from device to device, however, is not really common. Most devices are rather controlled by one or several JDF controller. These controller pass along individual and appropriate JDF data to each device and integrate the data they receive from the devices. This relieves the devices from the burden of understanding and managing the entire workflow and the controller might have other means (like private data bases) to determine the production workflow. This architecture, however, moves away from the vision of Industry 4.0.

5. XJDF (JDF 2.0) COMPARED TO JDF

XJDF is a redesign of JDF that is currently going on. JDF is a very powerful, but in the same time quite a complex language. There are node hierarchies to be observed, there are resources to be searched for in the data and there is a bundling of product and process descriptions. And JDF even is not pure XML any more, e.g. properties of so-called "Partitioned Resources" can be inherited. Thus JDF is hard to interpret, expensive to implement and prone to incompatibilities. Because of this complexity change orders and ganging are hard to implement in JDF. In particular, since a controller usually defines the production workflow internally in private data bases anyway, there is no need to describe the entire production workflow in XML as well. XJDF will become an interface language between a controller and a device only. Or, to say it in more general terms, XJDF is a communication protocol between two applications. This makes things a lot easier, especially for the devices. Any device receives only a single process node now, which contains all resources it needs for executing the process. References to resources outside the process node are not needed any longer. Change orders should be easier to handle, since now it is only necessary to send updated XJDF data to the device that needs to know about it. Also, XJDF is pure XML, so that standard XML tools can be used for handling JDF.
With XJDF there is no more fixed connection between product description and production processes. This will make the description of ganging jobs easy. Also, in future times, one might store product description outside of XJDF altogether. The product description might be stored together with the page description in PDF or PDF/VT (ISO 16612-2, 2010), while XJDF might only contain production description.

6. CONCLUSIONS

The JDF specification has anticipated the vision of "Industry 4.0". The current implementation of JDF-based workflow software, which predominantly can be found in offset and in digital printing, moves away from the idea of decentralization. This will be the case even more so for XJDF. It will be interesting to observe, if the vision of "Industry 4.0" will also recollect the concept of centralization in the years to come.

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TRENDS IN PRINTING INDUSTRY

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Abstract: *The aim of this paper is to present current trends in printing industry. This industry have experienced more fundamental changes in the last 20 years than in any similar period since Gutenberg. Last five Drupa fairs ware proving ground for digital printing and the future will definitely be digital. At Drupa 2016. we saw developments in heavy duty high quality and high volume ink jet presses in each segment of printing industry (sheetfeed and webfed, commercial, publishing, object, industrial, packaging, etc.). This reflects the market trend as during 2015 a big increase of digital printing happened and it has positioned itself in top 3 printing technology investments in all areas of the industry. This trend is expected to continue in the future. Smithers Pira projects a positive outlook for the print and printed packaging markets, with annual growth of 2% per year to 2020.*

Key words: printing industry, turnover, SWOT analysis, future trends

1. INTRODUCTION

Drupa 2016 is behind us. In 19 exhibition halls, 1,828 exhibitors from 54 countries presented new forward-looking concepts, best-practice business models, and technological innovations to 260,165 visitors from 183 countries and 1,824 journalists from 73 nations (Drupa, 2016).
The development in visitor attendance (2012: 314,248) reflects the worldwide consolidation occurring in the industry. This is why visitors' high decision-making competence had a particularly positive effect, all the more as every second visitor expected their company's business to develop very well over the next twelve months (Anon, 2016).
With 76% participation of international visitors at Drupa 2016 it increased by 16% compared to the 2012. Attendees from. Most of the visitors were form printing (54%) and packaging (11%) industry and they were in most cases from sheet fed offset and digital printing sectors with minority coming from flexographic and screen printing. A small number of visitors were from gravure, letterpress and other print sectors (Drupa, 2016).

Table 1: Drupa attendance (Drupa, 2016)

Drupa-year	Visitors	Exhibitors from countries
1951	195185	527 from 10
1954	226388	764 from 13
1958	185936	688 from 13
1962	180483	678 from 16
1967	214694	945 from 19
1972	268713	958 from 27
1977	284806	1108 from 22
1982	293059	1275 from 29
1986	373656	1465 from 33
1990	444214	1760 from 36
1995	385098	1670 from 44
2000	428248	1943 from 50
2004	394478	1866 from 52
2008	389993	1968 from 53
2012	314500	1844 from 52
2016	260165	1828 from 54

This Drupa was „digital printing Drupa", a fifth in a role overwhelmingly oriented towards digital technology. 1990 and 1995 already saw a plenty of digital innovations, particularly in the areas of data exchange and CtP. Ecommerce infected Drupa 2000, Drupa 2004 was characterized by workflow and press automation, jdf, lower-cost technologies such as small format CtP, process less plates and digital proofing and high speed mono inkjet. In 2008 inkjet proved its potential as the mature technology in terms of print quality, speed and cost (Augustin, 2016).
In Drupa 2016 we saw developments in heavy duty high quality and high volume ink jet presses in each segments (all printing applications, sheetfeed and webfed, commercial, publishing, object, industrial, packaging printing). Although, some of products introduced the latest nano and 3D presses, we must say that most interest was given to equipment extending existing commercial and packaging printing operations with complementing technologies.

2. PRINTING INDUSTRY - PAST, PRESENT, FUTURE

Traditional print markets have experienced more fundamental changes in the last 20 years than in any similar period since Gutenberg.
In 2015, printing industry achieved an estimated sales volume of US$ 760 billion. Table 2 shows sharing of global print market by printing sectors.

Table 2: Global Print Market by Product (Augustin, 2016)

Total Sales Turnover 2015	US$ 760 billion	
Commercial Printing	US$ 230 bn	30%
Packaging Printing	US$ 230 bn	30%
Publication Printing	US$ 180 bn	24%
Other	US$ 120 bn	16%

From table 2 we can see the same percentage for commercial and packaging printing with Publication printing below this level.
Table 3 show us global print market by region, Asia-Pacific area has biggest percent of total turnover, caused by the population numbers in the region. Although Europe as well as North America have less inhabitants then Africa, they are in the second and third places by total sales.

Table 3: Global Print Market by Region (Augustin, 2016)

Total Sales Turnover 2015	US$ 760 billion	
Asia-Pacific	US$ 240 bn	31,7%
Europe	US$ 218 bn	28,7%
North America	US$ 216 bn	28,3%
Latin America	US$ 68,4 bn	9%
Middle East	US$ 10 bn	1,3%
Africa	US$ 7,6 bn	1%

If we compare two richest region (Europe and US), we can find similar trends on the market. For example, during 2000 in European Union there were 134000 enterprises with 850000 employees and a sales turnover of US$ 238 billion. Today, in EU there are 118000 enterprises (-12%) with 680000 employees (-20%) and a sales turnover of US$ 228 billion (-4%). USA market shrank from 45000 enterprises, with 816000 employees and a sales turnover of US$ 124 billion to 26000 enterprises (-43%) with 446000 employees (-46%) and a sales turnover of US$ 887 billion (-30%). Total printing industry revenue decreased by 12%. At the same time, consolidation led to 40-50% increases in the average revenue per employee, without significantly improving profitability (Augustin, 2016). Concerning printing techniques used in production, Global Trends survey in spring 2014 reports change in demand for conventional (non-digital) print volume over the last 5 years. 46% reported a decline in demand versus 21% who reported an increase, a negative net balance of 25%. The result was almost identical across all regions [range 20-29%]. However the pattern varied between sectors, with a negative net balance in demand for packaging at 14%, commercial print at 33% and publishing at 42% (Drupa, 2014).

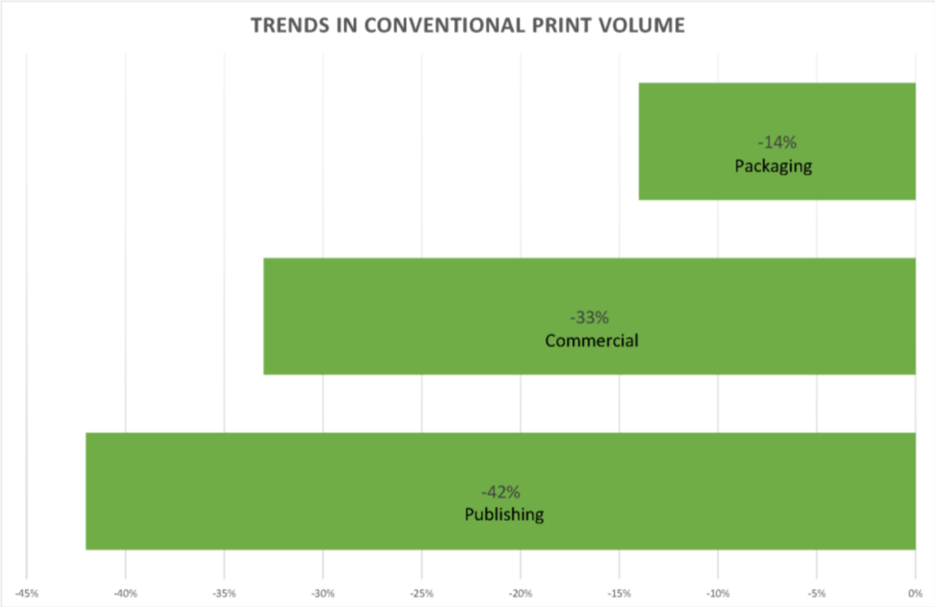

Figure 1: Trends in conventional print volume

As for demand for printing substrates over the same period, there was a striking variation in demand across the different substrates. For paper, a global net balance of 9% reported a decline in demand. However there were regional variations with most regions reporting a reduction in demand (ranging from North America with a net balance of 8% to Australia/ Oceania with 24%) but three developing regions with positive net balances i.e. still reporting growth (Middle East 8%, Africa 9%, Asia 22%). On other substrates, there were net balances in favour of growth in demand for carton board of 12%, for flexibles (plastics) of 22%, for metal/glass of 4% and 5% for fabrics (Drupa, 2014).

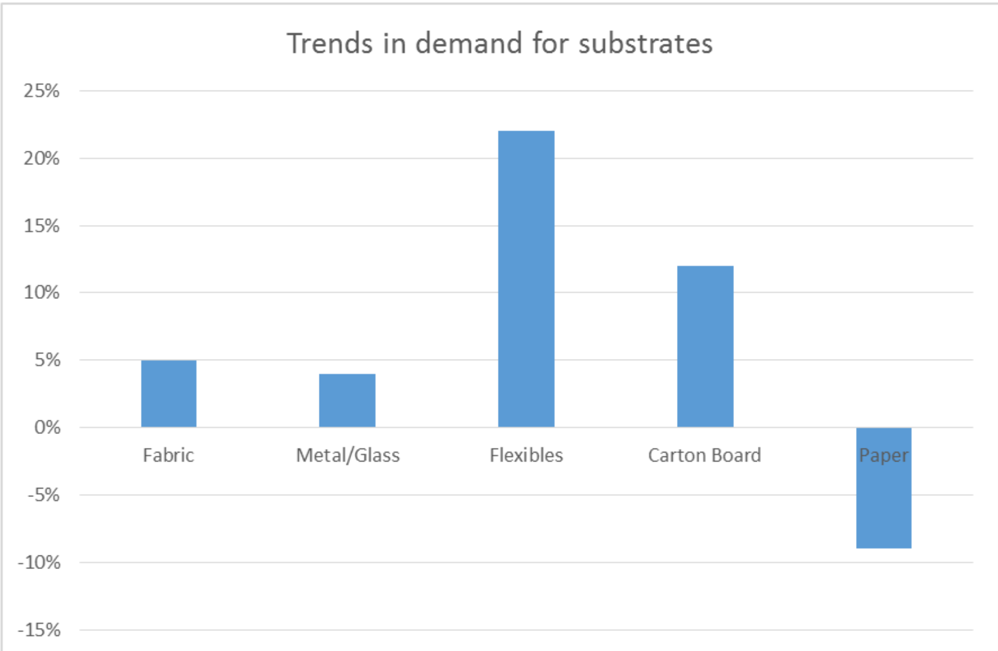

Figure 2: Trends in demand for substrates

The reduction in demand for print we are currently experiencing can be easily explained by the global financial crisis and the significant impact of digital media. However the reality is infinitely more complex and the root causes can be tracked back over half a century.

The digital technologies (particularly cutsheet colour + 28%) that dominate in terms of growth in print volume. There is still growth in sheetfed offset, thanks to publishing (net positive balance of +7%) and packaging (+12%). The growth in flexo and gravure from packaging (+18% and +3% respectively) and the growth of screen printing in functional prints (+11%) (Drupa, 2016 a).
The trends in conventional printing continue with ever-shorter run lengths, reduced lead times and some signs of a slowdown in the growth of the number of jobs. As for digital printing, there is a steady increase in the volume and value of the prints, with the exception of packaging where only 13% reporting that it represents more than 25% of turnover compared to 35% for commercial, 24% for publishing and 59% for functional. (Drupa, 2016 a).
More disappointing to report is that for the second year running there is no significant global increase in either the proportion of Web to Print installations (25% 2015, 26% 2016) or in the volume of business being processed through them. North America as a region and the Functional print market are the clear exceptions.

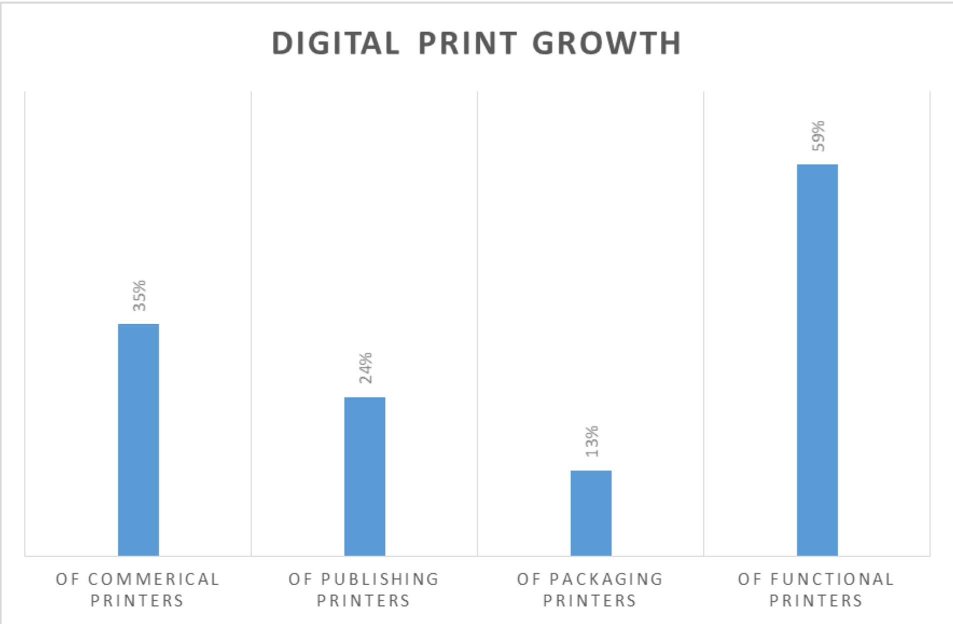

Figure 3: Proportion of digital print that is variable data by value

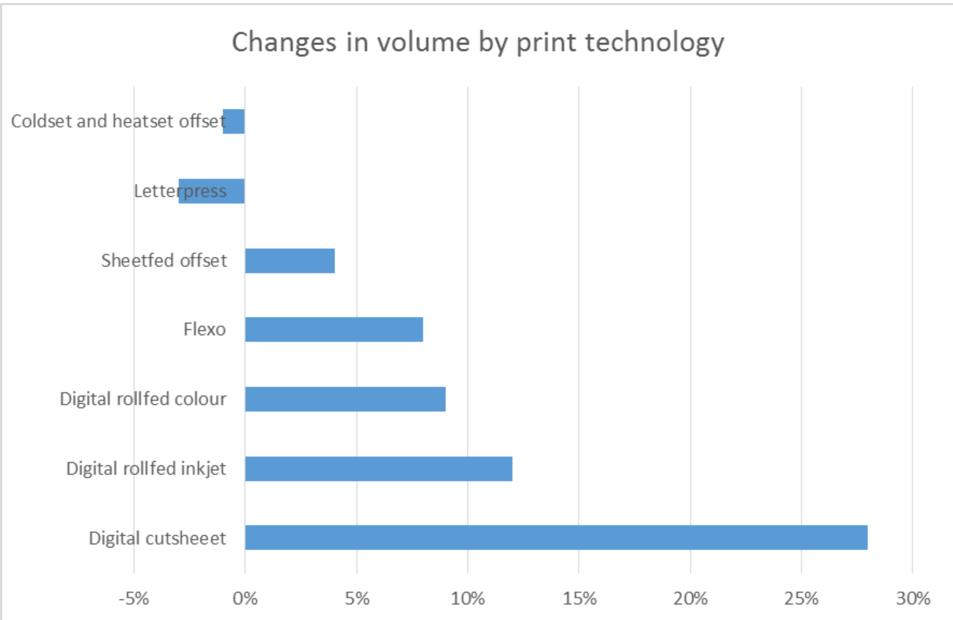

Figure 4: Changes in volume by print technology

Despite or because of the challenging market conditions both printers and suppliers remain committed to good levels of capital expenditure. In market terms, functional leads with a net balance of 41% reporting increased expenditure in the last 12 months, followed closely by packaging at 36% then commercial at 26% and publishing at 19%. Similar pattern is planned for the next year. Printing technology is the priority followed by Finishing and PrePress/Workflow/MIS (53%, 50% and 38% respectively) (Drupa, 2016 a).
In terms of investment in print technology, Digital cutsheet colour is the most popular choice for three of the markets (45% commercial, 38% publishing, and 48% functional) but comes third for packaging at 17% behind Flexo at 30% and Sheetfed offset at 26%. Sheet fed offset is also second choice for commercial printers (23%) and publishing printers (28%). Digital rollfed inkjet comes third for commercial at 16%, publishing at 14% and functional at 24% (Drupa, 2016 a).
Suppliers have continued to invest in most regions (exceptions being S/C America and Australia/Oceania in 2015) and plan to do so again next year. 42% stated their first priority was to develop new sales channels, followed by 31% who were developing new products or enhancing existing products. Encouragingly there was a positive net balance of 16% reporting an increase in Research and Development expenditure (Drupa, 2016 a).
Both printers and suppliers face rapidly changing markets and generally tough economic conditions. But the key underlying change for at least the commercial and publishing markets is the rapid and largely irreversible adoption of digital communications. All printers listed the key constraints are the lack of sales and the consequential strong competition. As for the lack of sales there was broad agreement that the challenge of finding new customers was the toughest challenge followed by that of finding good sales staff. The third most commonly reported constraint was lack of demand for conventional print, but here opinion was sharply divided between Commercial (39%) and Publishing (43%) printers and Packaging (22%) and Functional (24%) printers (Drupa, 2016 a).

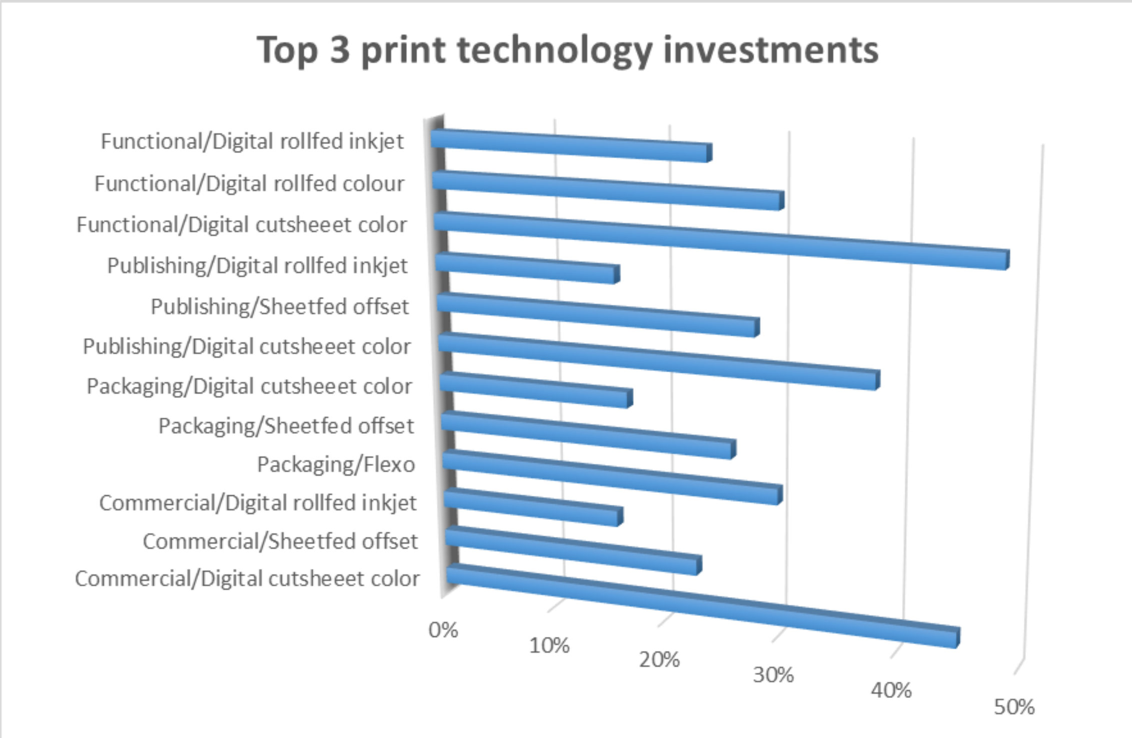

Figure 5: Top 3 print technology investments

In commercial printing, we can see slow progress in diversifying.
Given the severe decline in core print products, it is often the 'new' added value print applications that offer fresh opportunities for growth. It is therefore disappointing to report that with the exception of North America, the proportion of commercial printers that offer these added value services has not significantly increased over the last three years. 38% offer multichannel services globally with North America 45% and the rest of the world just 22%, probably reflecting the slower growth in use of the Internet in some regions (Drupa, 2016 a).

There is clear evidence of the growing impact of digital forms of publishing, most evidently in North America where the proportion of publishing printers reporting more than 10% of titles with online editions has climbed from 16% in 2013 to 50% in 2015. Globally 29% report variable content for more than 5% of titles and 30% report more than 5% of titles have an online edition (Drupa, 2016 a).
In general terms most packaging printers report healthy market conditions, so the pressure to change is less. Nevertheless 28% of packaging printers worldwide are now actively selling digital print (up 5% on last year). Of those, 18% reported strong demand for digital packaging, up 8% in the year. There is fairly widespread adoption of added value packaging, although it is still a small number that demand services such as variable content, personalisation, security features and interactive packaging.
Functional printers still continuing positive development, although we can say, this is a buoyant market, but perhaps functional printers are used to a more rapid pace of change. Digital inkjet clearly dominates and it was striking to see how rapidly it has grown in the ceramics application from 20% in 2014 to 87% in 2015 with a commensurate decline in screen and pad. It was a similar transformation in printed electronics from 40% in 2014 to 80% in 2015, but this time with digital electrographic the loser (Drupa, 2016 a). If we speak about global printing industry, and their strengths, weakness, opportunities as well as threats, good example is –swot analysis shown in table 4.

Table 4. Global Printing industry SWOT Analysis (Augustin, 2016)

Strengths	Weaknesses
• Print buyers and end-users are familiar to paper and print. • Printing, and particularly packaging printing, remains indispensable in most trade supply chains. • Print is durable, using a large variety of substrates from renewable sources. • Print has a higher depth of information than other media, and is less intrusive. • Tactile properties of print substrates cannot be matched by other media. • The printing industry has a traditional, historical and continued affinity with publishing, IT and the internet. • While being the earliest manufacturing sector, the printing industry is also part of the creative industries. • The printing industry provides high levels of customer satisfaction. • The industry has relatively high levels of technology investments. • The industry has a sustainable raw materials base and high levels of supplier knowledge. • The industry has high levels of technical competences, including know-how, skills and experience in data management. • The industry's knowledge base is relevant for customers, in many areas vital.	• Fragmented industry, most enterprises too small. • Immediacy and lower costs of electronic media . • Electronic media perceived as more attractive. • Distribution costs and time. • The industry's interest groups tend to be on the defensive. • Poor levels of marketing. • Poor levels of capital access. • R & D largely left to suppliers. • Low margins. • Varying capacity utilization (overcapacity in some regions). • Ageing workforce. • Short-term hire-and-fire policies. • Lack of reliable statistics and performance data in many areas.
Opportunities	**Threats**
• Increased service orientation and consultancy. • Web-to-print. • Exports. • Growth markets (packaging, on-demand, template based, variable printing) • Digital printing. • Use of internet for marketing, job intake and communication. • Complementing applications for print, tablets and web. • Crossmedia, database management, distributed printing. • Full service, logistics, fulfillment packages. • Value-added supply chain management. • Cost reductions, outsourcing, relocation, lean manufacturing. • Strategic partnerships.	• Increased switch to alternative/electronic media. • Competition: geographic, non-industry players. • New technologies. • High raw materials and equipment import taxes, high finished product export taxes. • Lack of sustainable business support. • Financing barriers. • Legislative overregulation. • Declining and fragmenting audiences. • Declining and segmented budgets. • Declining and segmented advertising revenues. • Skills shortages.

3. CONCLUSIONS

In conclusion, we can say that this is a really digital era. Continuing increase in number of the digital printing machines in the industry is to be expected. Also, the latest report from Smithers Pira projects a positive outlook for the print and printed packaging markets to 2020 (Smithers Pira, 2016).

Smithers and Pira in The Future of Global Printing to 2020 predicts the global market value $824 billion in 2020. This is $818 billion higher in comparison to 2010, but the total print volume will fall, from the 50.5 trillion A4 prints in 2010 down to 49.0 trillion A4 prints in 2020.

The reason for this fall is that electronic media is steadily replacing printed products. Packaging and labels will grow consistently. Digital printing in the commercial print sector and labels is faring rather better than the analogue alternatives and is forecast to increase in market share by 2020 as new applications, particularly in packaging, grow (Smithers and Pira, 2016).

There are declines in North America, Western Europe and Australasia, while Latin America, the Middle East, Eastern Europe and Africa all see growth. Asia is the biggest print region, growing in volume and value. China continues to grow and has overtaken the volume in the US during 2015 to become the biggest print market, although the value of the output is significantly lower reflecting the different product mix and lower pricing (Smithers and Pira, 2016).

Analogue machinery value is expected to fall, while the value of digital equipment more than doubles in real terms. Printing inks and coating use broadly follows print volumes, although there are market mix changes with increasing use of colour, more radiation curing and greater use of varnishes and coatings pushing growth. It is, however, the much higher valued digital grades that are showing growth (Smithers and Pira, 2016).

4. ACKNOWLEDGEMENT

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Printing added value

FUNCTIONAL ANALYSIS OF A PREMIUM PACKAGING

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Abstract: *The five sensory organs of the people play major role in marketing. The sense of smell, the aromas often affect the decisions during a consumer purchase. However, to be find out new marketing ideas are more and more difficult, so it is now primarily used as marketing tools for the design of packaging, that is affect more than one sensory organ. The aim of this research was to design and test a packaging for cosmetics which has unique solution, containing a micro-encapsulated label. The cardboard box of the product – a luxury categorized face cream – was covered with BOPP foil, to prevent the box from the damage. On the BOPP foil was fixed a label with micro-encapsulated layer. There is a short text for the consumers on the label to test the smell of the face cream. When the costumers scratch the encapsulated layer they could test and feel the scent of the face cream in advance. Aesthetic investigation of the finished cardboard box was done through a questionnaire filled out by those in the target group. Abrasion resistance and temperature resistance of micro-encapsulated layer as well as pressure resistance of the cardboard box were examined.*

Key words: packaging, micro-encapsulated label, abrasion resistance, temperature resistance

1. INTRODUCTION

Due to innovation, there are more and more kinds of special packaging at our disposal, which are realized in a creative form. According to OECD and the EU: "Innovation is the introduction of new or significantly improved products (goods or services) or processes, new marketing methods in business practices, in a workplace organization or in outer relationships."
Microcapsules are regular or most often irregular structures built up of one or more polymers which are provided with a permeable coating. Micro-encapsulating is a process in which a substance (core) is enclosed in another protecting material (shell). There are, chemical, physico-chemical and mechanical micro-encapsulating processes, the micro-encapsulated particles differ in size, morphology and shape. The particles the diameter of which is larger than 1μm are called micro-particles, while the smaller ones nano-particles. Micro- and nano-particles can be capsules or spheres (Figure 1.) (Agnihotri et al, 2012). The difference is between the relationship between the core and the shell. In case of a microcapsule these two can easily be isolated, while in case of a microsphere there are no such sharp limits (Stankovič, Urbas, 2016; Matson, 1970).

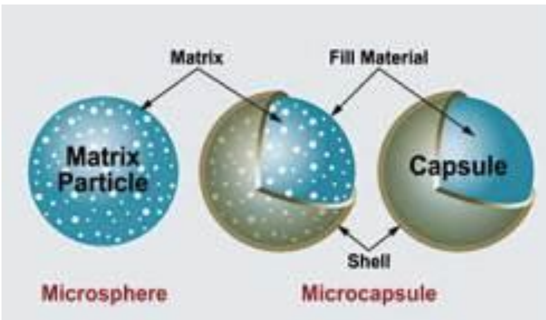

Figure 1: Mikrocapsules and microspheres

Nowadays, several fields of use of microcapsules are known (food industry, cosmetics and pharmaceutical industry, agriculture, biotechnology, detergents, textile industry, graphic and printing industry, photography, as well as biosensors, active coating, electronics, etc.). Since the 1930s, seasoning substances and since the 1940s vitamins have also been encapsulated. The technology mainly aims at strengthening their stability and at protecting the compounds, as well with different trace elements or in the case of food enriched with vitamins (Heike, 2007; Urbas, 2014; Dubey et al, 2009).

Making use of their favourable qualities they are also readily used in the cosmetics industry. The sweet-smelling pages of different magazines, the test bands of perfumes are also produced with the microcapsule method. When applying some physical effect (rubbing, heat) they break up, so the fragrance can be felt.
The sense of smell is one of our most important senses it belongs to the lymbic part of our brain like creativity, emotions and memory. The sense of smell and taste are in a direct relation with each other and influence each other. With the help of our tongue we can feel the basic tastes (salty, bitter, sweet, sour and spicy hot) but it is the sense of smell that helps us feel a lot of flavours. Fragrances are readily used in marketing and the advertising industry to win the consumers over and to motivate them. In the case of the box provided with a special layer, realized during the research work also this plays a major role (Anon, 2013; Anon, 2010).

2. METHODS

The aim of the research work was to design and test the packaging of a cosmetic product containing a micro-encapsulated label. On the finished packaging aesthetical and functional tests were done, in the interest of product protection suitability.
When designing the product, we satisfied several requirements. On the one hand we took into consideration the expectations of the partner company on the other hand we kept in view the demands of the target group of the product. When shaping the new brand of the product, the colour combinations and the graphic elements applied by the company were taken into consideration, then partly using them and rethinking, we realized the own brand. In the logo and also on the packaging, the colours characteristic of the target group were used to symbolize softness, feminineness, sophistication. The design was made with the Photoshop, the CorelDRAW and the Illustrator programs.
In connection with the appearance of the packaging an online survey was carried out, titled "Aesthetical analysis in connection with the visual appearance of a new facial cream box". The 3D design of the box was also attached to the questions. The target group was women aged between 25 and 35. We got 53 evaluable answers. In the first three questions the respondents gave their opinions scoring 1 to 10. The fourth one was a yes/no question. And finally, the last two were ones to express opinions, in which the respondents could freely form their thoughts about the watchword of the box, about the colours and the graphics. The questions were the following:

1. How impressively, do you think, the label with the inscription "Rub it!" draws the attention?
2. How well, do you think, the applied graphics reflects the packaged product?
3. How well, do you think, the overall impression of the packaging reflects the premium category?
4. Do you think the logo of the product is placed in a suitable place?
5. What do you think about the watchword of the product?
6. What's your opinion about the applied colours, graphics?

In the functional tests we examined how the packaging resists mechanical bearing forces while the product gets to the consumer through the distribution chain. The main aim was to determine the length of time in the course of which the encapsulated layer keeps the fragrance. The experiments were done in the material testing laboratory of SunChemical Hungary Printing Ink Ltd. The fragrance samples are delivered to the company in an already encapsulated form, the final homogeneous blend is due to the flow of ink that has been mixed by shaking, by vibration blender or biaxial blender. The ink can absorb a maximum of 35% dry material the strength of fragrance depends on it. The samples can keep their fragrance for half a year as is expected.
Depending on the examinations, test strips of different sizes and numbers were made on IGT C1 printability tester. A thin layer of ink of predetermined amount (1.5-2 g) was applied on the inking rollers, which was abraded (for about 120 s) until a thin, even layer of ink was formed on the rollers.
As a next step, the form cylinder was inked with this thin layer of ink, then the pressing force depending on the applied base material was set, finally the prints were made on the precut substrates. The applied layer was dried for a few seconds. The thickness of the applied ink layer was determined by the mass of the form cylinder weighed before and after printing, which equals 1.5 µm with an amount of ink on paper of 1.5 g/m^2. While printing, side abrasion was switched off, but even so there were capsules that broke up during the examinations. Abrasion resistance and temperature resistance tests were done on the test strips.

We examined how resistant the micro-encapsulated samples are to abrasion. The tests were carried out with manual abrading as well as on Taber Abraser 5135 abrasion testing equipment. Scent-printed paper strips of 3x3.5 cm size were abraded with a given number of abrasion, and we examined if the label is still sweet-smelling after 24 hours of evaporation, and if yes, to what extent. The intensity of the fragrance was checked with the help of six different people with "good sense of smell", who scored the intensity from 1 to 10. The tests were also done with BOPP foil (in case the box is covered with a layer of foil and during delivery the boxes are placed on one another in the multipack9. The instrument test was done with a load of 2.4 g/m^2 and 11.8 g/m^2. In the first case the mass of 1 box, while in the second that of 5 boxes was modelled. This can be an important factor during delivery and lading. The tests were increased with a scale of 50. The abrading surface was 6.5 x 6.5 cm^2 BOPP foil. It was also examined how the scent-capsules react to extreme, very high and very low temperatures. The circumstances of delivery were modelled with these tests. The tests were carried out with the help of climate test chambers of Discovery 110 type. The equipment is suitable for heat-retaining, cyclic tests on wide scale, thus simulating the different environmental effects affecting the sample. The scale of programmable temperature can extend from -40 °C to + 180 °C. The even distribution of vapour content and temperature is ensured by strong air circulation of great performance. For the climate test cycles the relative humidity can be programmed between 10% and 98%. The starting temperatures of the tests were -5°C, 45°C and 75°C. The scents on the samples were checked every hour. Relative humidity was 60%.

Further examinations were done on the cardboard box, testing with drop tests whether the chosen cardboard provides suitable protection to the product. The box was dropped from a given height several times until traces of damage appeared on the product. The examination was carried out in the finalized form, so the box was protected with a BOPP foil from different types of damage. In the surface pressure tolerance test we were trying to find out what load the box can stand, i.e. what units have to be formed so that the boxes remained undamaged. These tests were carried out with the help of weights. More and more weights were placed on the surface of the box until traces of damage appeared. In this case, the box was also covered with BOPP foil.

3. RESULTS AND DISCUSSION

From the point of view of branding, the new brand of the product (facial cream) was created accordingly to the image of the client. A sensual but at the same time crystallized effect was reached, which reflects premium category well. A simple, still effective brand name and watchword were found, which are easy to remember. The logo was placed on a clearly visible place, in an aesthetical way. The packaging of the product was formed taking into consideration the company's expectations. The protecting casing was made for a jar day cream. The brand was designed in a form that suits the image of the enterprise. The box was made from 350 g/m^2 cardboard. In the logo as well as on the packaging, colours characteristic of the target group were applied to symbolize softness, feminineness, sophistication.

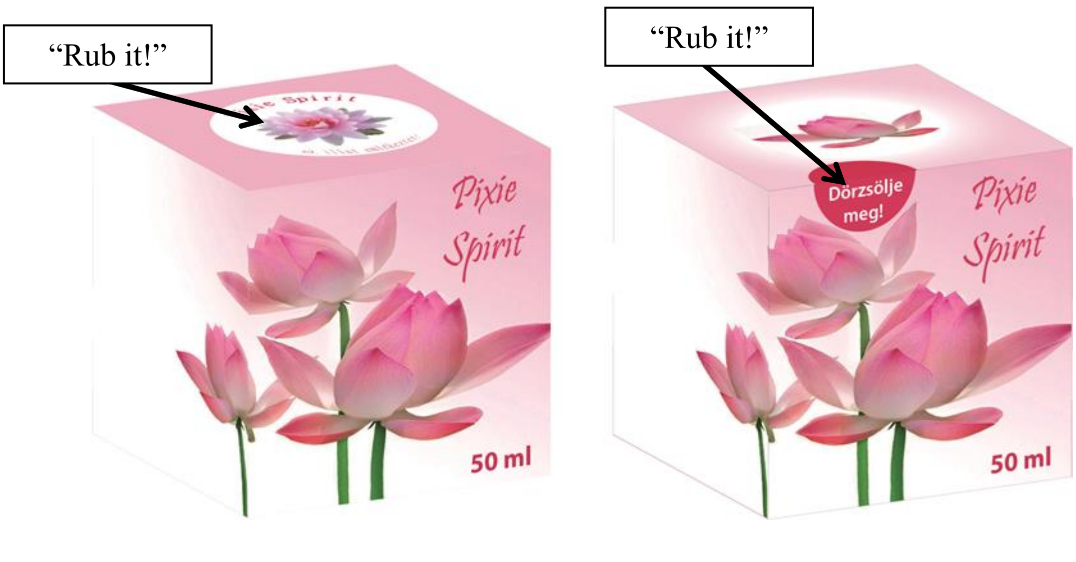

Figure 2: The box packaging with two different label solutions

The new brand name of the product was formed after collecting several key words (fragrance, dream, touch, sensitive, memories). Taking into consideration the already known requirements and category, we tried to embody them in one word, so the name of our product is: Pixie Spirit and the watchword attached to it: “Memory enclosed in fragrance.”
The ready product is additionally wrapped in BOPP foil with a wrapping machine, which further increases the resistance of the product to stress. The wrapping covers the whole box closing it at the bottom surface with a seam. To draw the consumer’s attention to it, a label with the sentence “Rub it!” was placed on it, minding not to cover any important information or graphics (Figure 2.).

3.1 Asthetical analysis

The data of the filled-in questionnaires were summarized and evaluated by questions. Based on the responses given for the first question, 43.4% of responders thought that the placed label “Rub it!” covered with a special layer attracts customers’ attention properly.
Only 30.2% of respondents thought the applied graphics reflects the aim, the meaning of the facial cream well, and 32.1% thought that the overall effect of the box reflects the premium category well.
To the question: “Do you think the logo of the product is placed in a suitable place?” 88.7% answered yes. In the answers to the last two questions, a large percentage of respondents thought the slogan would better suit a perfume than a facial cream, as it is not the main purpose of a facial cream to be fragrant. There were ones who liked the simple, straightforward sentence that was easy to remember. Based on the analysis, changes were made on the packaging (Figure 3.). The brightness of colours was decreased and the letters were redesigned with the green colour taken from the stem of the plant, giving the box a low-key, pastel-like appearance.

Figure 3: The modified box drawing and the place of the label

3.2 Abrasion resistance

Figure 4 shows the results of manual abrasion. The scent lost its strength a little already after 50 abrasions but only after 500 abrasions lost its fragrance totally.

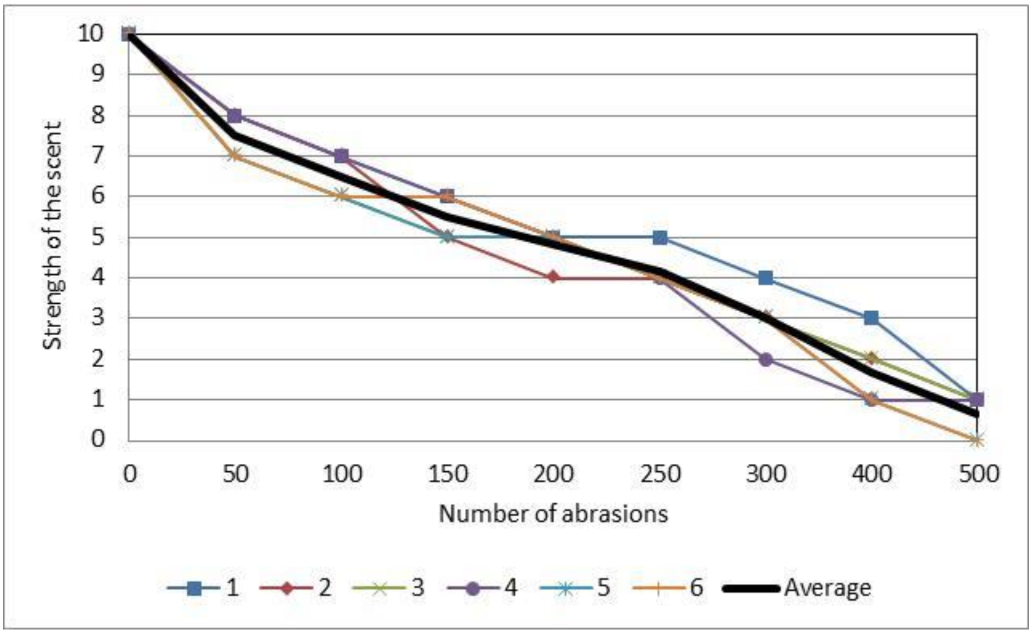

Figure 4: Abrasion resistance tested manually

Figures 5-6 show the results of tests done on abrasion testing equipment of Taber Abrasion 5135 type. The examinations showed that as an effect of abrasion with BOPP foil, already after 200 abrasions, the strength of scent decreased by 50%, under the load of 2.4 g/m^2, and after 160-170 abrasions under the load of 11.8 g/m^2. But in both cases, the fragrance could be felt after 300 abrasions.

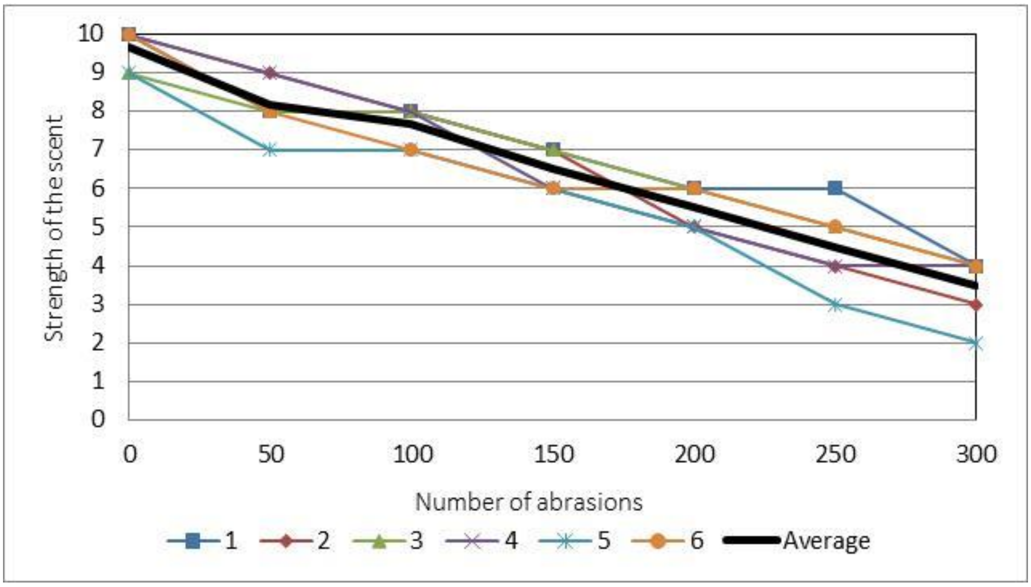

Figure 5: Abrasion of BOPP foil and the label to each other, under the load of 2.4 g/m^2

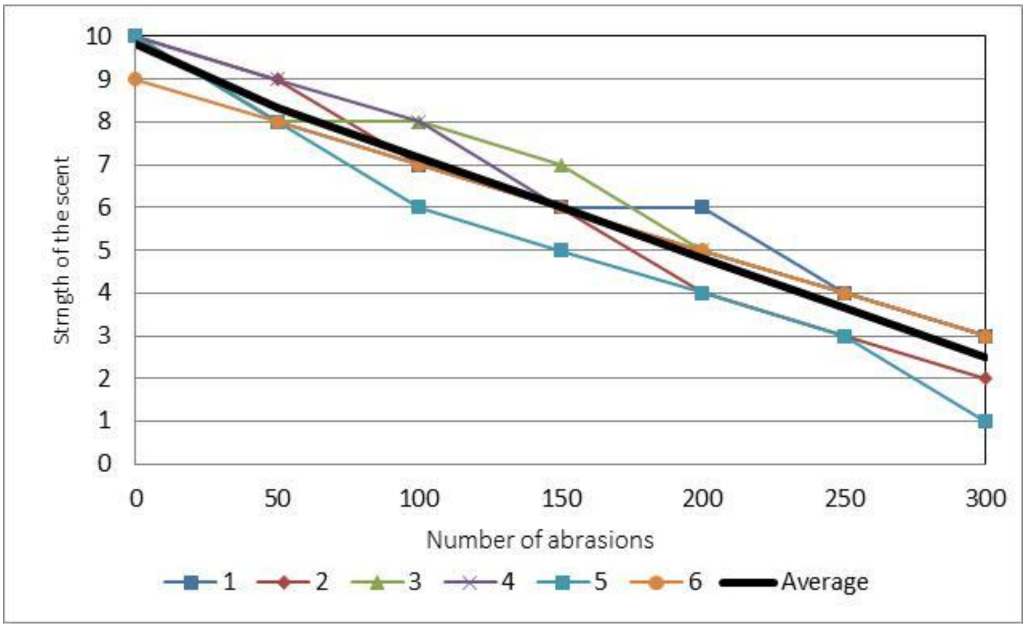

Figure 6: Abrasion of BOPP foil and the label to each other, under the load of 11.8 g/m²

3.3 Temperature resistance

The results of temperature resistance tests are shown on Figures 7-9. They show that the micro-encapsulated layer keeps its sweet-smelling ability better under cold conditions.

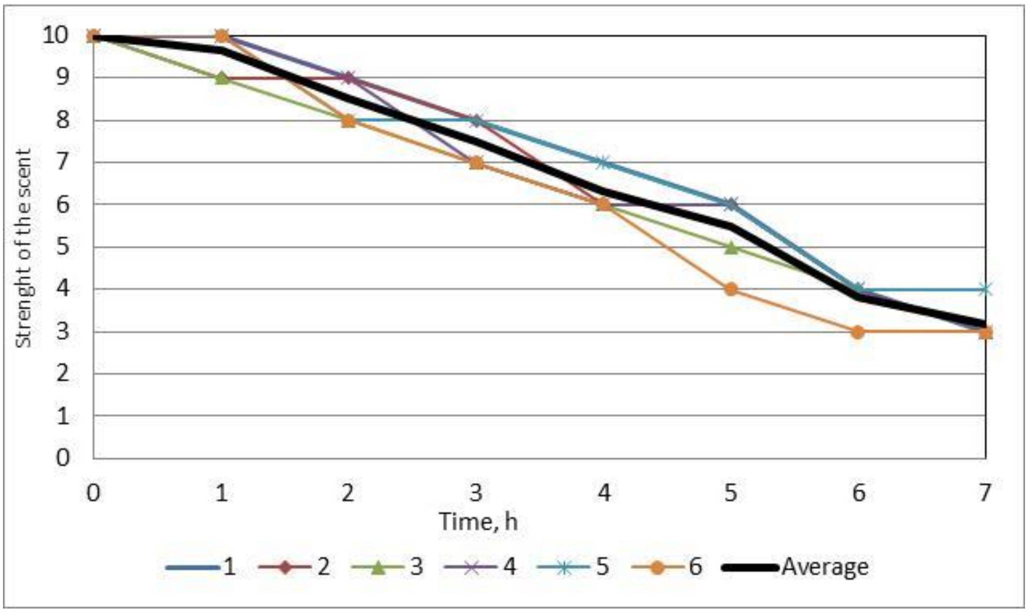

Figure 7: Cold (-5 °C) resistance during delivery

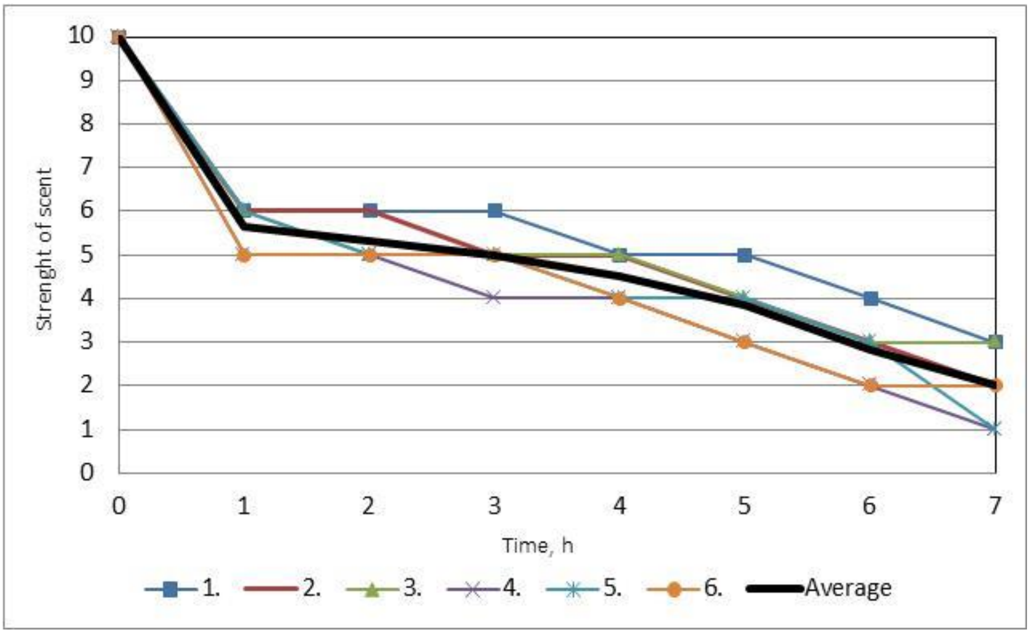

Figure 8: Hot (45 °C) resistance during delivery

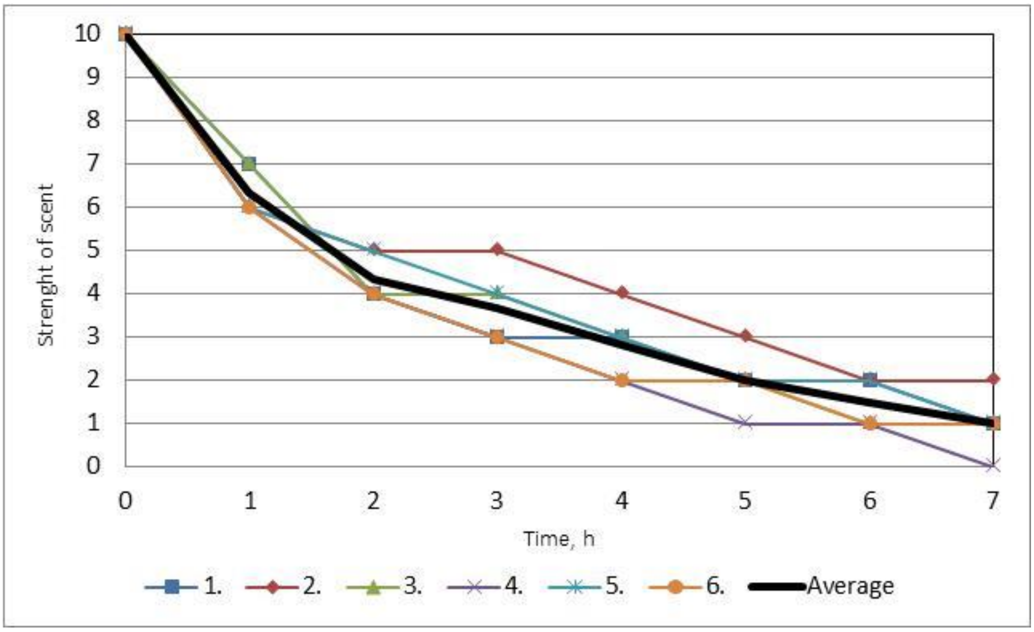

Figure 9: Hot (75 °C) resistance during delivery

During the tests for surface pressure tolerance the signs of overload appeared at 23 kg. The bottom of the box sank.

4. CONCLUSIONS

In the course of the research work, the design and testing of the packaging containing a micro-encapsulated label were carried out. The box was covered with BOPP foil with a view to hygienic aspects, which further enhances safety. Taking into consideration innovation and human curiosity the box was made interactive with a label covered with a special layer. Applying the micro-encapsulated label it is possible to try the fragrance of the product already in the shop.

Aesthetical and functional tests were done on the completed packaging to comply with product protection regulations. The analysis of the questionnaires showed that only 18.8% of respondents thought that the label “Rub it!” coated with a special protective layer does not attract buyers’s attention properly.

The results of the abrasion resistance test of the sweet-smelling layer in case of both manual abrasion and between the scented label and the BOPP foil show that the label can lose some of its fragrance already during delivery. But after a large number (300) of manual abrasion – although it loses some of its strength – the fragrance remains.

During weather resistance tests the qualities of the packaged product (facial cream) were taken into consideration. Due to the good heat-isolating glass jar and the base material of the box, the cardboard, the facial cream is more resistant to weather changes. During the examination the extremity of delivery circumstances served as a basis. The results showed that the micro-encapsulated layer keeps its sweet-smelling ability better under cold conditions. So, in summer it is worth delivering it in air-conditioned cars so that it can keep its special quality.

The result of the pressure tolerance test even more supported the quality of the well-chosen, resistant cardboard. Taking this into consideration we may say with full reason that the boxes can be placed on one another, even to 20 kg, without the packaging getting damaged.

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ANALYSIS OF THE EFFECT OF PAPER GRAMMAGE ON THE READING QUALITY IN BRAILLE PRINTING

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Abstract: *In graphic design and printing industries, individuals who can see are usually targeted and productions are made for them. In fact, when the user target groups of the printed products are considered, more work seems necessary for the individuals who cannot see. The purpose of this study is to determine the reading quality of the embossings of the printed press produced using Braille alphabet for visually impaired individuals depending on the embossings' endurance features about the paper. Embossings formed on the paper / cardboard surface for the Braille alphabet to be read enable the individual to perceive the product and the message by touching. The actualization of this perception for a long time by the help of the sense of touching depends on the endurance process of the Braille alphabet embossings on the substrate. The most important parameters, which determine this endurance process, are the grammage, thickness and moisture of the paper used and the amount and the features of the raw material, which make the body of the paper. The friction formed by every touching of the individual to actualize reading on the surface decreases the endurance of the embossings. Pressure and friction has caused by touching cause the embossings that form the writing to collapse, hence reading to be increasingly difficult. The frictional resistance process varies according to the sorts, grammage and the kinds of the papers and the pressure applied onto their surfaces.This study was conducted in order to determine the reading quality depending on the frictional resistance formed as a result of the collapse and abrasion of the embossings of the paper depending on the number of readings. 3 different papers at low, middle and high grammage used in Braille alphabet printing were selected and conditioned at 23^{o}C and 60% moisture for the determination of the frictional resistance process within the scope of the study. A standard size text was written (embossed) on these papers with Braille alphabet and the visually impaired subjects were asked to read it for 20 - 150 times in separate texts and the number of readings with optimum quality depending on the decreasing reading sensitivity and the suitable paper basis weight were determined.*

Key words: Braille, Legibility, Paper surface properties

1. INTRODUCTION

The Braille alphabet is an embossed writing system, which allows the visually impaired read tactually. The paper surface on which techniques such as braille typewriting, braille printing, screen printing and die stamping creates the fastness process of embosses depending on the grammage and physical properties of the paper and affect the reading quality. The moisture content of the paper affects the paper and print quality. Physical parameters such as the grammage, thickness, humidity, Cobb value, strength, surface smoothness and porosity values, optical properties, surface pH value and fiber direction of the paper are of great importance for the rapport between paper, ink and printing machine. Since paper is hydrophilic, it tends to absorb moisture when placed in an environment with a higher humidity value than its own and lose moisture otherwise. For this reason, the paper humidity and the ambient humidity must attain an equilibrium. The ideal relative humidity rate under standard conditioning and atmosphere is 55%.

1.1 Alphabet Systems for The Visually Impaired

1.1.1 Braille Alphabet

The main feature of the Braille alphabet system is that each letter is defined by embossing different cells within the cell system consisting of six dots. Thus, certain dots are embossed for each letter and confusion between letters is prevented. The alphabet is named after Louis Braille, the creator of the six-dot cell embossing system. The six-dot cell structure of Louis Braille and numbered representation of dots to be embossed for each letter are given in Figure 1 (Davidson, 2014).

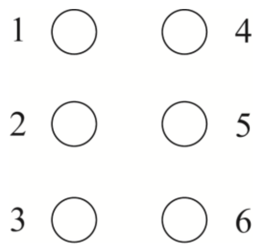

Figure 1: The six-dot cell structure of the Braille alphabet

Thanks to this six-dot cell structure, rows are created with equal letter size, spacing and position in texts. Figure 2 shows characters of the cell structure of the Braille alphabet represented for each letter.

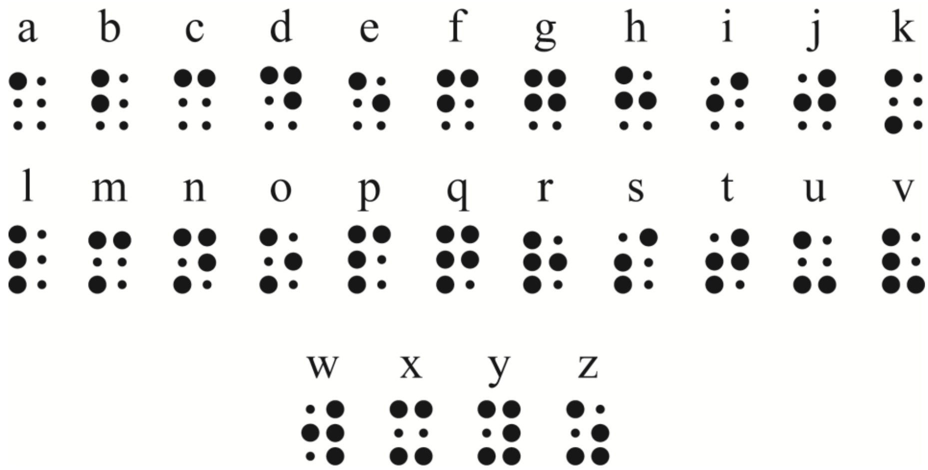

Figure 2: Type characters in the Braille alphabet

“Marburg Medium Dot Height” allows the visually impaired to read the Braille alphabet. The first of these standard dot sizes is “Marburg Medium” and the second is “Marburg Large” (Deutsche Blinden-studienanstalt e.V., 2016). Figure 3 shows Marburg Medium and Marburg Large measurement systems.

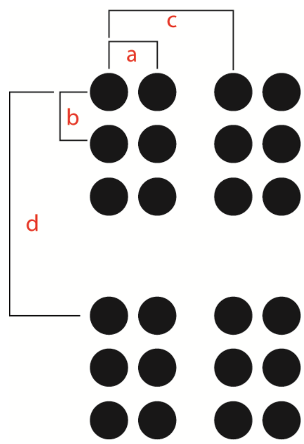

Figure 3: Marburg Medium and Marburg Large measurement systems

According to “Marburg Medium” dimensions, the distance between the centers of two dots on the x-axis (a) is 2,5 mm. In the same way, the distance between the centers of two dots on the y-axis (b) is 2,5 mm. The distance of the first character and the second character from the center (c) must be 6,0 mm.
From top to bottom, the distance of the first character and the second character from the center (e) must be 10,0 mm.

According to “Marburg Large” dimensions for the Braille alphabet, the distance between the centers of two dots on the x-axis (a) is 2,7 mm. In the same way, the distance between the centers of two dots on the y-axis (b) is 2,7 mm. The distance of the first character and the second character from the center (c) must be 6,6 mm. From top to bottom, the distance of the first character and the second character from the center (e) must be 10,8 mm (Deutsche Blindenstudienanstalt e.V., 2016).
The dot height recommended by Deutsche Blindenstudienanstalt e.V. for printing and legibility of the Braille alphabet is at least 0,5 mm (Deutsche Blindenstudienanstalt e.V., 2016). Although the same system is used for each language in the Braille alphabet, different dot patterns are used for different letters of each language [3-4]. For example, English does not have the letter “ü”, whereas Turkish does. For this reason, the letter “ü” is represented separately within the six-dot cell system of the Braille alphabet. Figure 4 shows the characters of the Turkish Braille alphabet.

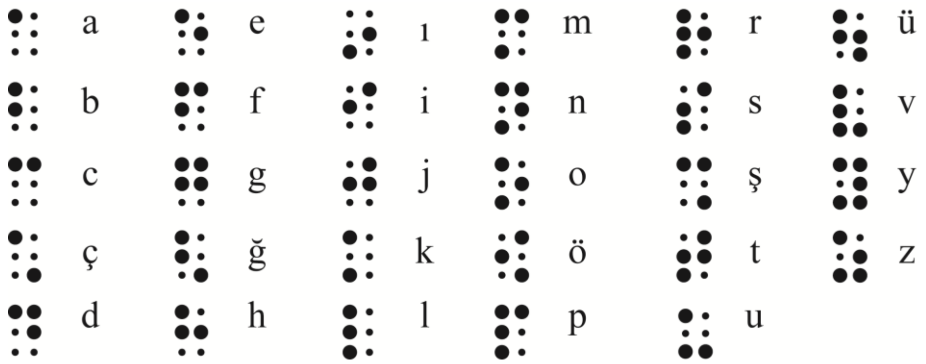

Figure 4: Turkish Braille alphabet

1.1.2 Moon Alphabet

The Moon alphabet system, developed by William Moon, is made up of embossed symbols derived from the Latin script (Tekiner, 2011). For this reason, publications utilizing the Moon alphabet is used by individuals who lost their sight as adults and cannot feel the Braille alphabet (but can partially read by touching) (Kaynar, 1995). Symbols corresponding to letters and numbers in the Moon alphabet can be seen in Figure 5 and Figure 6 respectively.

Figure 5: Symbols corresponding to letters in the Moon alphabet

Figure 6: Symbols corresponding to numbers in the Moon alphabet

Letters are printed larger in the Moon alphabet, which facilitates reading. Printing larger letters allows individuals with impaired sight to read better. Those who prefer the Moon alphabet are individuals who lost their sight later in life or have a high level of reduction in their sight due to old age (Hayta, 2015).

1.2 Embossing Printing Techniques for The Visually Impaired

1.2.1 Screen Printing Technique

In the screen printing technique, lacquer is used for embossing. First of all, the image is created in vector-based software (Adobe Illustrator, Corel Draw, etc.) for implementation. The image of braille texts or embossed diagrams is exposed to the screen printing mold. After transferring the image to the mold, the embossing treatment is applied to the surface of the plate with the help of lacquer. Once the printing of embosses are completed, ultraviolet light is used to dry the ink and ensure remain as embosses.
The ink providing embosses shows a high durability. Wear can be seen over time depending on the paper type used.

1.2.2 Swell / Microcapsule Paper Method

Swell paper, developed by Yvonne Eriksson of the Swedish Library of Talking Books in 1993, is a paper type containing microcapsules embedded on its surface (Axel, Levent, 2012). Swell paper consists of two layers. The first is the carrier layer, whereas the second layer is embossed by microcapsules. Microcapsules emboss when the paper is exposed to heat and create an image.

1.2.3 Thermoform Method

The thermoform method is an embossed image formation performed with the thermoform machine, a brand of the American Thermoform (ATC), and plastic thermoform papers (American Thermoform, 2016). The thermoform method involves two steps. The first step is the preparation of the sample. A copy of the sample is taken in the second step. The main sample is placed in the thermoform machine and the plastic paper plate is placed on top of it. The image is transferred onto plates as embossing with the help of the thermoform machine (Kara, 2011).

1.2.4 Embosser Printer Systems

Embosser printer systems are used for personal printouts, large-scale emboss prints and both personal and large-scale emboss prints. There are embosser printers capable of single-sided printing and double-sided printing. In addition to systems which can print A4 size and A3 size, there are also systems that can print in fascicle format. Embosser printers that can print in fascicle format are used in production of books and magazines with the Braille alphabet. The texts on the control buttons of the embosser printers are written with the Braille alphabet. In addition to text written with the Braille alphabet, some systems guide the user with voice notifications.

2. METHODS

2.1 Preparation of Test Pages

Two types of paper, uncoated white and coated gloss paper, were used for test pages. Accordingly, the papers used in the test pages were conditioned for 24 hours at 23°C temperature and 60% humidity (Tappi T402). Paper grammages were selected in a way that they would have an effect on reading quality after Braille embossing. Number of reading of the papers used in the study is given in Table 1, the technical data of the uncoated white paper is given in Table 2 and the technical data of the coated gloss paper is given in Table 3.

Table 1: Grammage, type and number of reading data of test papers

Grammage g/m²	Paper type	*Reading data / reading time*				
		1	20	50	100	150
90	uncoated white	+	+	+	+	+
160	uncoated white	+	+	+	+	+
170	uncoated white	+	+	+	+	+
170	coated gloss	+	-	-	-	-
180	uncoated white	+	+	+	+	+
190	uncoated white	+	+	+	+	+
250	uncoated white	+	-	-	-	-

Table 2: Technical properties of the uncoated white paper used in the study

Property	Test Method	Unit	Tol.	90 g/m²	160 g/m²	170 g/m²	180 g/m²	190 g/m²	250 g/m²
Substance	ISO 536	g/m²	±4%	90	160	170	180	190	250
Thickness	ISO 534 / TAPPI T411	µm	±4%	108	185	196	208	218	282
Bulk	ISO 534 / TAPPI T411	cm³/g		1.20	1.16	1.15	1.15	1.15	1.15
Opacity	ISO 2471 / TAPPI T519	%	-2.0	95.0	-	-	-	-	-
Brightness R457/D65	ISO 2470-2 / TAPPI T452	%	±2	103.7	103.7	103.7	103.7	103.7	103.7
Whiteness D65/10°	ISO 11475 / TAPPI T562	CIE	±5	148	148	148	148	148	148
Color a* D65/10°	TAPPI T527 / ISO 5631-2	abs.		3.0	3.0	3.0	3.0	3.0	3.0
Color b* D65/10°	TAPPI T527 / ISO 5631-2	abs.		-14.2	-14.2	-14.2	-14.2	-14.2	-14.2
Bendtsen roughness	ISO 8791-2 / TAPPI UM-535	µm	±50	150	230	230	250	250	250
Cobb	ISO 535 / TAPPI T441	g/m²	±5	25	25	25	25	25	25
Relative humidity	TAPPI T502	%	±7	40	40	40	40	40	40

Table 3: Technical data of the coated gloss paper used in the study

Property	Unit	Test Method	Tol.	Val.
Substance	g/m²	ISO 536 / TAPPI T410	±4%	170
Thickness	µm	ISO 534 / TAPPI T411	±4%	125
Bulk	cm³/g	ISO 534 / TAPPI T411	-	0.74
Opacity	%	ISO 2471 / TAPPI T519	-2.0	97.0
Whiteness D65/10°	CIE	ISO 11475	±3	119.0
Paper gloss	%	ISO 8254-1 / TAPPI T480	±5	74
Bekk smoothness	s	ISO 5627 / TAPPI T479	±30%	850
Relative humidity	%	TAPPI T502	±7	50

Different texts were prepared for each paper to be printed with Braille embosser. Thus, the visually impaired were prevented from memorizing the text on different types of paper surface and kept reading with the same tactile rate. The preparation of test pages was performed with an "Index Braille Box" embosser. This printer stands out among other printers with cylinders inside which create embosses (Kara, 2011). When the paper passes through the cylinder, each letter is embossed with the Braille alphabet in accordance with the command received from the computer. When the paper completes its passing through the cylinder, the desired text is embossed on the paper surface.

2.2 Analyses of The Study

In order to investigate the effect of paper grammage on reading quality in Braille printing for the visually impaired, opinions of the participants were received once the first reading of the test pages was completed. Thus, the data required for the analysis of effects of paper grammage and surface properties and fastness between the first reading and the final reading were collected. To investigate the the effect of paper grammage on reading quality, analyses were performed by having visually impaired participants from different age groups and educational levels read the test pages.

2.2.1 Research Methods

The study was designed as a case study in order to determine the effect of paper grammage on reading quality in Braille printing and determine factors related to paper surface affecting reading quality. The study was supported with qualitative data. Face-to-face interviews were held and opinions of the visually impaired participants were voice-recorded in order to collect qualitative data.

2.2.2 Study Group

The study group consisted of visually impaired individuals over the age of 18 from the Istanbul Branch of Six Dots Foundation for The Blind and the Visually Impaired Technology and Education Laboratory of Boğaziçi University. Being at least 80% visually impaired and being able to read using the Braille alphabet were determined as the inclusion criteria of the study and the institutions were selected accordingly. The study was conducted in order to reveal opinions and experiences of visually impaired individuals related to the effect of paper grammage on reading quality and participation was on a voluntary basis.

2.2.3 Data Collection Tools and Data Collection

Semi-structured interviews were held to collect data for the study. In addition to noting answers given to questions and opinions of the participants, voice-recording was used during semi-structured interviews to improve the data collection process. In order to enhance the internal consistency of the study, findings were given directly without any interpretations. The study data were collected in a time period when the participants felt comfortable to express themselves. Interview questions were directed at each participant with the same voice tone and the same words to communicate the same meaning. The collected data were transcribed and themes and sub-themes were created with content analysis.

2.2.4 Data Analysis

The content analysis technique was used to analyze the data. The assessment was performed by examining notes and voice-recording taken during semi-structured interviews. Themes and sub-themes obtained as a result of data analysis are given in Table 4.

Table 4: Themes and sub-themes obtained as a result of data analysis

1.	**Opinions Related to Type of Material**
	1.1. Opinions related to uncoated white paper 1.2. Opinions related to coated gloss paper
2.	**Opinions Related to Readability Quality**
	2.1. Opinions related to the effect of paper grammage on print quality 2.2. Opinions related to the effect of number of readings on reading quality 2.3. Opinions related to tactile sensitivity of the individuals

In accordance with the data obtained in the study, two main themes and five sub-themes were created. Within the scope of the first main theme, content analysis was applied to the data in accordance with opinions related to paper types used in test printing. Two sub-theme were found under the first main theme as a result of the analysis. Within the scope of the second theme, the data were analyzed in accordance with opinions of the visually impaired participants related to reading quality of embossed test papers and three sub-themes were created.

2.2.5 Findings

Opinions of the participants are presented after coding on the basis of confidentiality without giving any names. To this end, the participants were coded as "B" to express "visually impaired". Also, each participant was assigned a number in addition to the code such as "B1, B2, B3, B4, B5". The questions asked during interviews were grouped according to sub-problems when presenting findings and opinions of the participants were given.

- Opinions Related to Type of Material

The question asked in relation to this theme was, "Does the type of paper used in Braille printing affect the reading quality?" Two sub-themes were created as a result of this question. The examination of the data forming these two sub-themes showed that the type of paper used in Braille printing for the visually impaired affected the reading quality.

- Opinions Related to Uncoated White Paper

Once the participants completed reading different test pages prepared, they expressed similar opinions regarding the effect of the type of paper on tactile sensation and reading quality. The opinions emphasized by the visually impaired participants under this sub-theme are as follows:
In relation to uncoated white paper, one of the participants expressed his opinion as, "The smoothness of the paper surface facilitates feeling embosses." (B1). Another participants expressed his opinion as, "It is better if the paper type has a surface similar to cardboard. Because fingers hold on the surface more comfortably." (B4). It is seen in this sub-theme under which the participants expressed similar opinions that the smoothness of the paper surface is effective on the optimum reading quality.

- Opinions Related to Coated Gloss Paper

The participants stated that the coated gloss paper type, which was the other type of paper used for Braille printing, had negative effects on reading quality. The opinions related to this sub-theme are as follows:
It was seen that three of the participants (B1, B2 and B3) similar opinions related to that the coated gloss paper reduced sensibility during reading. Participant B2 stated, "It is difficult to feel embosses and read since the paper surface is slippery." Another participant expressed his opinion as, "The slipperiness of the surface makes it difficult to understand letters." (B1). Participant B3 stated, "The surface of the paper feels slippery since we did not use this type of paper when reading in the past and it makes reading difficult."

- Opinions Related to Readability Quality

The question asked in relation to this theme was "Does the paper grammage affect readability quality?" Also, the following questions were asked to obtain more data related to the subject:

- Does the number of readings affect reading quality?
- Is the number of readings effective on reading quality depending on grammage?
- Do single-sided printing and double-sided printing affect reading quality?
- Does the tactile sensitivity of individuals affect reading quality?
- Which paper grammage produced the optimum reading quality among test pages?

Three sub-themes were created as a result of the data obtained from these questions. The data forming these three sub-themes showed that paper grammage, number of readings on the paper surface and tactile sensitivity of individuals were effective factors to achieve the optimum reading quality.

- Opinions Related to The Effect of Paper Grammage on Print Quality

The participants expressed the following opinions after their first reading of the test pages printed with different grammages:
For the paper type with lowest grammage among the test pages, 90 gsm, one of the participants stated, “This paper is thin. I can read the embosses, but this is a one-off paper. Embosses will deform quickly. This paper would only make a scratch paper.” (B2). Another participant expressed his opinion as, “Such thin papers can only be used to learn to write Braille alphabet on tablet. It is too thin for reading, it would be very difficult to maintain after just one reading and it would deform very quickly.” (B3). Another participant stated, “Such thin papers are difficult to read and it is not possible to emboss with every method desired.” (B1). Another participant expressed his opinion as, “It is possible to read, but not good. If it was not a single page, but a book with overlapping pages, embosses would be squashed due to pressure. This is not suitable for mass distribution and I have not seen it used for that.” (B4). Another opinion was, “This type of paper can only be used for daily reading. Print it, read it and throw it away. Like newspapers.” (B5).
The participants had similar opinion regarding the 160 gsm paper type after the first reading. One of the participants stated, “It is possible to read the surface of this paper, it is easier to understand compare to the previous paper.” (B3). Another participant expressed his opinion as, “It felt thinner since we used thicker papers to learn to read the Braille alphabet but it is readable.” (B5).
Regarding the 170 gsm paper type, one of the participants stated, “The embosses have sufficient height to feel and it is comfortable to read.” (B3). Another participant expressed his opinion as, “It is readable and it has the height that we are used to. Also, it offers better readability if you ask me.” (B2). The other three participants gave similar opinions and agreed that the 170 gsm paper offered ideal reading.
After reading the 180 gsm test page, one of the participants stated, “It becomes more difficult to form embosses as the strength of the paper increases. It is readable, but the height of embosses is somewhat less than other papers.” (B3). Another participant expressed his opinion as, “I can read it.” (B5). Another participant noted on the subject, “It is possible to read this page, but the previous one was easier to read if you ask me. Papers with higher grammage than this paper would not offer good readability” (B2).

Upon reading the 190 gsm test page, one of the participants stated, “This paper pushes it too far, it is too thick.” (B2). Another participant expressed his opinion as, “The 190 gsm paper could be used in cases of necessity, it is readable, but not good.” (B3). Other participants gave similar opinions regarding the grammage of this test page.
Regarding the 250 gsm paper, which was included in the study to investigate the highest printable grammage and whether it could be read or not, the participants noted that it was unreadable and too thick. This is because the printer was not able to provide sufficient height due to the high grammage of the 250 gsm paper and thus the participants could not read the text.

- Opinions Related to The Effect of Number of Readings on Reading Quality

The opinions of participants were received again after 20 readings, 50 readings, 100 readings and 150 readings. The opinions of the participants in relation to number of readings are as follows:
After the 20th reading of the 90 gsm test paper, one of the participants noted, “It has the same feeling with the first reading and it is still too thin to read.” (B3). Another participant stated, “It is readable, but too thin.” (B4). Other three participants gave similar opinions after 20 readings as well. After the 50th reading of the test page, one of the participants expressed his opinion as, “50 readings was not that different from 20 readings. However, some letters were not notable because the paper is too thin.” (B2). The other participants gave similar opinions after 50 readings stating that it was readable, but not good. After 100 readings, one of the participants expressed his opinion as, “The paper deformation started, there are collapses in embosses obstructing reading. Also, walls forming dots are too thin.” (B3). Another participant noted, “This paper is too thin and it feels worn as the number of readings increases. It is not good for reading.” (B1). After 150 readings, the participants expressed similar opinions stating that the embosses on the test page collapsed or burst and the reading quality was poor.
After the 20th reading, the 50th reading and the 100th reading of the 160 gsm test paper, the participants noted that they did not feel much deformation and were able to read the paper. After 150 readings, one of the participants stated, “I can feel that embosses started to flatten out, but it is readable.” (B1). Another participant noted, “It is readable, but it is a single-sided print. Maybe if it was a double-sided print or exposed to pressure, embosses could be deformed.” (B2).

After the 20th reading, the 50th reading and the 100th reading of the 170 gsm test paper, the participants expressed similar opinions and noted that reading quality was not poor and the paper was readable. After 150 readings, one of the participants noted, “I still can not feel the deformation on this paper. It is readable.” (B5). Other four participants expressed similar opinions regarding the subject.
After the 20th reading, the 50th reading and the 100th reading of the 180 gsm test paper, the participants expressed similar opinions and stated that the paper was readable. After 150 readings, one of the participants noted, “There is flattening in on tips, it may be related to the thickness.” (B3). Another participant stated, “It is readable, but more difficult due to paper’s thickness.” (B2).
After 20 readings, the participants who struggled to read the 190 gsm test paper expressed similar opinions and noted that embosses could not be read well due to the thickness of the paper. One of the participants stated, “This paper is both thick and deformed. It is difficult to read.” (B4). Another participant noted, “The paper is too thick and the printing is double-sided, hence it is difficult to read. It does not offer good readability.” (B2).
Due to the inability of the participants to read the paper in the first reading and their complaints about the thickness of the paper and impossibility of feeling embosses, the number of readings was not increased for the 250 gsm paper.

- Opinions Related to Tactile Sensitivity of the Individuals

Two of the participants had difficulties with reading the test papers due to their lower tactile sensitivity and increased deformation associated with the number of readings. After the 150th reading of the 180 gsm test paper, one of the participants expressed his opinion as, “I do not really like the embosses, they are flatter than what I am used to.” (B5). Struggling more than other participants after the 20th reading of the 190 gsm paper, one of the participants noted, “It is difficult to read this paper, I can not really feel this one because my tactile sensitivity is low. Other papers had better readability.” (B1).

3. CONCLUSIONS

In accordance with the opinions of the visually impaired participants, it was observed in this study that physical and chemical properties of papers used in printing aimed at these individuals had an impact on reading quality and comfort. The thickness of 90 - 120 g/m^2, which was too thin, and emboss walls thinner than what the individuals were used to caused difficulties with reading. In addition, it was found that collapses or bursts occurred in papers within this grammage range as the number of readings increased. Also, the deformation of embosses accelerated when exposed to too much pressure during reading or externally. The analysis of these papers between 90 - 120 g/m^2 showed that the reading quality was low and the papers could only be used as scratch paper for learners of the Braille alphabet. A grammage between 180 - 300 g/m^2 caused the paper to be too thick and embosses to fail to reach desired height. Since papers have higher strength especially after 190 g/m^2, tips of embosses were observed remain flatter as a result of pressure. Increased flattening on tips with increased number of readings hindered the tactile sensitivity of the visually impaired participants. The difficulty in reading or the inability to read as a result of the decline in the tactile sensitivity showed that papers with high grammages did not offer a quality reading. The fact that “Braille Index Box” embosser used to prepare test pages gave an error after printing the 250 g/m^2 test paper showed that papers with a grammage above 190 g/m^2 could not be printed using this type of embossers and could lead to problems in other embossing machines (Braille Typewriter, Thermoform Machine and similar embossing systems) as well.
Another factor observed in analyses performed within the scope of the study was that low tactile sensitivity in the visually impaired due to reasons such as diabetes made it more difficult for them to read test papers with an excessively low or high grammage. In accordance with surface properties of the papers, it was found that the reading quality was good with high grade papers, whereas the reading quality was way below expectations with coated papers since fingers could not hold on to the surface. It was understood from statements of the participants and surface examinations of embosses after the first reading and the 150th reading that both emboss quality and reading comfort were optimum with 160 - 170 g/m^2 papers.

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THE POSSIBILITY OF MICROCAPSULES APPLICATION USING PAD PRINTING TECHNOLOGY

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Abstract: *Microcapsules are small spheres that vary in their morphology and size, and generally consist of two parts: the core and the shell. Regarding the encapsulated core material inside the microcapsules, they are used today in various fields of application, such as in medicine, pharmacy, agriculture, construction, chemical and food industry, biotechnology, electronics, as well as in printing and textile industry. In order to fulfill their basic purpose, microcapsules need to be applied on the target areas of the substrate material without damage, using different application techniques such as coating, spraying and printing. The aim of this research was to determine the properties of the prints, made on different substrates with pad printing technology, and microcapsules, which were added into the printing ink. Selected microcapsules were characterized according to their size and volume distribution as well as surface morphology, using SEM microscopy and digital image processing. The core of the microcapsules was the phase change material (PCM). Properties of the prints were determined by spectrophotometric and digital image processing methods. Correlations between the results of the prints and the microcapsules were determined and will be presented as final results.*

Keywords: pad printing, dry PCM microcapsules, size and volume distribution, paper substrates

1. INTRODUCTION

The pad printing or the gravure offset printing is an indirect gravure printing technology that uses an intermediate element – a silicone rubber pad, for image transfer from the engraved printing plate onto the substrate material (Deco TECHnology Group Inc, 2015); (Kipphan, 2001). Despite certain limitations, regarding the maximum image size that can be printed, the pad printing technique has numerous advantages such as possibility to print on 3D objects, structured surfaces and various substrates types (ceramics, glass, metal, synthetic material, paper, wood), while it is simple and inexpensive technology. The products that are usually printed with pad printing technique are promotional materials, computer and medical components, products of electronics, semiconductors, automotive and plastic industry components, CDs, toys, household appliances, sporting goods and many more (Anon, 2008; Anon, 2012; Automated Industrial Systems Inc., 2012; Buhrer, 1990; Deco TECHnology Group Inc, 2015; Kipphan, 2001; Merillampi et al., 2011; Mooring et al., 2005; Nomura et al., 2014; PDS International Limited, 2015; Pröll, 2015; Sharon, 2007). The most important elements that are included in the pad printing process are the printing plate (made with etching, laser engraving or photopolymer methods) (Pudas, 2004), the doctor blade, the silicone pad, the ink (mixed with solvent) and the printing substrate. The printing inks, used within this printing technique, are highly viscous and highly pigmented (Kipphan, 2001). Regarding the printing plate, an important parameter presents the engraved depth of the printing elements, which can vary from 25 μm to 65 μm. But since the pad can only transfer a limited quantity of the ink (approximately 10 μm), greater depth is unnecessary (Kipphan, 2001; Pröll, 2015). The printing pad characteristics such as: shape, size, hardness, material and surface finish (Izdebska & Thomas, 2016), as well as the smoothness of the substrate surface (Leppavuon et al., 1994) play very important role in the final print quality.

So far, various materials such as paper, cardboard, plastic materials, and textiles have been enriched with the use of the microcapsules. Microcapsules can be deposited onto the surface of the substrate material (Urbas et al., 2014; Pavić, 2015) either by using various printing technologies (screen printing, sheet-fed and web offset printing, gravure, flexography, rod coating, inkjet and xerographic printing), where the chosen printing method dictates the amount of the microcapsules (screen printing enables the highest amount of the microcapsules) (Savolainen et al., 2011), or they can be added after the end of a printing processes via coating or spraying, and nevertheless they can be incorporated into the material itself (Rodrigues et al., 2009; Pavlović et al., 2014; Goetzendorf-Grabowska, et al., 2004; Goetzendorf-Grabowska et al., 2008; Gosh, 2006; Chovancova et al., 2005). The main advantage of the printing process for microcapsule's transfer is that they can be relatively evenly applied to the target areas (Starešinič et al., 2011). Besides integrated visual and tactile elements in the prints, introduction of the microcapsules added another aspect to the final printed product, which can be smell or some other microcapsule's functionality that adds value to the end product (Pavić, 2015; Rose, 2007). However, adding a new functionality to the prints using microcapsules affects basic physical, mechanical and optical characteristics of the printed substrates (Blanco-Pascual et al., 2014; Pavić, 2015; Urbas & Stankovič Elesini, 2015; Tarnopol, 2011).

The microcapsules are small spheres that usually consist of two parts: the core, an active ingredient in the form of either solid, liquid or gas, and the shell, that protects the core material, usually made of natural or synthetic polymers (Gosh, 2006). They emerged in the 1950s, and their the most successful commercial use in the graphic industry was for the carbonless copy paper production (Dubey et al., 2009). Since then, microcapsules applications became more diverse with constant development, so today they found their use in various fields of application such as: medicine, pharmacy, agriculture, construction industry, chemical industry, food industry, biotechnology, cosmetic industry, photography, electronics, textile and printing industry (Pavlović et al., 2014; Boh et al., 1999; Boh et al., 2003; Boh, 2007; Poncelet & Boh, 2008). Depending on the application, a wide variety of core materials can be encapsulated, including dyes, pigments, catalysts, monomers, curing agents, plasticizers, flame retardants, nanoparticles, and phase change materials, while the shells can be made to be a permeable, semi-permeable, or impermeable (Gosh, 2006). The microcapsules can be premixed either in the ready-to-use inks, or mixed with the conventional, the UV and the plastisol printing inks or they can even be mixed with the printing varnish (MicroCapsules-Technologies, 2007; Kipphan, 2001; Savolainen et al., 2011; MikroCaps, 2013; Rose, 2007; Kondo et al., 1975; Kulčar et al., 2010).

The aim of this research is to examine the possibility to print microcapsules using a pad printing technique, and to determine in what extent the addition of phase change material (PCM) microcapsules into the pad printing ink, as well as printing of different ink layer thicknesses, affects physical and optical characteristics of the prints made on four different paper materials.

2. MATERIALS AND METHODS

This research studies the possibility to print microcapsules using pad printing technique on four different paper substrates. It examines the influence of printed microcapsules with pad printing ink, using two different ink layer thicknesses, on the color and physic characteristics of the prints.

2.1 Printing equipment and materials

As a printing master for pad printing process, a Nyloprint WS 0.73 printing plate was used (FlintGroup, Luxembourg), which is a water soluble printing plate with steel base and photopolymer photosensitive layer, with the hardness of 77 Shore D. The plate was exposed (12.7 mW/cm^2 UV lamps intensity) using Nyloprint CW 22×30 Kombi platemaking device (BASF, Germany). A positive film (D_{min}= 0.185; D_{max}= 4.372) was used for plate exposure (80 sec.) to generate printing and non-printing elements, and a 200 lpi screen film was used for subsequent definition of the printing elements depth. The later was performed with two different exposure time settings on the solid tone patches in order to obtain various printing elements depth, and therefore two different ink layer thicknesses on the prints (20 sec. – R_{20} solid tone patch, and 60 sec. – R_{60} solid tone patch). The depths of the printing elements were 81.88 μm for R20 solid tone patch and 32.08 μm for R_{60} solid tone patch (measured using handheld micrometer (Käfer, Germany)). The plate developing process (160 sec. at 30°C water temperature) and the drying process (10 min. at 60 °C) were conducted using the same, previously mentioned platemaking device. The processed pad printing plate consisted of two solid tone patches (R_{20} and R_{60}), with different depths and five line elements (0.5 pt, 1 pt, 2 pt, 3 pt and 4 pt wide).

The TICP 1-1010 single color automatic pad printing machine, with open inkwell system and a round pad (Ø 10 cm), was used for the print job. Printing pressures pad/printing plate and pad/substrate were the same (the air pressure setting on the printing machine was 5.5 bar). The four different paper substrates were used as samples, which were cut into the 10x10 cm pieces before the printing process. Two sets of the samples were printed, one with the white pad printing ink MS-Weiss (PRINTCOLOR, Switzerland) and

Tiflex 2881 solvent (France), without the microcapsules and one sample set with the addition of the dry microcapsules made of melamine formaldehyde shell which exhibited slight orange colour tint. The mean diameter of the sampled PCM microcapsules in this research was 2.24 µm, which fits the theoretical dimensions of both engraved printing plate depth and the maximum ink thickness that printing pad can pick up. The microcapsules (Figure 1) were directly, manually mixed into the mixture of printing ink and solvent, in the 10% mass concentration.

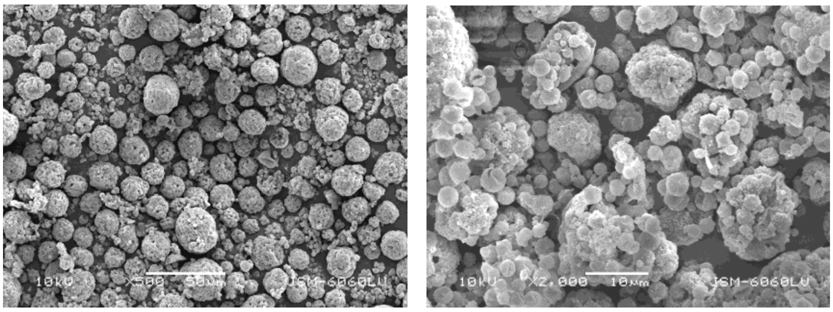


Figure 1: The appearance of dry PCM microcapsules at the 500× magnification (left) and at the 2000× magnification (right)

The used paper substrates (Table 1) had two different basic weights and surface finishes – glossy and matte. They possessed similar optical characteristics (whiteness/yellowness), which were determined by using SpectroDens instrument (Techkon, Germany). As expected, glossy paper substrates showed lower surface roughness values (R_a parameter) compared to the matte ones, in both grain directions. This paper substrate characteristic was measured with the Portable Surface Roughness Tester TR200 (Time High Technology Ltd., China).

Table 1: The basic characteristics of the paper substrates

Paper manufacturer		Nevia		Enova	
Basis weight [g/m^2]		170	170	250	250
Surface finish		matte	glossy	matte	glossy
Whiteness/Yellowness		99.84/-7.09	98.46/-6.42	99.62/-6.77	96.62/-5.76
Surface roughness R_a [µm]	MD	0.50	0.38	0.60	0.36
	CD	0.67	0.45	0.75	0.43
Thickness [µm]		155.88	146.92	253.38	214.13

2.2 Characterization of the prints

Once the samples were printed and dried, printed segments were cut and prepared for SEM analysis by a standard procedure (vapor deposition of a 9.2 nm gold layer, treated for 90 seconds with an electrical current intensity of 130 mA) using a JSM 6060 LV electron microscope (JEOL, USA). The microscope was used for the analysis of the microcapsules morphology and the size/volume distributions as well as the surfaces of the samples printed with the mixture of ink and microcapsules. The software for the digital image analysis, ImageJ (ImageJ, 2004), was used for determination of the microcapsules size and measurements of the printed lines width. The line characteristics measurements were performed on the micrographs, made by VT-300 Portable Digital Microscope (ViTiny, USA). The optical characteristics of the prints, relative spectral reflectance and L*a*b* values, for subsequent ΔE_{ab} color differences calculation, were determined using SpectroDens measuring device (Techkon, Germany).

3. RESULTS

For the purpose of the research, microcapsule characteristics (shape, size and volume distributions), printed solid tone and printed line characteristics, and the optical properties of the prints were analysed.

3.1 Microcapsules size and volume distributions

Figure 2 presents the microscopic image of dry microcapsules, which were used in the printing process (on the left), and their size and volume distribution (on the right). As it can be seen the size of used microcapsules was very small. Even though they possessed a regular round shape, they created large agglomerates, which were the result of the microcapsule drying process (Stanković Elesini et al., 2016). It must be emphasized that the larger agglomerates can affect the visual appearance, the performance and functionality of the printed area (Urbas et al., 2014; Chen et al., 2014).
Determination of the microcapsules' diameters were performed by ImageJ software (ImageJ, 2004), where measurements of large number of diameters (almost 600) were performed on previously recorded SEM micrographs. Observing the image of the microcapsules, apart of the large agglomerates, they are similar in the size, which provided relatively narrow and uniform, slightly asymmetric size distribution (Figure 2; blue bars and orange curve). The largest number of sampled microcapsules had the diameter size between 1 µm and 3 µm (70.94 %). The mean diameter of the measured microcapsules was 2.24 µm (st. dev. 0.87, median 2.29), with the minimum and the maximum of 0.36 µm and 6.74 µm, respectively. For the simplification of the microcapsules volumes calculus, the microcapsules shapes were approximated with the ideal spheres. The microcapsule volume distribution (Figure 2; grey curve) is very similar to the microcapsule size distribution curve, where microcapsules in the size range between 2 µm and 4 µm participate with 82.92 % in total microcapsules volume amount.

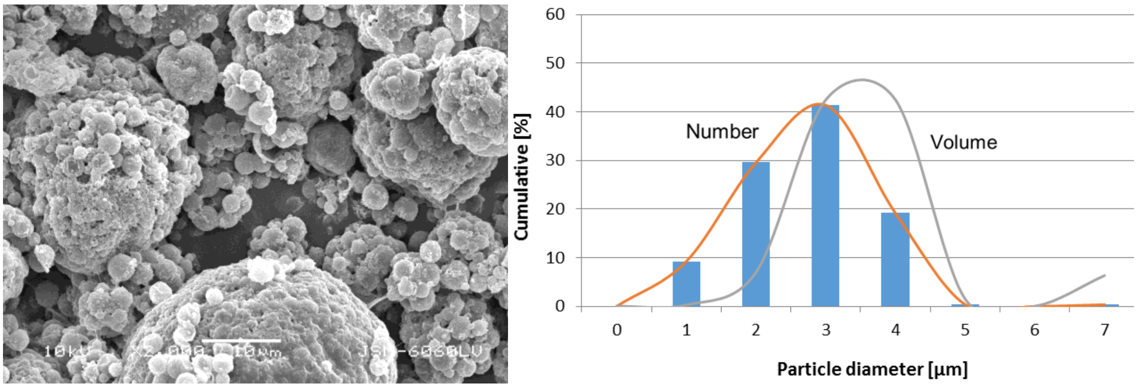


Figure 2: The appearance of the dry microcapsules (left) and obtained microcapsules size and volume distribution (right)

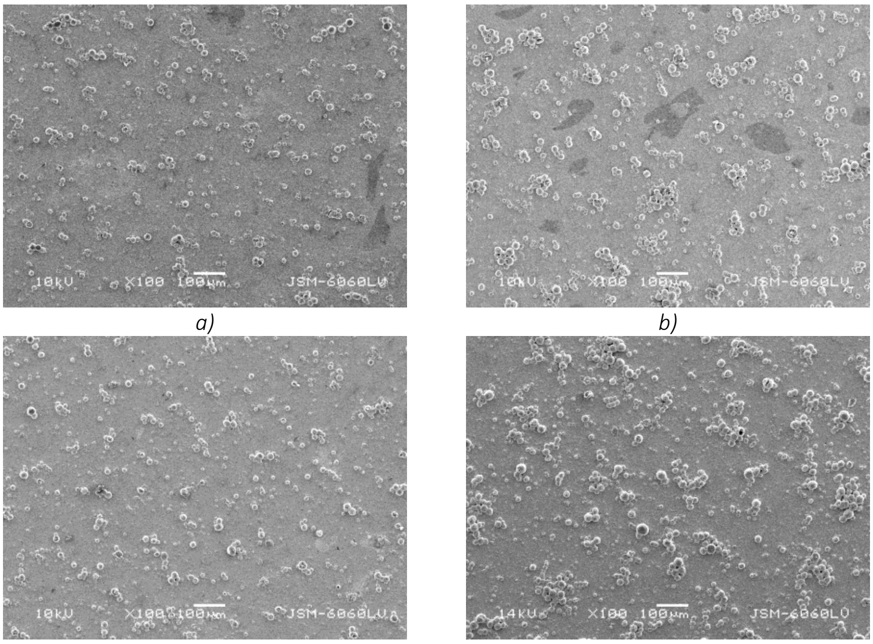
3.2 Analysis of printed samples

The thicknesses of the paper substrates and the printed samples were measured using the handheld micrometer (Käfer, Germany) (Table 2). The thickness of the prints was calculated as a difference between the values of unprinted and printed samples thickness.
The glossy paper substrates were thinner compared to the matte samples with the same basis weight, which can be contributed to the rougher surface structure of the matte paper substrates. The thicknesses of the printed ink layers with microcapsules were much higher than the thicknesses of the printed ink layers without the addition of the microcapsules. The reason lies in the agglomeration of the microcapsules, which tend to join into clusters, thus influencing the higher ink layer thicknesses. Generally, higher thickness differences were observed between R_{20} and R_{60} solid tone patches in the case of printed ink layers with microcapsules than in the case of the samples printed solely with ink. As expected, the R_{20} solid tone patches enabled higher printed ink layer thicknesses compared to the R_{60}, because of the higher depth of the printing element. Paper substrates with higher basis weight enabled higher printed ink thicknesses for both R_{20} and R_{60} solid tone patches. The glossy paper substrates also possessed higher printed ink layer thicknesses compared to the matte paper substrates with the same basis weight. The reason for thinner printed ink layer in the case of matte paper substrates lies in their rough surface structure in which the printed ink has probably penetrated, thus reducing the overall ink layer thickness. According to all mentioned, it can be concluded that the addition of the microcapsules significantly increased the thickness of the printed samples.

Table 2: The characteristics of the printed samples

Paper manufacturer		Nevia		Enova	
Ink layer thickness without MK [µm]	R_{20}	2.71	4.08	4.00	4.96
	R_{60}	2.54	3.17	2.29	3.83
Ink layer thickness with MK [µm]	R_{20}	18.42	20.38	19.83	20.42
	R_{60}	12.92	12.50	14.83	14.88

Figure 3 presents the SEM images of the prints, printed with the microcapsules on 170 g/m^2 matte and glossy paper substrates. On the prints, the individual microcapsules can hardly be seen, but the microcapsules agglomerates can be easily spotted. Analyses has shown that the agglomerated microcapsules were not damaged during the pad printing process, which may be the result of relatively low printing pressure and a low hardness of the used silicone pad. This implies that the pad printing technique can be considered as a suitable printing technique for the microcapsules transfer. The microcapsule agglomerates on the prints had relatively regular, sphere like shape as individual microcapsules. In the Figure 3 (b) and (d) it can be noticed that printing with higher ink deposition (R_{20} solid tone patch) enabled increased amount of the microcapsules on both printed paper substrates.



a) *b)* *c)* *d)*

Figure 3: The appearance of the solid tone patches of the samples printed with microcapsules on the 170 g/m^2 paper substrate in two ink layer thicknesses: a) matte R_{60}, b) matte R_{20}, c) glossy R_{60} and d) glossy R_{20} (100× magnification)

In the Table 3 are presented measured line widths on the samples printed with and without microcapsules on all four paper substrates. From the obtained results, it can be concluded that the addition of the microcapsules generated to the narrower printed lines for all samples and printed line widths. The addition of the microcapsules increases the overall ink mixture viscosity, which affects the reduction of the extent of printed ink bleeding on the printing substrate.

Table 3: Measured line widths on the prints with and without microcapsules

		170 g/m² glossy		170 g/m² matte		250 g/m² glossy		250 g/m² matte	
		without MC	with MC	without MC	with MC	without MC	with MC	without MC	with MC
Line width [mm]	0.5 pt	0.243	0.169	0.228	0.140	0.247	0.187	0.197	0.202
	1 pt	0.401	0.307	0.391	0.276	0.391	0.352	0.389	0.331
	2 pt	0.788	0.697	0.761	0.678	0.768	0.710	0.764	0.730
	3 pt	1.153	1.051	1.083	1.043	1.153	1.061	1.117	1.091
	4 pt	1.473	1.424	1.419	1.390	1.476	1.398	1.471	1.440

3.3 Optical characteristics of the prints

3.3.1 The relative spectral reflectance of the prints

The Figure 4 presents the relative spectral reflectance curves of the printed samples printed with and without the microcapsules in two different ink layer thicknesses (R_{60} and R_{20}). The longer exposure (R_{20}) resulted in shallower printing elements, while the shorter exposure time (R_{60}) led to the generation of deeper printing areas and thus larger amounts of the printing ink with the microcapsules on the prints. From the presented results in the Figure 4, it can be concluded that the prints without microcapsules on all paper substrates have almost the identical spectral curves (blue and green curves). Different ink layer thickness caused certain color deviations on the prints printed with microcapsules. Thicker ink layer (R_{20} – red curves) and thus more orange microcapsules in the printed ink layer led to lower spectral reflectance curves peaks, i.e. a bit darker prints compared to the prints with thinner ink layer (R_{60} – yellow curves).

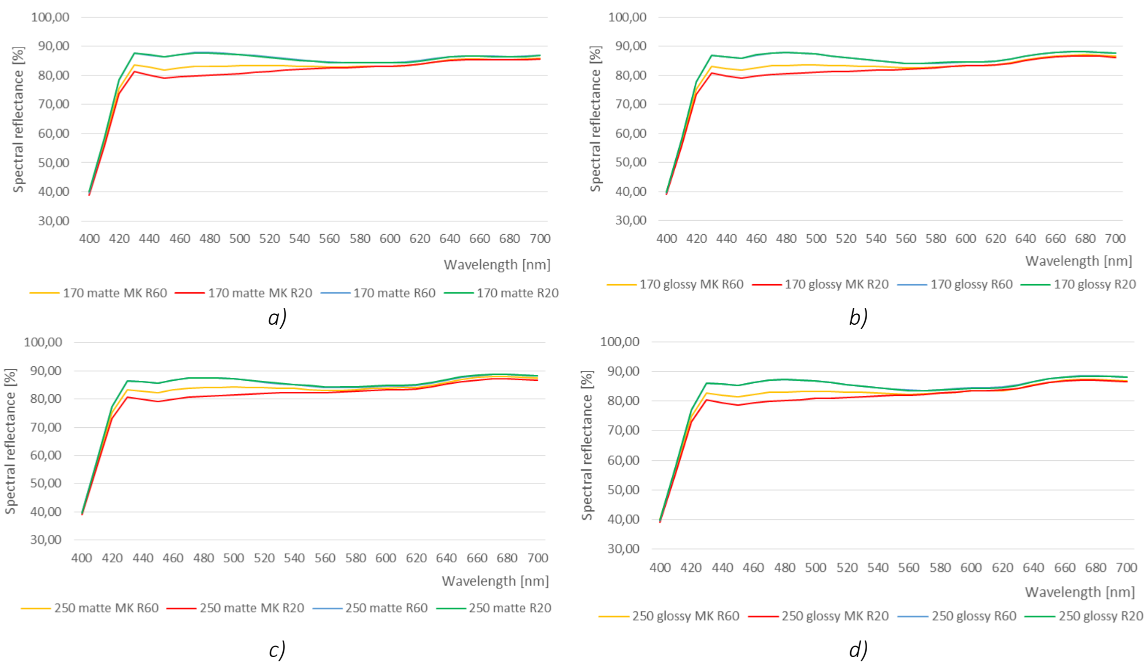


Figure 4: The relative spectral reflectance data of the printed samples with and without microcapsules using two different ink amounts (R_{20} and R_{60}): a) 170 g/m² matte, b) 170 g/m² glossy, c) 250 g/m² matte and d) 250 g/m² glossy paper substrate

3.3.2 The analysis of the color differences – ΔE_{ab} values

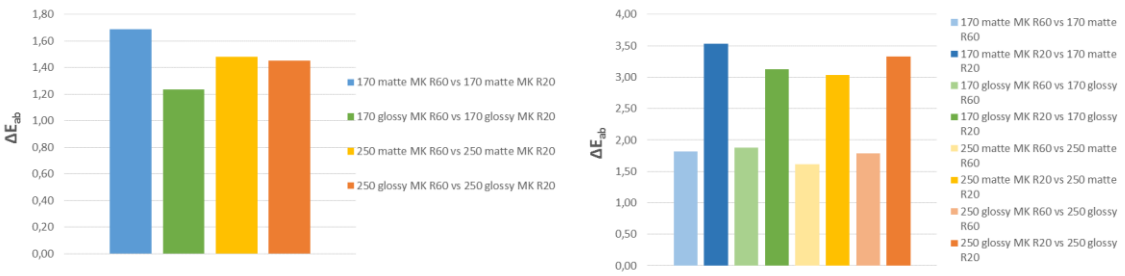
In the Table 4 are presented color difference (ΔE_{ab}) values and the corresponding tolerances within the printing industry. The color differences between the samples printed only with the white ink without microcapsules for all paper substrates and ink layer thicknesses were negligible (max. ΔE_{ab} = 0.15 between the samples 250 g/m² gloss R_{20} and 250 g/m² gloss R_{60}), and can be classified into normally invisible color difference group.

Table 4: ΔE_{ab} values and the corresponding tolerances (Efi, n.d.)

ΔE value	Meaning
0-1	A normally invisible difference
1-2	Very small difference, only obvious to a trained eye
2-3.5	Medium difference, also obvious to an untrained eye
3.5 - 5	An obvious difference
> 6	A very obvious difference

The color differences between the samples printed with microcapsules on the same paper substrate with two different ink thicknesses and therefore different microcapsule amount (Figure 5 a), are all in the group of very small color differences – ΔE_{ab}=1–2 (max. ΔE_{ab}=1.69 was observed between the samples 170 g/m^2 matte MK R_{60} and 170 g/m^2 matte MK R_{20}). This was an expected result because the color of the microcapsules was orange, so a higher microcapsules amount generated larger color deviations due to the white ink color.

The comparison between the samples printed with and without microcapsules on the same paper substrate and ink thickness (Figure 5 b), resulted in higher color differences compared to previously two analyzed samples. The samples printed with thinner ink layer (R_{60}) showed color differences in the range of ΔE_{ab}=1.62–1.87, which were as well very small. The higher color differences were observed with the samples with thicker layers of printing ink (R_{20}), due to the higher amount of orange microcapsules (ΔE_{ab}=3.03–3.53), which can be classified as medium to obvious color differences.



a) *b)*

Figure 5:** ΔE_{ab} **color differences between: a) the samples printed with microcapsules using different ink amount on the same paper type, b) the same paper type samples printed with and without microcapsules using the same ink amounts

4. CONCLUSIONS

From the presented results it can be concluded that the pad printing technology can be successfully used for printing of dry microcapsules, which was supported by the image analyses of the appearance of multiple microcapsule agglomerates on the printed solid tone sample patches, which had no visible damages that could be contributed to the printing process. With printing the selected paper substrates, measured physical and optical characteristics of the prints changed. In samples, printed with microcapsules, the measured thickness of printing ink layer increased, also on the account of the present microcapsules agglomerates. Used microcapsules in the printing ink also influenced the generation of narrower line elements and beside mentioned changed the optical characteristics of the prints. Regarding the color change of the samples, printed microcapsules brought generally medium color differences, which could be contributed to the fact that the ink color was white and the color of the microcapsules was orange.

5. ACKNOWLEDGEMENTS

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PACKAGING UPGRADED WITH MICROCAPSULES AND FUNCTIONAL PRINTING

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Abstract: *This study examines the field of functional packaging, specifically fabrication of three different types of board boxes with added value. In addition to protecting the product and providing information for the customer, packaging nowadays also has to attract and interact with the customer. During our study, packaging prototypes in the form of boxes were made and upgraded with microcapsules and functional printing. Two prototype boxes were coated with a composition containing microencapsulated fragrances and fire retardants. Microcapsules, produced by in situ polymerization process, contained a core of a chosen active substance, and an impermeable wall that enabled controlled release of active substances under mechanical pressure or heat. Lavender essential oil was used as a fragrance and triphenyl phosphate as a fire retardant. The third packaging prototype was interactive and enhanced by functional printing, more specifically by a printed electroluminescent screen, and a printed touch-sensitive sensor connected through an adjusted circuit. Printed electronics is based on flexible materials, e.g. plastic foils, paper and textiles, and conventional printing processes, such as screen printing, flexography, gravure printing, and inkjet. Conductive inks are used in the printing of printed electronics. Our elements were both printed by screen printing and then implemented on packaging prototypes.*

Key words: packaging, microcapsules, coating, functional printing

1. INTRODUCTION

In this research, three different packaging were upgraded with microcapsules and functional printing. Microencapsulation is a technology of coating, storage and target release of active substances at the micro level. Small nuclei are coated with protective spherical membranes. Microcapsules are micrometere-sized spherical or aspherical particles. They are composed of a core with active substances and walls of polymeric or inorganic materials. A fragrance and a fire retardant were used as an active substances in this research. Microcapsules with impermeable walls were produced by in situ polymerization process. The impermeable wall enabled a target release of an active substance by pressure or fire (Ocepek et al, 2012). Printed electronics have been penetrating the market niches that conventional electronics cannot reach for some time now, e.g. in packaging and posters, bringing a new view on electronics and their applications (Mraović et al, 2014). They are based on flexible materials, e.g. plastic foils, paper and textiles, and conventional printing processes, e.g. screen printing, flexography, gravure printing and inkjet. Conductive inks are used in the printing of printed electronics (Starešinič, Muck, 2010). In this research, a printed capacitive-based sensor was printed and used as a switch for turning on the printed electroluminescent screen.

2. METHODS

2.1 Microencapsulation

2.1.1 Fire retardants

Fire retardants reduce the flammability of the material to which they are applied. They do not burn. However, these materials show certain physical and chemical changes after the removal of a flame source (Golja et al, 2014). A triphenyl phosphate (figure 1) was used as an active substance for fire retardants.

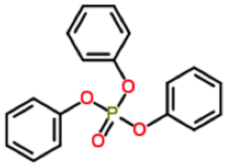

Figure 1: Chemical formula of triphenyl phosphate

2.1.2 Fragrances

Microencapsulated essential oils are used for target release of fragrance. They can be used on packaging to attract a customers and to give them some information about the product. In research lavender essential oil was used as a fragrance.

2.1.3 Synthesis of microcapsules

Microcapsules were prepared by in situ polymerisation method of aminoaldehyde prepolymers in 1 L laboratory reactor (Šumiga et al, 2011); (Šumiga, 2012). Partly methylated trimethylolmelamine (Melamin) was used as a prepolymer for microcapsule wall, and lavender essential oil (Etol) or melted triphenyl phosphate (Kefo) as a core material. Styrene-maleic acid anhydride copolymer (Hercules) was added as an emulsifier/modifying agent. Analytical grade sodium hydroxide (Kemika) was used to terminate the polycondensation, and ammonia (Kemika) for removing residual formaldehyde released during the process. In the synthesis of microcapsules, an aqueous solution of partially neutralized styrene-maleic acid anhydride copolymer was prepared, and methylated trimethylolmelamine prepolymer was added while mixing. The core material was emulsified by a turbine impeller at 1500 rpm. Polycondensation reaction took place at 70–80 ^oC for 1 hour; the reaction was terminated by raising pH to 7.0, and residual formaldehyde was removed by adding ammonia scavenger at 50^oC. Aqueous suspension contained about 30% dry matter. Average diameter of microcapsules was 5 – 10 µm.

2.1.4 Determination of optimal microcapsule coating thickness

Microcapsules were applied onto board samples of dimensions 4 x 30 cm to determine the optimal coating thickness. Four different thickness of coating were examined: 6 µm, 24 µm, 50 µm and 100 µm. The effect of a binding agent in the suspension of microcapsules was also investigated. Two different coatings were tested: without and with 30 % added binding agent.

2.2 Application of microcapsules on boxes

Corrugated board boxes with a grammage of 480 g/m^2 were coated with microcapsules using the screen printing technology. For multiple screen coating the emulsion SAATIGRAF HS3 (SAATI Chemicals, Italia) was used. Screen printing was performed with a screen-printing mesh of 77 lines per centimeter. For coating, the microcapsule suspension, 30 % binding agent was added.

2.3 Functional printing

During research, interactive packaging with touch sensitive sensor and electroluminescent screen was made. Both elements were printed using screen printing technology with conductive inks. Packaging was designed in computer program EngView Package Designer and then cut out on a flatbed cutter. The printed sensor and screen were connected with the suited circuit. The circuit was developed in collaboration with Institute Jožef Stefan in Ljubljana. Sensor operates on the basis of an electrical capacitor. A capacitor is an electrotechnical element which stores electric charge. It is made of two metal electrodes (plates) with the surface S and the distance between them d. Air or another dielectric material can be found between the plates (figure 2). When the capacitor is connected to the voltage, it stores charge. The capacitance shows how much charge a capacitor can store at specified voltage. It depends on the surface of electrodes, the distance between them and the dielectric properties of the material between them.

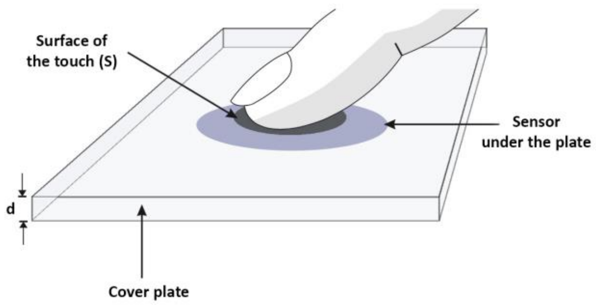

Figure 2: Graphical display of sensor elements

The capacitive switch operates on the principle of the change in capacitance. In a normal (inactive) state, the sensor (capacitor) has nominal capacitance. When the surface of the sensor is touched, the capacitance increases. This effect occurs due to the change in the permittivity of the entire system and the intake of the charge that the user brings with their finger. The change in the capacitance can only be measured with a measuring circuit (chip). The printed screen works because of electroluminescence. It occurs when a substance emits a light because of electric charge. The electroluminescent screen is made of phosphor layer located between two conductive layers. Between them, there is a dielectric layer. The EL screen was printed in following layers (figure 3):

1. transparent conductive ink,
2. phosphor ink,
3. dielectric ink,
4. silver conductive ink.

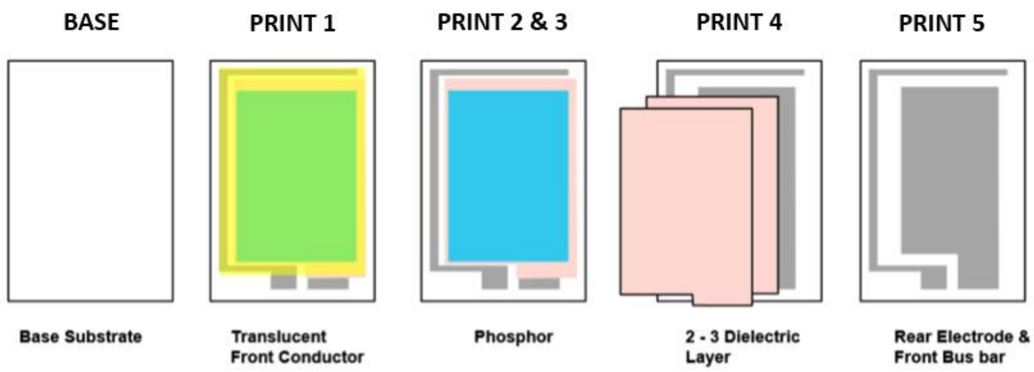

Figure 3: Sequence of layers needed for printed EL screen

3. RESULTS

3.1 Microcapsule coatings

3.1.1 Fire retardants

Microencapsulated fire retardants showed best results when they were applied in a thickness of 100 µm. To protect the entire area, microcapsules were screen printed on the entire surface of the box. The coating layer was applied only on the outside.

3.1.2 Fragrances

The intensity of the essential oil was observed in four time periods: after coating was dried, in 1 day, in 7 days and in 30 days after drying. The fragrance intensity was sufficient at all applied thicknesses. Therefore, the minimal coating thickness 6 µm was defined as optimal. Because the microencapsulated fragrance was effective enough, coating was applied only on specified areas and not on the entire surface like in the case of fire retardants.

3.2 Functional printing

The central component that connects the printed sensor and EL screen is Adafruit pocket inverter, powered by four AAA batteries. The chip QTouch was integrated onto the sensor and pocket inverter following the recommendation of the manufacturer (Atmel). The main circuit components were the pocket inverter, chip QTouch, printed sensor, *Cs* and *Cx* capacitor, and EL screen. When the sensitive sensor is touched, the charge is transferred to the sensor. This charge is stored on the *Cs* and *Cx* capacitors. *Cs* must be larger than the *Cx* capacitor. The chip measures the change of the charge on the *Cs* capacitor, which forms a bond between the SNSK and SNS sense pins on the chip. The two resistors, *Rs* and *R1*, are integrated into the circuit for an evenly charging and discharging of the capacitors, and consistently turning on and off the EL screen. The printed sensor needs a lower voltage to operate. Therefore the voltage from the 4 AAA batteries is enough (6V). The EL screen needs 180V to function, for this reason, the circuit includes a transformer, which increases the voltage. The sensor was used as a switch for turning on the EL screen on a cardboard packaging.

Figure 4: Interactive packaging with touch sensitive sensor and EL screen

4. DISCUSSION

4.1 Microcapsule coatings

Microcapsules are an effective accessory for different types of secondary packaging. They add value and enrich packaging. In this study, two kinds of microcapsules were used: fire retardants and fragrances. With same method, other kinds of microencapsulated active compounds can be applied too, such as; antimicrobial compounds, phase change materials, heat- and light-sensitive materials, etc. Depending on the purpose of the application, different release types of active substances can be achieved. An impermeable wall material allows target release when needed (pressure, temperature, fire, light, enzymes, etc.), while permeable and semi-permeable wall materials allow a constant and prolonged release of active substances. Despite all advantages of microcapsules produced by *in situ* polymerization, in most cases, they are not suitable for direct contact with food. Their recycling can also be an issue. Nevertheless, microcapsule coatings add value to the products, and future research of alternative materials and processes will definitely resolve most of this issues.

4.2 Functional printing

These interactive elements can be integrated into packaging to enhance its functionality, interactivity and added value. They are also well suited to paper products such as books, magazines, posters and the like. Touch sensitive keyboards, remote controls and other devices using keys also represent possible applications. Although the sensors are affordable, they currently encounter the same problem as RFID technology. As things currently stand, they cannot make significant inroads in the packaging industry since the price of many products is still too low to make it cost effective. Nevertheless, progress has been rapid, and a very bright future indeed awaits printed electronics for higher priced paper-based printed materials, such as interactive posters and books, and packaging for more expensive products, such as jewelry, watches, electronic products, etc.

5. CONCLUSIONS

In our research, three different packaging with added value were produced. Simple techniques were used to make significant improvements on the packaging. Used microcapsules with fire retardants can reduce damage in case of fire during transport and storage. Fragrances can interact with the customer and so improve sales of the product. The interactivity applied to the third box in the form of printed switch and EL screen, improves product functionality and interactiveness, and consequently, increase its value. First, two applications with microcapsules are especially well suited for secondary packaging, while printed electronics is appropriate for higher-priced products.

6. ACKNOWLEDGMENTS

Special thank you goes to Institute Jožef Stefan for their help with the circuit. Corrugated board boxes used in this study were kindly donated by DS Smith, Packaging Division, Slovenia.

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PRODUCTION OF TACTILE ILLUSTRATIONS

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Abstract: *Preparation of printed material for blind and visually impaired presents a special field in the graphic industry. Until recently embossing has been the leading technology for printing braille but in the last years UV ink-jet and 3D printing are taking their share in the field.*
Printing braille has been used for more than a century and has therefore been defined with different standards, regulations and recommendations, which specify all the parameters of the braille dot as well as its cell – their height, diameter, distance between separate dots and cells etc. The same properties need to be fulfilled also when printing tactile illustrations. Jet, presenting and printing illustrations for blind and visually impaired is a whole another story. Not only that the presentation of different graphics and illustrations of people, animals, objects, and other needs to be taken into account but also the combination of differently structured printed surface needs to be used.
This research paper will present how certain graphic designs need to be printed so blind and visually impaired can successfully recognize them. When printing illustrations namely, not only the height of the printed objects is important, but also the amount of selected raised object, their formation and the selected texture.

Key words: tactile illustrations, printing braille, relief surface, texture

1. INTRODUCTION

Designing and production of illustrations presenting the content of the book, regardless to its intent, age group of the reader, the genre etc., presents a challenge, which is in most cases left to the illustrator and the author of the book. How to present a representative illustrated content, which will satisfactory fulfill the expectations of the reader is already complex and extensive for readers with normal sight and even more for the blind and the visually impaired people. Regarding all mentioned tactile illustrations for the blind and the visually impaired children are the one that are the most demanding. The lack of tactile children's books on the Slovenia market can be contributed to the fact that a) in Slovenia blind and visually impaired readers are in minority according to the normal sighted people and b) the presentation, preparation and production of tactile children's book is very complex task. Most often these books are hand made with different materials and are rarely completely produced by printing. Experts and tiflo-pedagogues often produce them from different materials that are combined and glued together on different paper or textile materials (Kermauner, 2009).
In our previous research, a printed children's tactile illustration book (Glavičić, 2015) was designed and its prototypes were developed by using suitable paper substrate as a base and special printing inks, which fulfilled the regulations and demands for braille tactile perception – adequate height, size and tactile recognition of prints. During producing of the first prototype of the tactile book, the illustrations and the text were design by taking into account requirements, which were found in the professional literature. However, after the first printed prototype was tested by the blind and the visually impaired readers, some errors and important findings were recognized. Thus the aim of this article is to present those recognitions and requirements, which need to be considered when designing the tactile book for the blind and the visually impaired readers.

2. PRODUCTION AND PRESENTATION OF ILLUSTRATED TACTILE BOOK

The blind and the visual impaired people experience "visual" objects and surroundings through touch. Those objects and surroundings could also be illustrated in the tactile manner. Although tactile image can't completely replace all the visual material, it can serve as a precious source of information (Kermauner, 2009; Claudet, 2008). As such it needs to fulfill certain requirements such as relief images (produced from different materials or textures), text printed in braille (Piccardi, 2011; Brvar, 2010; Braille Authority of North

America, 2010; Tiresias, 2009) and in Latin (for visually impaired, however the size of characters needs to be a bit larger than ordinary; recommended size is 14-18 pt), the background in a slight contrast with the text etc.
In the continuation, some important requirements, which could be taken into account when designing the tactile book for the blind and the visually impaired readers are presented as the important insights of our research.

2.1 General requirements

Dimensions (the format) and the layout of the illustrated tactile book can differ, depending on the age of the child, for whom the illustrated tactile book is designed. For younger aged children book dimensions can be at first smaller and then gradually progressing to larger, but never bigger than the format A4, either in landscape or portrait layout (preferable landscape). This size responds to the surface, which can be covered by the size of the two palms, thus enabling adequate tactile sensation of the printed surface. It must be emphasized that the most important fact is that the tactile illustrated book enables simple exploration of the tactile illustration.
Paper substrate shouldn't be too smooth or too rough and it must not have high gloss. The color of the paper substrate needs to be in the proper shade for achieving adequate color contrast with the printing ink. Its thickness needs to be adequate as well as its grammage, so that the proper durability of the tactile printed book is achieved. Illustrated tactile book needs to be firm with hard covers.
Printing ink needs to be suitable for achieving the adequate height. This can be achieved either by multi-layer printing or by the use of special printing inks, which enable their expansion to adequate height. The printing ink must have high adhesion to the surface of the printing material for achieving adequate durability and resistance to rubbing and touching. Due to the use of different printing inks for printing children's books these inks need to have appropriate composition, which fulfills the requirement of standards and regulations for printing inks for children. And as one of the most important properties of the printing inks they need to enable printing with distinguished surfaces (e.g. velvet-like, smooth-like, fur-like, cold-like, warm-like, etc.) (Manojlović, 2013).
Printing of the tactile books, regardless to their end users, can be performed by different printing techniques, which can also be combined. Most often tactile illustration books are printed with screen printing, flexo or with ink-jet printing, though other techniques (like microencapsulated paper, embossing etc.) can also be used. Printing can be performed on one or even better on both sides, where in the case of folding the printing material needs to withstand the forces of cracking. When printing in color, it should be considered that the colored non-tactile background is in the proper contrast with the tactile surface, thus enabling visually impaired better perception.
Printed tactile books intended for the blind and the visually impaired readers should also be properly ***binded***. The most suitable type of binding is the wire or the spiral binding, which enables full openness of the tactile illustrated book, and thus smooth and undisturbed tactile recognition and reading (Figure 1).

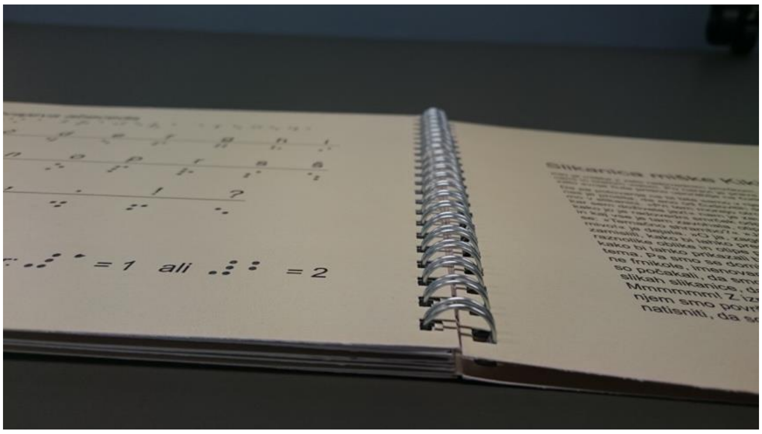

Figure 1: Opened children's tactile book.

2.2 The content and illustrations layout requirements

The contents of ordinary children's illustrated books are usually colorfully written, with emphasized key concepts, dynamically evenly or unevenly distributed text threw out the page, written in one or many colors. These texts are supported with different illustrations, which can realistically or unrealistically present the content of the book. Due to the fact that text written in braille occupies more space, the content needs to be limited to the only essential information, which can be properly supported by designed illustrations. Though, it is necessary to emphasize that illustrated content needs to be directly associated with the content of the book, otherwise the reader will be unable to recognize the presented tactile illustration.

Layouts of the content and the illustrations need to be always in the same order, preferably text written on the left and illustrations on the right side of an open book. Text can preferably be printed in Latin and in braille, where a consideration of positioning the braille before Latin was proposed by Kermauner (Kermauner, 2009). It is also recommended to begin the new page with the braille so the reader can always know where to start reading. According to this requirements, the text presented in Figure 2 isn't positioned properly.

With designing the children's tactile books, it is suitable to use larger but not too big font of braille for easier reading. Because the regulations define the specific dimensions of the braille cell and individual dots (German Institute for Standardization, 2007; Osterreichisches Normungsinstitut, 2006; Fajdetič, 2015), text written in braille needs to be left aligned, later also enabling easier detection of the text position.

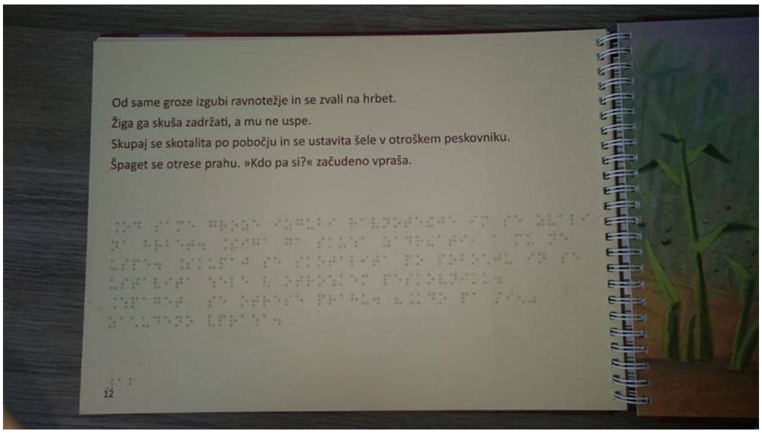

Figure 2: Unsuitable positioning of the text in the children's illustrated tactile book "Žiga Špaget gre v širni svet" by Aksinja Kermauner

2.3 Illustrated content requirements

Illustrations need to be as much realistic as possible, namely, some children were born blind and their perception is based solei on realistic comparison. For that purpose, stylization is not desirable, although a certain degree of simplification is allowed.

In the illustration all body parts and elements of presented object need to be presented (e.g. the dog must have four legs, two eyes, two ears etc.). When drawing illustrations for the blind and the visually impaired it is suggested that all the important lines, defining the distinguished features of the presented object (e.g. person, animal, object etc.) have the same adequate thickness (width of the tactile lines). Thinner lines can be used for defining the edges of less important but still significant features. The amount of lines defining the distinguished features should be kept to a minimum (Claudet, 2008; Piccardi, 2011; Braille Authority of North America, 2010; Tiresias, 2009). Beside mentioned movement or any kind of action (e.g. tail waving, shouting etc.) drawn in the illustration is inappropriate due to the fact that the blind and the visually impaired are not familiar with the ways and the manners of this presentation. Above listed presented properties in a wrong and correct manner are shown in the Figure 3.

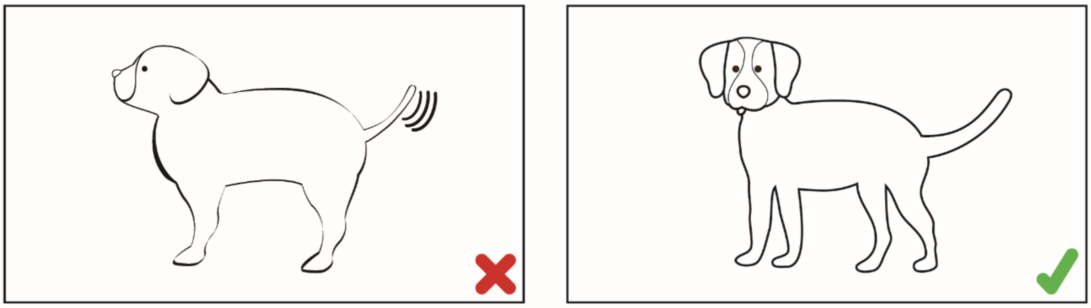

Figure 3: Wrong (left) and correct (right) illustration of a dog

Very often illustration of the people or the animals are drawn in a manner where special facial or character features are exposed, for example big eyes (Figure 4), large nose, long legs etc. Presentation of those features is not suitable for the blind and the visually impaired people because they are not familiar with this method of character depiction. When presenting specific properties and features of illustrated object it must be considered that too many information can mislead the blind or the visually impaired reader. Due to excessive amount of information the reader can't recognize the tactile image (Kermauner, 2009); Kaneko and Oouchi, 2010; Brvar 2010).

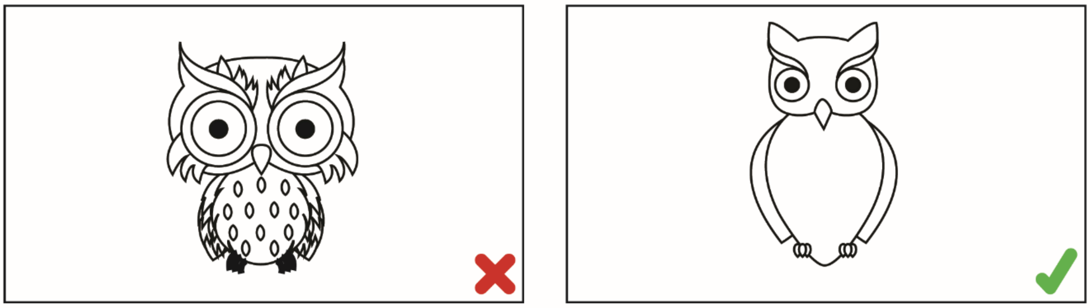

Figure 4: Wrong (left) and correct (right) illustration of special features of an owl

All objects need to be in proper size ratio according one to another and the size of the particular illustrated person, animal or object needs to stay almost the same throughout the whole book. The use of perspective could be misleading, due to the fact that reader, which were born blind, have no idea what and how objects look in perspective (Figure 5). Similar applies also for the shadows. If possible, objects need to be illustrated as standing on the ground, which must also be drawn.

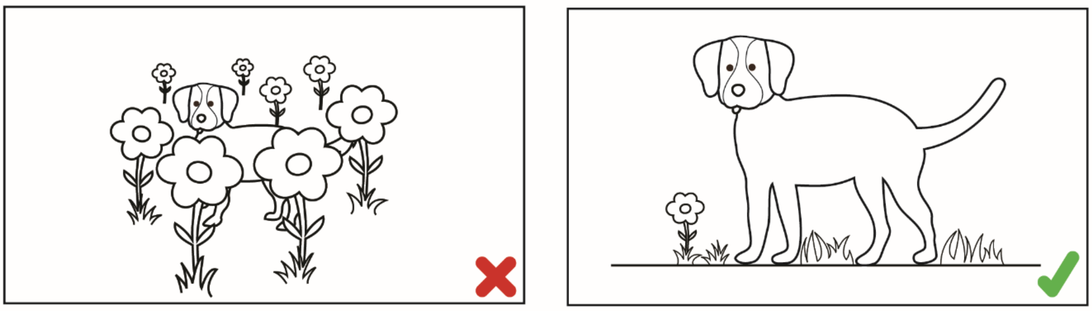

Figure 5: Wrong presentation of objects in perspective (left) and correct (right) presentation of illustrated objects in size ratio, without perspective

In some cases, illustrations of the certain elements can be not only drawn with outer lines and characteristic features but their surface can also be structured, so their properties can be easier recognized. When presenting for instance the furry surface of an animal it is not advisable to draw the fur in the shape of several lines (see Figure 6 left) because those lines can prevent detection of basic features. Therefore, differently structured surface, which when touched resembles to a specific surface needs to be considered. In this way presented surface needs to be explained in a key (legend) on the side of the illustration (Figure 5 right) (West Lafayette, 2002; Braille Authority of North America, 2010).

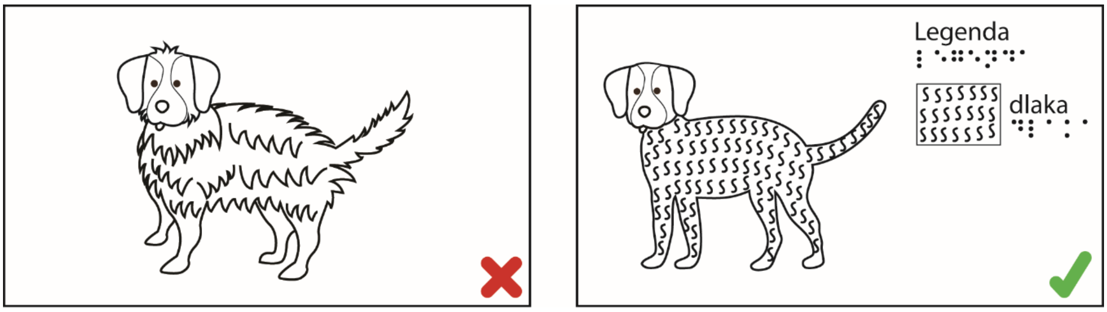

Figure 6: Inappropriate (left) and appropriate (right) presentation of the structured tactile surface

Instead of using the structured surface, distinguished surface of some illustration elements can also be formed by the use of different effective printing inks. It is known that effective inks e.g. expanding and other functional inks by which can be simulated grained (e.g. sand), rough (e.g. orange), smooth (e.g. leaves of grass) surfaces and feel sensations (smoot surfaces are often colder while soft surfaces are warmer), can simulate certain tactile surfaces (Glavičić, 2015; Krivec et al., 2014).
In some cases, illustrated objects can be simplified and presented with the simplified shape or symbol (mark) (Figure 7). In these cases, also as previous, those symbols need to be interpreted in a key (legend) where a simple symbol representing the selected element needs to be described.

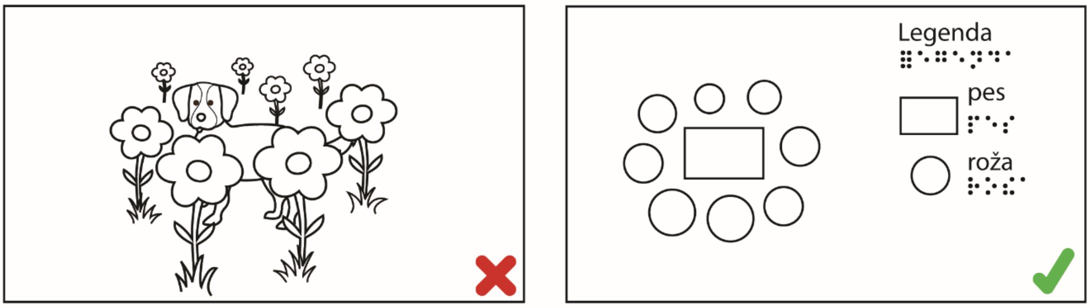

Figure 7: Inappropriate presentation of large amount of objects on left (presented in perspective) and more appropriate presentation on right with simplified shapes, where their meaning is presented in the key (legend)

3. CONCLUSIONS

This study has shown that in designing and producing of tactile illustrated books a large amount of parameters needs to be considered. Though this paper shows just the most significant ones, it is our belief that every illustration is its own project and that in every single one certain specifics can occur. In all cases it is recommended to consult with experts, especially with those who can see the world in the dark.
Tactile illustrated children's books need to be designed and produced in an interesting, attractive and mostly safe manner so they can be used by the blind and the visually impaired people as well as normal sighted. The esthetic aspect must not be overlooked where clear depictions and artistic expressiveness of the illustrations needs to be properly combined. Ultimately, even the blind and the visually impaired readers, young or old have every right to an aesthetic experience and pleasure during illustrated tactile reading.

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Graphic materials and processes efficiency

DETERMINATION OF FOUNTAIN SOLUTION'S FUNCTIONALITY

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Abstract: *Lithography is a printing technique in which selective adsorption of printing ink on the printing plate is achieved by opposite surface properties of printing and nonprinting areas. It is a two liquids technique where beside printing ink fountain solution must be used to enable nonprinting areas to repel the printing ink. Fountain solution is composed of water and some additives including buffer and surface active substances. The buffer solution must keep the fountain solution in defined pH value range (4.5 – 5.5) as lower or higher pH value would significantly influence printing process and/or stability of the printing plate. Surface active substances are added in order to decrease surface tension of the solution and enable coverage of the nonprinting areas on a printing plate with lower amount of the solution. Most common surface active substance used in lithography is propan-2-ol (isopropyl alcohol, IPA), but as it has bad influence on ecology and human health, in recent years fountain solutions with lower IPA amount or even without IPA (alcohol free fountain solution) have been developed. The aim of this paper is to determine functionality of the fountain solutions prepared with various amounts of IPA. For the purpose of this research, two sets of the fountain solutions, FS1 and FS2, were prepared and characterized by measuring pH value, electrical conductivity and surface tension. In addition, the Pruefbau MZ II Multipurpose Printability Testing System was used to determine amount of the fountain solution needed to cover nonprinting areas on the printing plate and disable adsorption of the printing ink. To detect chemical wear of the printing plate by the fountain solution, potentiodynamic polarization measurements were performed. Results showed that solutions FS1 have higher pH value and higher electrical conductivity than solutions FS2.In both sets it is visible trend of increasing pH value and decreasing electrical conductivity by addition of IPA. The surface tension is lowest by FS1 in which 4 %vol of IPA is added, even more the whole FS1 set has lower surface tension than the lowest surface tension measured in set FS2 (measured in sample with 12.5 %vol of IPA). The contact angle values were in good correlation to the surface tension values (calculated Spearman's correlation coefficient was 1 for FS1 and 0.9 for FS2). In simulated printing process, better spreading of the solution on the printing plate surface was achieved using FS2, where for almost all solution samples even 5 µl were enough to reach optimal area coverage. The electrochemical measurements showed that there is no corrosion for all investigated fountain solution samples.From this research one could conclude that investigated samples do not cause corrosion of the aluminum based lithographic printing plates. The addition of the IPA causes reduction of the surface tension that leads to lower contact angle measured when applying fountain solution onto the nonprinting areas of the lithographic printing plate. The simulation of the printing process using the Pruefbau MZ II Multipurpose Printability Testing System could be used as a tool in defining amount of fountain solution needed to disable adsorption of the printing ink, but the process should be fine tuned.*

Key words: lithography, fountain solution, printability testing, surface tension, contact angle

1. INTRODUCTION

Lithography is a printing technique in which selective adsorption of printing ink on the printing plate is achieved by opposite surface properties of printing and nonprinting areas. It is a two liquids technique where beside printing ink fountain solution must be used to enable nonprinting areas to repel the printing ink (Wilson, 2005). Fountain solution is composed of water and some additives including buffer and surface active substances. The buffer solution must keep the fountain solution in defined pH value (4.5 – 5.5) as lower or higher pH value would significantly influence printing process and/or stability of the printing plate. Surface active substances are added in order to decrease surface tension of the solution and enable coverage of the nonprinting areas on a printing plate with lower amount of the solution. Most commonly used surface active substance in lithography is propan-2-ol (isopropyl alcohol, IPA), but due to its bad influence on ecology and human health (NIOSH, 2016), in recent years fountain solutions with lower IPA amount or even without IPA (alcohol free fountain solution) have been developed (Deshpande, 2011). Furthermore, with the increase of the environmental behavior, some governments have issued guidelines to reduce amounts of alcohol in fountain solutions (U.S. Environmental Protection Agency, 2006).

2. MATERIAL AND METHODS

For the purpose of this research two sets of commercial fountain solutions were prepared. First set (FS1) was prepared using concentrate, which is used for composition of the low alcohol or alcohol free (without use of IPA) fountain solution and the second set (FS2) is made of concentrate in which lower amounts of the IPA should be added (to 12 %vol). Each set consists of five samples by changing the amount of the IPA. The FS1 was made by adding 4 %vol of the concentrate (as proposed by the producer) in the distilled water and then adding 0, 1, 2, 3 and 4 %vol of IPA. The FS2 was made by adding 2.5 %vol of concentrate (proposed amount of the producer is 2 – 3 %vol) in the distilled water and adding 2.5, 5, 7.5), 10 and 12.5 %vol of IPA. Characterization of the fountain solutions was performed by measuring pH value, electrical conductivity and by calculating surface tension. Surface tensions of prepared fountain solution samples were calculated using stalagmometric method (drop weight method). This method is one of the most commonly used to determine surface tension of a liquid. The method is based on the Tate's law (1) (Tate, 1864):

$$mg = 2\pi r\sigma \tag{1}$$

where *m* is mass of the liquid droplet, *g* is gravitational acceleration, *r* is radius of the nozzle and *σ* is surface tension of the liquid.
Alternatively, as the surface tension is proportional to the weight of the drop, the surface tension of the unknown liquid could be compared to a reference liquid of known surface tension (2).

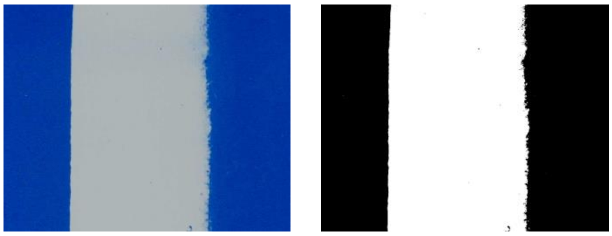
$$\sigma_s = \sigma_r \, \frac{m_s}{m_r} \tag{2}$$

where σ_s is surface tension of an unknown liquid, σ_r is surface tension of referent liquid, m_s is mass of droplet of the unknown liquid, m_r is mass of droplet of the referent liquid.
The surface tension for the purpose of this paper was calculated using equation (3), which is derived from the (2) introducing number of droplets in the same volume of liquid.

$$\sigma_s = \sigma_r \, \frac{n_r \rho_s}{n_s \rho_r} \tag{3}$$

where σ_s is surface tension of an unknown liquid, σ_r is surface tension of referent liquid, n_s is number of droplets of the unknown liquid, n_r is number of droplets of the referent liquid, ρ_s is density of the unknown liquid, ρ_r is density of the referent liquid.
The density of the liquids was calculated using pycnometer and as a referent liquid water was used.
The pH value was measured by pH meter "WTW" GmbH pH 340/SET – 1 and conductivity was measured using "WTW" GmbH LF 330/SET. To determine interaction between fountain solution samples and printing plate contact angle (CA) on the nonprinting areas of a conventional aluminum based printing plate. The printing plate was exposed by a metal-halide lamp for 60 pulses (the exposure unit calculates amount of energy on the plate surface) and developed in fresh sodium based alkaline developer for ten seconds. The contact angles were measured using Dataphysics' OCA 30 unit. This unit highly automated to disable influence of the operator on the results. It is equipped with an automated dispense unit to use drops of defined volume, automated movement of sample table, video system to enable measurement of the contact angle at precisely defined time after initial solid-liquid contact. These features enable better control of the measurements as they have significant influence on CA results (Cigula et al, 2010). Measurements were conducted using the Sessile drop method, at 24°C with drop volume of 1 µl. CA computations were made using Laplace-Young fitting method. In addition to the contact angle computation, to detect interaction between printing plate's nonprinting areas and fountain solution, printing simulation was performed. The Pruefbau MZ II Multipurpose Printability Testing System, equipped with the offset attachment (to enable offset printing simulation) was used for the printing simulation. This laboratory unit enables printing in precisely defined conditions regarding amount of fountain solution and printing ink, printing speed and printing pressure. For the purpose of this experiment, the printing speed was 1 ms^{-1}, printing pressure was 150 Ncm^{-2} and the amount of the fountain solution was 4, 5 and 6 µl. The printed plate samples were developed and dried at room temperature (24°C) just before the start of the printing process simulation.
The plate samples were then scanned using Epson Perfection V750 Pro and analyzed using ImageJ image analysis software (ImageJ, 2016). The ImageJ is an open source software and is constantly been developed

to meet needs of the users. The images were converted into a black&white and then area not covered by printing ink was calculated (Figure 1).



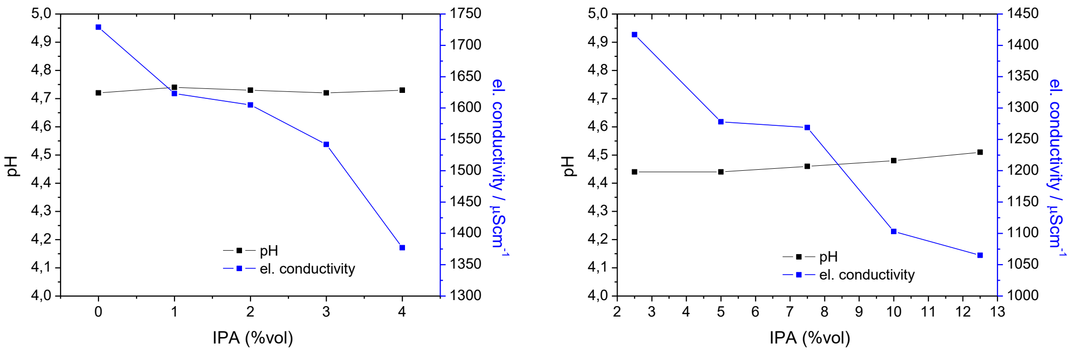
a) b)

Figure 1: Images of printing plate samples: a) original image, b) converted image

To detect possible chemical wear of the printing plate in the fountain solution a potentiodynamic polarization was performed. The potentiodynamic polarization was conducted using Ametec VersaSTAT3 Potentionstat and Galvanostat. The measurements were conducted in a standard three electrode electrochemical cell. The electrochemical cell consists of saturated calomel electrode (SCE), graphite counter electrode and working electrode (plate samples). The prepared fountain solution samples were used as the electrolyte was. The potentiodynamic polarization was performed in potential range of ±250mV from the open circuit potential measured one hour after plate sample was immersed in the electrolyte. The measurement were conducted at temperature of 24°C.

3. RESULTS AND DISCUSSION

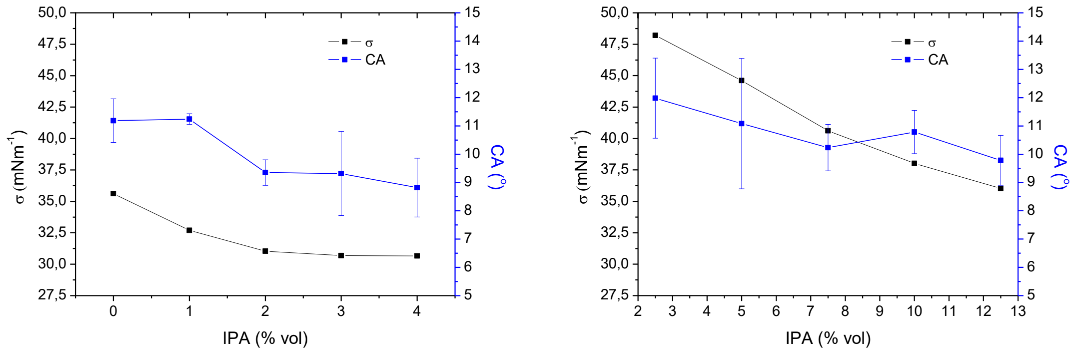
In Figure 2 one could see the results of the pH value and electrical conductivity of prepared fountain solution samples. Both sample sets have similar results, the pH value is stable, i.e. does not significantly change by addition of IPA. Nevertheless, pH value increases with the increase of the IPA amount added as could be seen in Figure 2b, where amounts of the IPA are higher. This is probably due to a slight dissociation of the IPA in water.



a) b)

Figure 2: pH value and electrical conductivity of solutions: a) FS1, b) FS2

On the other hand, IPA amount significantly influence electrical conductivity, causing it to decrease.
At both samples the electrical conductivity decreases for nearly 400 µScm^{-1}, but as FS1 (Figure 2a) has a higher initial value, the decrease is about 5% lower. The decrease of the electrical conductivity is probably caused by low dissociation of the IPA in water and therefore decreasing the fraction of the ions in the solution. The influence of the IPA amount in a solution on its surface tension and interaction with the printing plate surface is presented in Figure 3. It could be seen that decrease of the surface tension with the amount of the IPA added is more present in the FS2 in comparison to the FS1. Furthermore, adding more than 3 %vol in FS1 is not efficient as sample with 4 %vol has almost the same surface tension as previous sample (Figure 3a). On the other hand, the trend of the surface tension value of FS2 samples show that further addition of IPA would probably decrease surface tension of solution even more (Figure 3b).

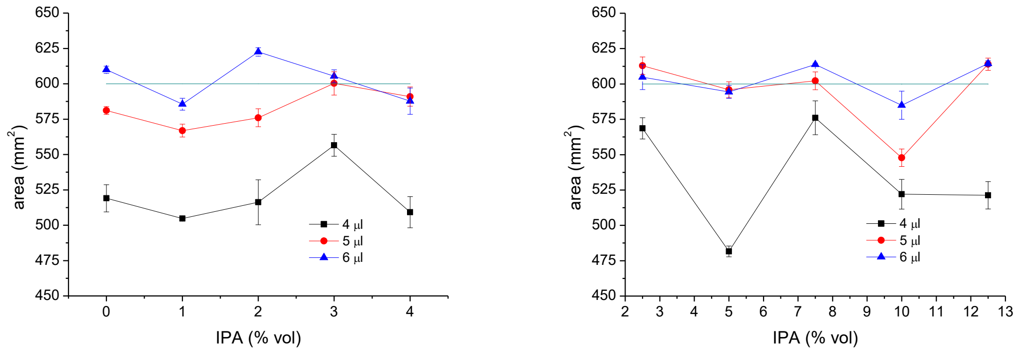


a) b)

Figure 3: Surface tension and CA of solutions: a) FS1, b) FS2

The FS1 solutions were made of commercial concentrate that could be used even without adding IPA, so it has in its composition some surfactants with lower hazardous influence than IPA (according to the technical data sheet glycol derivates are present in concentration of 15-25% (Vegra, 2016)). The FS2 solutions were made of concentrate in which no glycol derivates are present, according to the safety data sheet (Vegra, 2015).

The increase of the IPA amount in a fountain solution causes decrease of the contact angle when applying the solution onto nonprinting areas of the lithographic printing plate. The CA is lower when using FS1 in comparison to the one measured using FS2. The surface tension and the CA correlate, as could be seen when calculating the Spearman's correlation coefficient. The calculated results were $r_s = 1$ for FS1 and $r_s = 0.9$ for FS2.



a) b)

Figure 4: Area of the nonprinting areas covered with the fountain solution: a) FS1, b) FS2

In Figure 4 one could see the results of the calculated area covered by the fountain solution before inking. The green line at 600 mm^2 is denotes optimal wetting of the printing plate's nonprinting areas. It could be seen (Figure 4) that 4 µl of the solution is not enough for preventing inking of the area for both solution sets. Increasing volume of the fountain solution applied the area not covered by printing ink increases. Using solutions from set FS1 it could see increase of the area without inking when using 4 and 5 µl, with exception of solution with 4 %vol of IPA (Figure 4a). Use of 6 µl causes more area without ink than optimal, meaning too much of solution was applied on the printing plate's surface causing spreading of the fountain solution out of the zone where fountain roller passed over printing plate's surface. Although results of the contact angle and surface tension of investigated solutions imply lower functionality of FS2 set, results of the area not covered with ink show that even 5 µl is enough to reach optimal area of the printing plate covered by fountain solution (Figure 4b). The electrochemical measurements showed that in all solutions in the investigated potential spectra (±250 mV) from open circuit potential current is lower than 1 mA. If the current is lower than 1 mA, the corrosion of the material is very slow and it is not significant to the exploitation of printing plate (Prioteasa et al, 2010).

4. CONCLUSIONS

This research was conducted to determine functionality of the two fountain solutions, one proposed to use IPA and the other to be used with low amount or even without addition of IPA.
Furthermore, printing process simulation by a printability tester was introduced as a tool in defining fountain solution functionality.
From this research it could be concluded that investigated samples do not cause greater corrosion of the aluminum based lithographic printing plates, i.e. it does not influence. The addition of the IPA causes reduction of the surface tension that leads to lower contact angle measured when applying fountain solution onto the nonprinting areas of the lithographic printing plate. The simulation of the printing process using Pruefbau MZ II Multipurpose Printability Testing System could be used as a tool in defining amount of fountain solution needed to reject printing ink, but the process should be fine tuned.

5. ACKNOWLEDGMENTS

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OPTIMIZATION OF FENTON PROCESS DEGRADATION OF REAL TEXTILE WASTEWATER USING EXPERIMENT DESIGN

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Abstract: *The main goal of this study was the examination of heterogeneous Fenton oxidation of real wastewater from textile floor-coverings industry using iron impregnated clay as a catalyst. In addition, optimization of significant Fenton process parameters (H_2O_2 concentration, pH value, catalyst dosage and reaction time) and stability of the catalyst was carried out using response surface methodology on the basis of central composite design (CCD). The obtained high correlation coefficient (0.80) for dye decolourization as well as for leaching of iron was employed to optimize the process. Considering the results of applied model, the optimal conditions were the following: c(H_2O_2)=4.99 mM, pH=3.36, m(catalyst)=0.39 g and reaction time was 221 minutes. Under these terms, it was achieved maximum dye degradation and minimum iron leaching which totaled 61.09 % and 0,007 mg/l, respectively.*

Keywords: Fenton, CCD, ANOVA, impregnation, Na-bentonite

1. INTRODUCTION

The textile industry has one of the longest and most complicated industrial chains in manufacturing industry (EIPPCB, 2003). During wet processing of textiles, large amount of polluted water is discharged in environment through effluents (80-100 m^3/t of finished textile) (Aslam et al., 2004; Savin and Butnaru, 2008; Wang et al., 2011). These wastewaters have characteristic high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), total solid matter, total Kjeldahl nitrogen, pH and intense color (Nidheesh et al., 2013). Additionally, intensive color ranges may be from 2 to 60 % of the initial dyes that are not linked to the textile after dyeing process (Husain, 2006).

Since the national legislation has set stringent criteria of aquatic ecosystem quality, great importance has given to the treatment of effluent. Treatment of colored effluents can be conducted by advanced oxidation processes (AOPs), which leads to the formation of chemical species with exceptional oxidative abilities. Among them, Fenton process is known as a reaction between hydrogen-peroxide, as the oxidant, and iron species, as a catalyst, to generate highly reactive hydroxyl radicals ($HO^•$) that can efficiently degrade dye molecules (Pignatello et al., 2006). Under the optimal conditions and sufficient contact time mineralization of organic molecules into CO_2, H_2O and inorganic components that are stable end-products of chemical oxidation is possible (Nidheesh 2015).

Optimization of treatment process must be evaluated, by means of discovering experimental conditions at which it produces the best responses. The response surface methodology (RSM) is an important tool for the design and optimization of processes. The main types of RSM designs are full factorial design, central composite design (CCD), Box-Behnken design and D-optimal design (Bezerra et al., 2008). In this study, CCD with RSM was used to verify decolourization efficiency and leaching of iron ions as responses for different independent experiment parameters in the heterogeneous Fenton oxidation of real textile floor-covering effluent. To evaluate efficacy of applied treatment, optimization of aforementioned parameters was conducted to get maximum dye degradation with the best catalyst stability (minimum iron leaching).

2. METHODS

2.1 Materials

All chemicals used in this work were purchased commercially and were used without any further purification. The following chemicals were used: 30 % H_2O_2, H_2SO_4, Na_2SO_3, Na_2CO_3, $Fe(NO_3)_3$ x 9H2O (Sigma-Aldrich Company), Na-bentonite, used as a catalyst support, was Claris-p70 class (Bentoproduct Ltd., Bosnia and Herzegovina). Real textile wastewater was collected from a Serbian textile floor-covering manufacturer (Sintelon Ltd., Republic of Serbia), which had COD=1134 mgO_2/l, TOC=337,1 mgC/l, total N=57,34 mgN/l, total P=7,07 mgP/l, pH=7,34 and DBS=62,8 mg/l. Modification method of raw clay using impregnation with Fe (III) ions was described in our previous work (Kulić et al., 2016), and catalyst was named as FeBent.

2.2 Heterogeneous Fenton process

Oxidation of textile effluent was conducted as follows: convenient amount of FeBent was added to 100 ml of real sample, after what pH value was set with diluted sulfuric acid. Hereafter, initial concentration of hydrogen-peroxide was added and mixing of this mixture was set at 500 rpm at vibrating mixer (Heidolph Vibramax 100) during a predetermined time. After the end of the Fenton reaction saturated solution of Na_2SO_3 was added to the mixture, for reaction termination. The catalyst was separated by centrifugation (Sigma 3-30K) for 5 minutes at 10000 rpm. Evaluation of treatment efficacy was executed by measuring absorbance at UV/VIS spectrophotometer (UV 1800, Shimadzu, Japan), λ_{max}=301 nm. Percent of dye degradation was calculated according to the formula (1). The content of leached iron was determined by atomic absorption spectrophotometer (Perkin Elmer Analyst 700).

$$\frac{A_0-A}{A_0}\cdot 100 = DECOLOURIZATION\ (\%) \tag{1}$$

Where A_0 was initial absorbance value for effluent, and A value was sample absorbance after specified reaction time and condition.

2.3 Experiment design

Effect of four independent variables (A-initial concentration of H_2O_2, B-pH value, C-dosage of FeBent and D-reaction time) on two responses (R1-decolourization efficacy and R2-catalyst stability) were investigated employing CCD experimental design and RSM by the software Design-Expert 10.0.3. (Stat-Ease Inc., Mineapolis, USA). The actual values of coded maximum, central and minimum levels (-2, -1, 0, +1, +2) for each variable are given in table 1.

Table 1: Coded and actual values for experimental parameters

Symbol	Parameter	Unit of measure	Range of independent variables				
			-2	-1	0	+1	+2
A	Initial concentration of H_2O_2	mM	0	5	10	15	20
B	pH value	-	2.0	2.5	3.0	3.5	4.0
C	Initial dosage of FeBent	g	0.0	0.1	0.2	0.3	0.4
D	Reaction time	min	60	120	180	240	300

3. RESULTS

Employing the CCD has been designed 28 experimental runs, including 4 central point repetitions (runs 1, 6, 12 and 17). The relation between the independent variables and responses (decolourization efficiency and iron leaching content) was described by a second order polynomial model, so the experimental data were fitted by square function. ANOVA test was conducted and statistical significance of applied models is shown in table 2. It’s apparent that the modelled responses fit well with experimental data. The coefficients of determination (R^2) for process efficiency and catalyst stability were 0.8033 and 0.8405, respectively. Also, p-values are less than 0.05, indicating that each of applied models was statistically significant.

Table 2: ANOVA test results for quadratic model

Source	Sum of Square	Degrees of Freedom	Mean Square	F Value	p-value Prob> F	
			Decolorization efficiency			
Model	5317.06	14	379.79	3.79	0.0108	Significant
R^2=0.8033						
R^2_{adj}=0.5914						
DECOLOURIZATION = $56,18620 + 1,39531A - 1,07834B + 9,29718C + 7,25418D - 0,29195AB - 7,11480AC - 0,18770AD - 2,63004BC + 0,75852BD - 0,14665CD - 1,69114A^2 - 1,61051B^2 - 6,28040C^2 - 2,68127D^2$						
			Iron leaching			
Model	12.80	14	0.91	4.89	0.0034	Significant
R^2=0.8405						
R^2_{adj}=0,6687						
LEACHING OF IRON IONS = $0,33275 + 0,044917A - 0,56008B + 0,040167C + 0,033750D - 0,096375AB - 0,010125AC - 0,099875AD - 0,16425BC + 0,10650BD - 0,063500CD + 0,036937A^2 + 0,38856B^2 - 0,026562C^2 - 1,87500E - 004D^2$						

The order of runs, the real value factors, the actual experimental and predicted values for the efficiency of decolourization and leaching of iron are given in Table 3. The actual value of the efficiency of decolourization and catalyst stability varies between 0.50 to 70.78 %, and 0.01 to 3.74 mg Fe/l, respectively. Interactions among the four independent and two dependent variables can be shown as model equation (table 2), as well as illustrations on the basis of the contour response plot (figure1 and 2).

Table 3: The matrix of the experimental design, with actual and predicted values for dependent variables

Std Order	Run Order	Parameter				Decolorization efficiency (%)		Iron leaching (mg Fe/l)	
		$c(H_2O_2)$	pH	m(FeBent)	time	Actual	Predicted	Actual	Predicted
27	1	10	3.0	0.2	180	56.16	56.19	0.40	0.33
13	2	5	2.5	0.3	240	70.78	69.01	1.43	1.33
11	3	5	3.5	0.1	240	51.61	36.42	1.28	0.64
14	4	15	2.5	0.3	240	51.66	57.78	1.20	1.39
2	5	15	2.5	0.1	120	35.50	35.53	1.43	1.35
25	6	10	3.0	0.2	180	54.81	56.16	0.36	0.33
9	7	5	2.5	0.1	240	30.81	31.22	0.68	1.03
22	8	10	3.0	0.4	180	51.24	49.66	0.51	0.31
10	9	15	2.5	0.1	240	54.26	48.44	0.87	1.13
5	10	5	2.5	0.3	120	58.50	55.93	1.10	1.40
20	11	10	4.0	0.2	180	29.54	47.59	0.09	0.77
26	12	10	3.0	0.2	180	57.59	56.19	0.25	0.33
23	13	10	3.0	0.2	60	29.73	31.41	0.35	0.26
24	14	10	3.0	0.2	300	51.70	60.42	0.37	0.40
6	15	15	2.5	0.3	120	38.00	45.45	1.33	1.86
19	16	10	2.0	0.2	180	59.55	51.90	3.74	3.01
18	17	10	3.0	0.2	180	56.19	56.19	0.33	0.33
17	18	0	3.0	0.2	180	36.10	46.63	0.27	0.39
1	19	5	2.5	0.1	120	16.50	17.56	0.79	0.85
12	20	15	2.5	0.1	240	52.57	52.48	0.50	0.36
15	21	5	3.5	0.3	240	66.38	63.69	0.04	0.29
18	22	20	3.0	0.2	180	52.35	52.21	0.75	0.57
4	23	15	3.5	0.1	120	42.50	36.54	0.16	0.15
16	24	15	3.5	0.3	240	60.08	51.29	0.12	-0.04

Std Order	Run Order	Parameter				Decolorization efficiency (%)		Iron leaching (mg Fe/l)	
		$c(H_2O_2)$	pH	m(FeBent)	time	Actual	Predicted	Actual	Predicted
21	25	10	3.0	0.0	180	0.50	12.47	0.01	0.15
3	26	5	3.5	0.1	120	28.50	19.73	0.06	0.03
8	27	15	3.5	0.3	120	39.00	35.94	0.20	0.01
7	28	5	3.5	0.3	120	49.50	47.58	0.30	-0.07

4. DISCUSSION

ANOVA analysis consists of determining what independent variables significantly affect the response using Fisher's statistical test (Bazerra et al., 2008). F-values for decolourization efficiency and leaching of iron ions of 3.79 and 4.89, respectively, implies the importance of the models. Also p-value less than 0.0500 indicate that model terms are significant, and on the other hand, values greater than 0.1000 indicate the model terms are not significant. According to this statement, terms C, D, AC and C^2 for decolourization efficacy, and B and B^2 for leaching of iron ions are significant model terms.

In figure 1, the contour response plot indicates that the high efficiency of decolourization was achieved with the increase of the initial dosage of FeBent (fig. 1b, 1d) and with long contact time (fig. 1f). According to some authors (Idel-aouad et al., 2011; Ji et al., 2011; Babuponnusami and Muthukumar, 2014), decolourization is in direct proportion to a catalyst dosage, because with its increase there is a larger amount of available active sites, which produce $HO^{\bullet}$ and therefore the organic pollutant degradation increases. The excess of the catalyst may lead to a reduction of $HO^{\bullet}$ production, because of reducing the total number of protons that are reacting with the H_2O_2 molecule (Nidheesh et al., 2013). In addition, dye removal can also occur due to adsorption on the catalyst surface, and to determine the role of this process, test without the presence of H_2O_2 was conducted (run 18, table 3). The achieved removal efficiency was 36.10 %, which indicates the existence of adsorption on FeBent due to the increased mesoporosity after raw clay modification with impregnation method (Hou et al., 2011). The results of BET test are shown in the work of Kerkez et al., 2015. When varying the entire range of H_2O_2 concentration and pH values over time (fig. 1c and 1e), an increase in the degradation of dye molecules was observed with longer periods of heterogeneous Fenton reaction. The same trend was noticeable with the variation of FeBent dosage (fig. 1f), with intensive discoloration when applying higher catalyst dosages and longer reaction period. From figure 1a can be seen that at lower pH values and higher concentrations of H_2O_2 slightly increases the % of decolourization. The efficiency of oxidation is reduced due to the instability of H_2O_2, which begins to decompose into molecular oxygen without forming a sufficient amount of $HO^{\bullet}$(Gou and Dahnan, 2003). At the same time, the higher pH values of 3 allows the hydrolysis and precipitation of the iron ions on the surface of the catalyst, which leads to a lower rate of $HO^{\bullet}$ production. Therefore, an optimum pH value for Fenton process is around 3 (Ramirez et al., 2010; Babuponnusami and Muthukumar, 2014).

Second investigated dependent variable was the content of leached iron ions, or catalyst stability, which contour response plots are shown in figure 2. With the increase of reaction solution pH value, regardless of the initial H_2O_2 concentration, it was observed a drop in the content of leached iron ions (fig 2a). The influence of catalyst dosage and reaction time of heterogeneous Fenton process for varying the pH of the aqueous phase, it can be seen that low pH value lead to significant leaching of FeBent active ions. This condition can cause increasing of treatment efficiency by involving homogeneous Fenton process (Hassan and Hameed, 2011). On the other hand, with an increase of pH value comes to decreases of leached iron content (Bečelić-Tomin et al., 2014). Change of the initial H_2O_2 concentration does not significantly affect the leaching of iron with the variation of the initial FeBent dosage and reaction time. A similar trend is also present with the variation of the catalyst dose and reaction time.

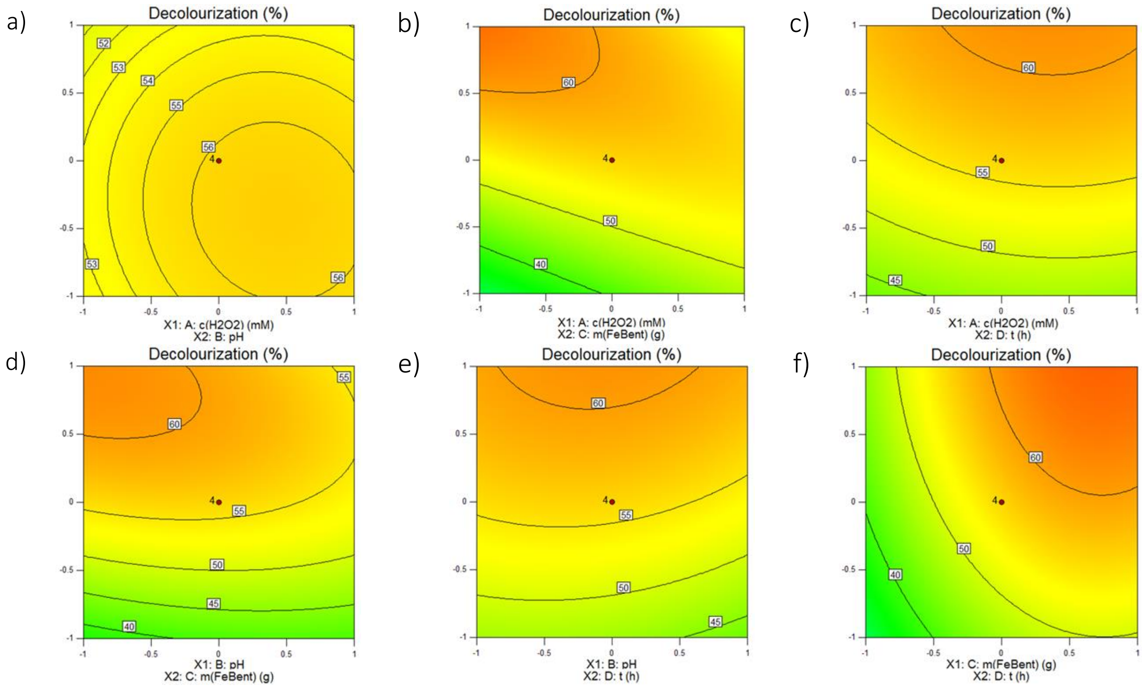

Figure 1: The effect of initial H_2O_2 concentration, pH value, FeBent dosage and reaction time on the decolourization efficiency

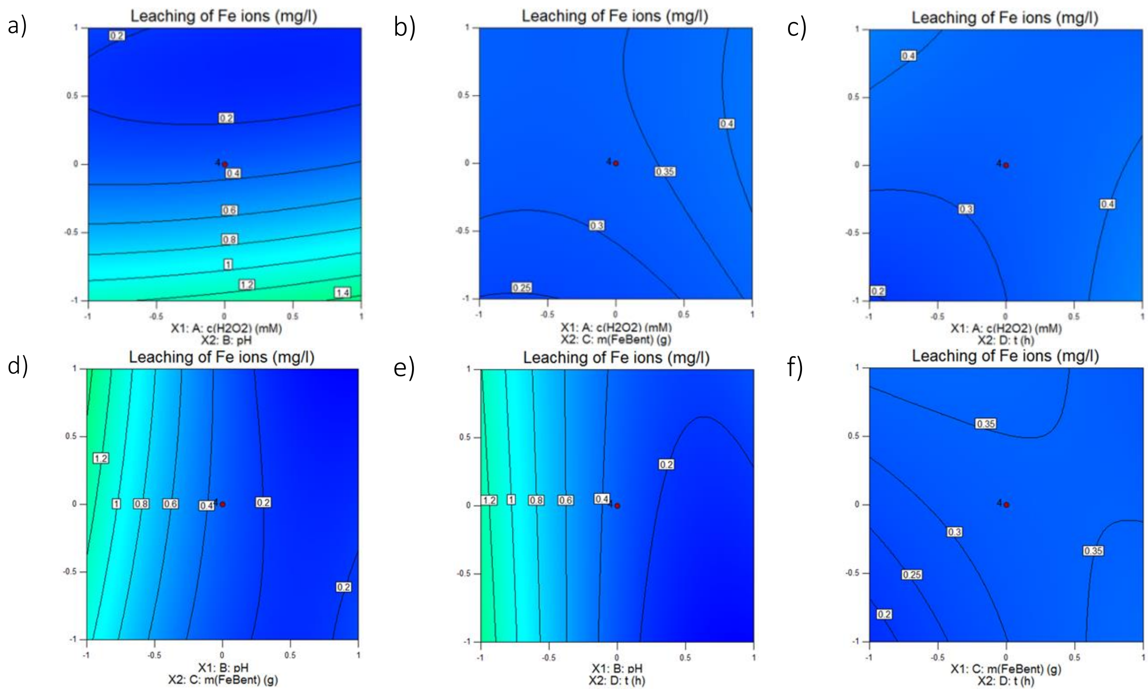

Figure 2: The effect of initial H_2O_2 concentration, pH value, FeBent dosage and reaction time on the leaching of Fe ions

The desired goal of the model is to maximize decolourization efficiency and minimize leaching of iron ions to achieve highest treatment performance. The optimum values of the independent variables are shown in table 4. After verification through a further experimental test with the predicted values, the result indicates that the maximum decolourization efficiency was obtained when the values of each variable were set as the optimum values.

Table 4: Optimal values for the independent variables and heterogeneous Fenton process efficiency

Parameter	Actual Value	Decolourization efficiency (%)	Leaching of iron ions (mg Fe/l)
Initial concentration of H_2O_2 (mM)	4.99	61.09	0.007
pH value	3.36		
Initial dosage of FeBent (g)	0.39		
Reaction time (min)	221		

5. CONCLUSIONS

This study aimed to determine the efficiency of the heterogeneous Fenton process for the degradation of real textile wastewater, while monitoring the stability of the applied impregnated clay. A central composite design was carried out to optimize the most significant the treatment parameters (H_2O_2 concentration, pH value, catalyst dosage and reaction time). Based on the experimental results, an empirical relationship between the response and independent variables was obtained, expressed by a second-order polynomial equation, as well as by contour response plots. Under optimal conditions, 61.09 %, dye decolourization was achieved and high catalyst stability was observed.

6. ACKNOWLEDGEMENTS

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POLYGLYCEROLS AS A MODERN ENVIRONMENTALLY FRIENDLY ADDITIVES IMPROVING THE ABRASION RESISTANCE OF PRINTED FILMS

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Abstract: *The aim of this work was to study the influence of primary and secondary hydroxyl groups in the irregular branched polyglycerol macromolecules on the selected properties of prints. The impact of branched polyglycerol on the rheology behaviour of water-based flexographic ink with an addition of 1% of polyglycerol is presented. Laboratory printing was performed on various plastic films (BOPP, PE, PET). Dry and wet abrasion resistance of printed samples as well as adhesion between films and ink was studied. The wettability of substrates by printing ink influence the adhesion between the substrates, in this case various plastic films, and the dried ink film.*

Key words: abrasion resistance, flexographic printing, modern additives, wettability effect

1. INTRODUCTION

Nowadays, due to the ecological reasons, the attention in the printing industry is focused on production of water-based and water-reducible flexographic inks in order to minimize the evaporation of organic solvents into environment (Havlinova et al, 1999). The surface tension of flexographic printing ink has to be lower than the surface free energy of the plastic film to allow proper wetting and adhesion between the layers of the ink film and the plastic film. Water has a surface tension of 72 mNm^{-1}, while organic solvents have values around 20mNm^{-1} and the surface free energy of plastic base is in the range 30-40 mNm^{-1} (Table 1). Therefore, it is necessary to add organic co-solvents or surfactants into water-based inks to reduce their surface tension and to achieve proper wetting and print adhesion. The adhesion of the water-based ink film to the plastic film is worse than solvent ink because of the low proper wetting of these surfaces. Moreover, the wet rub resistance of overprinted plastic films with water-based inks is usually poor (Renthozg et al, 2006).

Table 1: Values of surface free energy of chosen films (source: own elaboration according to (Izdebska et al, 2016)

Films	Surface free energy mNm^{-1}
PP	29–30
PE	31–36
PET	43–47
PLA	~50
PVC	36–39
PA	34–57
PS	43–44
ABS	35–42

Previously, we showed that commercially available hyperbranched polyesters, such as polymers from the Boltorn™ family, have improved colour fastness to rubbing of solvent-based printing inks (Żołek-Tryznowska et al, 2012; Żołek-Tryznowska et al, 2013). Polyglycerols, unlike polyesters, are more stable against acidic or basic hydrolysis (McKee et al, 2005), thus they can be used as performance additives for water-based printing inks. Furthermore, the advantage of polyglycerols in contrast with polyesters is their remarkable solubility in water, due to the functional hydroxyl end groups. Polyglycerols are environmentally friendly, biodegradable, biocompatible and non-toxic (Striba et al, 2010; Frey et al, 2002). Furthermore, oligoglycerols (2–10 units) are approved as food and pharma additives by the FDA (Frey et al, 2002), and therefore hyperbranched polyglycerols have already found application in drug delivery systems (Hu et al, 2012). Traditionally, oligo- and polyglycerols are used in different industries, e.g. food, pharmaceutical, cosmetic, soap, toothpastes, fuel, and paint (Pagliario et al, 2010).

Hyperbranched polyglycerols have already found applications as surfactants in liquids for treating lithographic printing plates (Maessenet al, 2007) or as an organic solvent in aqueous inkjet printing ink in order to prevent paper deformation (Hayashi et al, 2008).
The aim of this work is to present a possibility of applications of branched polyglycerols to improve selected properties of ink. In this work we have investigated two polyglycerols: branched polyglycerols containing predominantly primary hydroxyl groups (PG-1) or primary and secondary hydroxyl end groups (PG-1,2) and their effect on the adhesion between the dried ink film and the printing base. The influence of polyglycerol on several printing ink properties (rheology, contact angle) and print adhesion parameters (wet and dry abrasion resistance) was estimated.

2. METHODS

The structures of obtained polyglycerols are presented on Figure 1. The modifications of inks were prepared according to the descriptions of our previous works (Żołek-Tryznowska et al, 2012; Żołek-Tryznowska et al 2013, Żołek-Tryznowska et al, 2015). As a original printing ink the water-based printing ink (Chespa, Poland) was used, colour black. As a printing bases three various polymer films were used: polyethylene (PE), oriented polypropylene (BOPP) and polyethylene terephthalate (PET) films. The plastic films were activated by a corona treatment, they were transparent and had a thickness of 50 µm for PE, 20 µm for BOPP and 12 µm for PET.

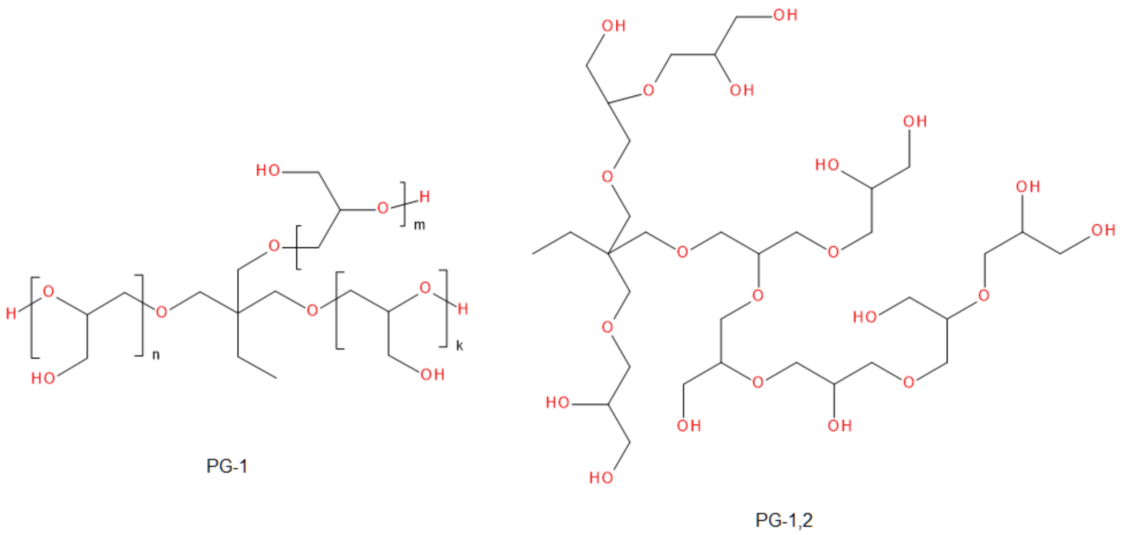

Figure 1: Investigated polyglycerols with primary and primary and secondary hydroxyl end groups

The rheological characteristics of the printing inks were specified by the flow time in a flow cup (volume 100 ml, outlet diameter of 4 mm) according to an ISO standard ISO 2431:2011. The measurements were performed at 23±1 °C and the relative error of measurements was less than 3%; the kinematic viscosity was 19±0.5 s for all printing inks.
Contact angle and surface tension measurements of the investigated inks was measured using a DSA 30E drop shape analysis system (Krüss, Germany). In order to measure contact angle, smooth and horizontal sessile drops of the liquids were deposited on a solid surface – plastic film (BOPP, PE, PET) using needles of 0.5 mm diameter. The contact angle was measured on static drops. The drop shape analysis was done 15 s after the drop deposition with Tangent method 2. Surface tension of the investigated inks was measure using pendant drop method with needles of 2 mm diameter. Environmental conditions were stable with temperature 23 ± 0.5˚C. The reported contact angle values are the mean of five samples.
Laboratory printing was carried out with a Flexiproof instrument (TMI Machines, UK). The printing speed was 60 m·min^{-1} and the printing pressure (pressure between plate cylinder and pressure cylinder) was 38, 31 and 26 units for PET, BOPP and PE plastic films, respectively. The printing plate, made of a photopolymer prepared by the digital laser–photochemical method, had dimensions of 260×90 mm and a thickness of 1.7 mm. The pressure between the anilox roller (ink capacity 6 cm^{3}·m^{-2}, screen ruling of 160 and 200 lines per cm) and the plate cylinder was 98 units. All factors were kept constant during the

printing process (printing speed, anilox roller and printing pressure). Printing was performed under controlled environmental conditions of 23 ± 0.5°C and 50 ± 1% relative humidity (RH).
The adhesion quality test was assessed simply by a tape test using tesa tape, which was attached firmly to the print and peeled off rapidly by hand according to PN-EN 15386:2007. One test on two different overprinted strips was carried out for each sample 15 minutes and 48 h after printing.
The abrasion resistance of the printed films was studied at least one week after printing using an Ink Rub Tester (TMI Machines, Canada) according to TAPPI T 830 standard. An offset paper strip (90 g, Arctic Paper Kostrzyn, Poland) was attached to a weight (0.9 kg) and automatically rubbed 100 times at a speed of 100 cycles/min along the overprinted sample. The dry abrasion resistance was quantified by analyzing the colour of paper stripe and the print according to gray scale. Colour fastness to wet abrasion of the prints was quantified after 30 rub cycles by analyzing the colour of paper stripe and the print according to gray scale. On the sample 0.1 ml in 5 drops of water was placed and the offset paper strip was attached to a weight (0.9 kg) and rubbed. The measurements were performed on two different overprinted samples.

3. RESULTS AND DISCUSSION

Printing inks must fulfill one extremely important assumption on a printing press they must be fluid, and after printing on a base, they must dry as quickly as possible (Leach. 1993; Izdebska et al, 2016). Therefore, flow behavior and viscosity of printing inks determine the printing process. For printers, knowledge of the flow behavior, the flow time, and the tack of the printing ink is essential (Izdebska et al, 2016). On the other hand, the wettability of the printing ink affects the thickness of the dried ink layer and the adhesion forces between the printing base and the dried ink layer.
Before laboratory printing, selected properties of the investigated printing ink were measured: the rheology (kinematic viscosity and flow curve) and contact angle of investigated printing inks.

3.1 Printing ink rheology

Flexographic printing inks require low kinematic viscosity, which allows regular ink flow in the printing unit. Thus, all the investigated printing inks were tested using a flow cup, which is the simplest way of measuring the kinematic viscosity in industrial practice. The flow time of the flexographic printing inks is equal to 18–35 s (outlet diameter of 4 mm) (Havlínová et al, 1999). All investigated inks exhibited kinematic viscosity in the range of 18-19 s. The viscosity *vs*. shear rate and shear stress *vs*. shear rate plots for investigated printing inks are shown in Figure 2.

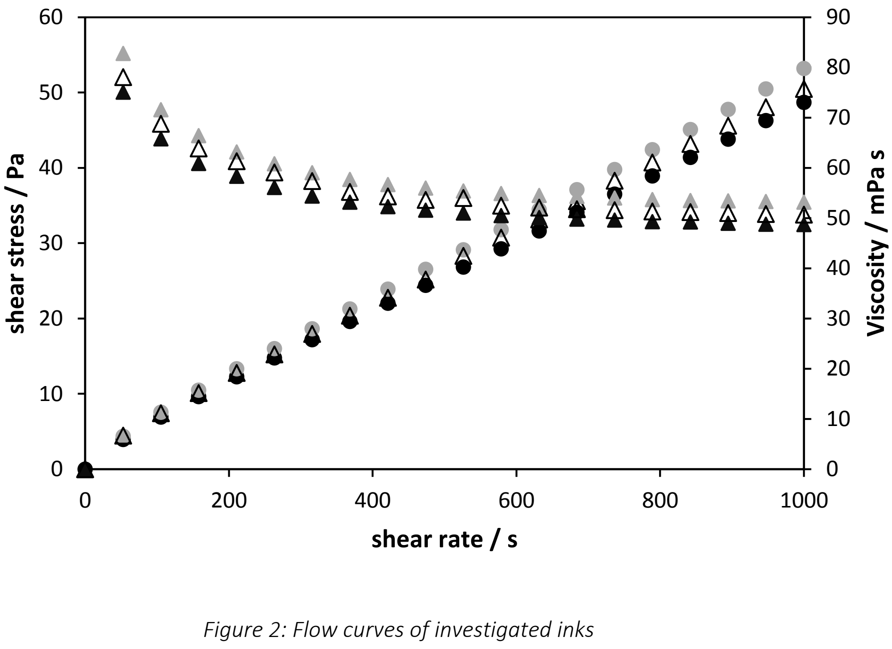

Figure 2: Flow curves of investigated inks

The presence of polyglycerols had a noticeable effect on the flow curve. The flexographic printing inks are shear-thinning or pseudoplastic materials (Mezger, 2014), thus the viscosity of the investigated inks decreased when the shear rate increased.
The flow curves were fitted by the Ostwald–de Waele model, according to equation (Mezger, 2014):

$$\tau = c\gamma^{p} \tag{1}$$

where c is a consistency coefficient and exponent p is a power-law index, τ is the shear stress and γ is the shear rate. Power-law index p characterizes the flow behavior: $p < 1$ for shear thinning flow behavior; $p > 1$ for shear-thickening flow behavior and $p = 1$ for ideal viscous (Newtonian) flow behavior. The parameters c and p along with R-squared values of the fitting for the investigated printing inks are listed in Table 2.

Table 2: Ostwald–de Waele model parameters along with R-squared values of the fitting calculated for the flow curves of printing inks: the original printing ink FlexiWet and printing inks with the addition of polyglycerols

Printing ink	c (Pa·s)	p	R^2
Original printing ink	0.126	0.857	0.999
With addition 1% of PG-1	0.147	0.840	0.997
With addition 1% of PG-1,2	0.139	0.856	0.998

For the investigated printing inks the p was less than 1, but the values of p indicates that the flow behavior tends to the Newtonian flow.

3.2 Wetting effect

The printability of polymer printing bases depends on wettability of the base by the printing ink. It should be noted that the water base printing ink are characterized by worse wettability of the polymer base because of high surface tension of water in contrast to solvent printing inks. Furthermore, the wettability of the base by the inks influence the adhesion between the base and the dried ink layer, the print quality and mechanical properties of prints. Lower contact angle is connected with better wettability, that is related with better adhesion of the ink to the base. The wettability may be estimated as a direct measurement of the static contact angle of the ink on the printing base. The values of contact angle of the ink without and with addition of investigated polyglycerols are shown in Table 3. The addition of PG-1 decreases the contact angle of the ink, therefore the improve of the wettability is observed. On the other hand, the addition of PG-1,2 increases the contact angle of the ink. The highest contact angles are observed for PE film and the lowest contact angles for BOPP film. The addition of PG-1 decreases the contact angle about 9-12%.

Table 3: Contact angle of the original flexographic printing ink and after the addition of polyglycerols

Base	Original printing ink	With addition 1% of PG-1,2	With addition 1% of PG-1
BOPP	29.5	31.8	27.1
PE	58.0	64.7	52.4
PET	34.5	37.7	30.7

3.3 Adhesion properties

The adhesion of the dried ink film to the base was examined as a simple quality test, which is commonly used in industrial practice. The adhesion after 48 h of the dried ink to the base changes in the following sequence:

$$\text{BOPP} \geq \text{PE} > \text{PET}$$

The adhesion of printing ink to the PET base is significantly poorer than adhesion to BOPP or PE base, despite a quite good wettability of the substrate by a printing ink. It may be related with interactions between PET film and ink components, e.g. printing ink polymer (in this case resin). The abrasion resistance of the prints is a very important property, especially for prints intended for packaging. The dry and wet abrasion resistance was quantified according to gray scale for assessing colour changes and one for assessing staining. Table 4 represents the rub resistance evaluated by the gray scale.

Table 4: Colour fastness to dry and wet abrasion resistance for the investigated samples. The values are quantified on a grey scale (1–5)

Printing ink	Dry abrasion resistance		Wet abrasion resistance	
	Print[a]	paper stripe[b]	Print[a]	paper stripe[b]
PE				
Original printing ink	5	5	5	2
With addition 1% of PG-1,2	2.5	2.5	1.5	2
With addition 1% of PG-1	5	5	5	2.5
BOPP				
Original printing ink	5	4	5	1.5
With addition 1% of PG-1,2	4	4	1.5	2
With addition 1% of PG-1	5	5	5	2
PET				
Original printing ink	5	4.5	4.5	2
With addition 1% of PG-1,2	3.5	3.5	4.5	1.5
With addition 1% of PG-1	5	5	5	3

[a] gray scale for assessing colour changes
[b] gray scale for assessing staining

The dry and wet abrasion resistance of overprinted PE, BOPP and PET base by printing ink containing PG-1,2 is visibly worse than prints overprinted with original printing ink or printing ink with addition of PG-1. This effect is directly connected with the wettability of those printing inks. Moreover, the addition of polyglycerols with primary hydroxyl functional end groups increases the wet and dry abrasion resistance of dried ink layer. The increases is observed for all investigated printing bases. It might be connected with the greater capacity of primary hydroxyl groups in the macromolecule for hydrogen bonding.

4. CONCLUSIONS

In this work we have demonstrated the wettability effect of branched polyglycerols and the primary and secondary hydroxyl groups impact on the adhesion properties. The impact of the polyglycerols on the rheological properties, contact angle and wet and dry abrasion resistance is reported in this paper. The addition of branched polyglycerols strongly affects the wettability of the polymer base by printing ink.
The results obtained support the use of branched polyglycerols as performance additives for water-based printing inks and may open up new possibilities for applications of these polymers.

5. ACKNOWLEDGMENTS

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INTERACTIONS IN POLYVINYIL ACETAT – PAPER ADHESIVE JOINT AND INFLUENCE ON ITS ADHESION PARAMETERS

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Abstract: *Adhesives have a wide range of applications in various industries including the printing industry. Water based emulsion adhesives being used in printing industry are most often based on polyvinyl acetate (PVAc) homopolymers, especially in bookbinding for short run book production and caseing in. Polyvinyl acetate emulsion adhesive formulations are affordable, regarded as being nontoxic and easy to handle. Designing durable and quality short run products requires understanding the interactions between used materials in adhesive joint and the basic components of paper and adhesive. In this study, the adhesive parameters of polyvinyl acetate adhesive on five paper samples containing different shares of inorganic fillers (0%, 18.5%, 20.5%, 21% and 30%) have been investigated. Paper samples were investigated in the terms of surface roughness, moisture, ash and $CaCO_3$ content. The moisture content was similar as well as surface roughness of all paper sample, except roughness of paper with 0% of inorganic fillers – filter paper. Ranking based on ash content was same as one based on $CaCO_3$ content. Besides the different paper properties, the varying amount of water (0%, 2.5% and 5%) in adhesive have been studied as well. Polyvinyl acetate adhesive was applied on all samples under the same conditions (23°C and 50% RH) and method. The analysis of the surface free energy (SFE) and its polar and dispersive components of paper and adhesive was performed by contact angle measurements. Based on those measurements, excluding a hydrophilic filter paper again, all other paper samples showed hydrophobic character and small SFE values (under 40 mJ/m^2). There was no large impact on SFE of hydrophilic adhesive samples due to added amount of water. According to the obtained results, the interfacial free energy between two phases and mechanical work of the adhesion was calculated.*

Key words: adhesion, PVAc adhesive, paper, inorganic fillers, surface free energy

1. INTRODUCTION

The market for print products is constantly changing. Instead of high volume production runs, smaller volumes tailored to individual consumer requirements are in demand. Due to digital printing, highly personalized media - such as photo books, calendars, catalogues, planners or specialized journals and books are now economically feasible. According to Canon, in the year 2000, almost 40% of print products had volumes of over 10,000 copies. This share is expected to decline to 25% in 2020. As a result, more than half of the printing products will be in short runs between one and 2,000 copies; and, in 2010, the short run share already was 48%. Besides the constant print products volume reduction, 95% of active Croatian graphic companies have been qualified as small (Croatian Chamber of Economy, 2015; Biagianti, Lanter, 2014; Romano, 2008). So, designing durable and quality on-demand or self-published single or short run products requires more attention in every aspect of production – prepress, press and frequently neglected postpress processes.

Unlike other, postpress or more often called finishing processes in graphic industry, include various types of bonding and adhesives. According to DIN 16 920, adhesives are non-metal materials which bond assembly parts by means of surface adhesion and internal strength. They are used to join two or more components together through attractive forces acting across the interfaces. The components being joined are commonly referred to as adherends or substrates. On the one hand substrates are bonded by means of the surface adhesion between the adhesive and substrates, i.e. adhesion, and on the other hand substrates are bonded by means of the internal strength of the adhesive material, i.e. the cohesion. Implicit in the formation of an acceptable adhesive bond is the ability of the adhesive to wet and spread on the adherends being joined. Attainment of such interfacial molecular contact is a necessary first step in the formation of strong and stable adhesive joints. Once wetting is achieved, intrinsic adhesive forces are generated across the interface through a number of mechanisms. The precise nature of these mechanisms have been object of physical and chemical study since at least the 1960s, with the result that a number of theories of adhesion exist. The main mechanism of adhesion is explained by the adsorption theory, which states that substrates stick primarily because of intimate intermolecular contact. In adhesive joints this contact is attained by intermolecular or valence forces exerted by molecules in the surface layers of the adhesive and adherent. In addition to adsorption, four other mechanisms of adhesion have been proposed: mechanical interlocking, interdiffusion, adsorption and surface reaction – chemical reaction, and electronic or electrostatic attraction theory. In general, more than one of these mechanisms play a role in achieving the desired level of adhesion for various types of adhesive and adherend (Bujanić, Magdalenić Bujanić, 2011).

Polyvinyl acetate (PVAc) adhesive is used for short run book production, caseing in, or production of only a few pieces of some graphic product. Polyvinyl acetates are economically important products with many desirable features. Besides the graphic industry, they are used as adhesives for porous materials, particularly wood and cloth. They belong to the group of thermoplastic polymers that are capable of being reversibly deformed within a specific temperature range. They are obtained by vinyl acetate emulsion polymerization in presence of polyvinyl alcohol (PVA) as protective colloid and are well known as cold or white glues (Figure 1). White glue can be converted into gel glue or polyvinyl alcohol through a base induced hydrolysis reaction. These dispersions have a reactive solid content of 40-70% in order to tailor the product for the particular application and set through evaporation and diffusion of the water into the substrate and at the same time by coalescence of polymer particles. A pure PVAc emulsions without any plasticizer will become hard and brittle upon aging. However, the addition of the proper amount of plasticizer will soften it and eliminate embrittlement with age. All PVAc adhesives are affordable and cheap, very easy to handle and there are no problems of toxicity (Bendror, 2016; Paris, 2000; Salvini, Saija, Finocchiaro, Gianni, Giannnelli, Tondi, 2009; Šedivka, Bomba, Böhm, Boška, 2015).

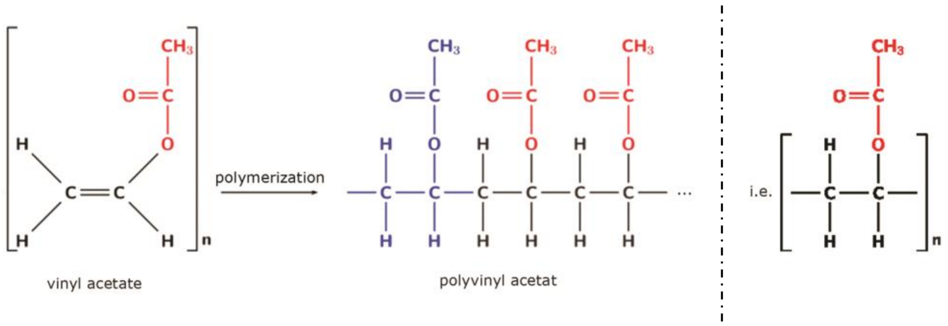

Figure 1: Vinyl acetate polymerization

For short run production and on demand printing office papers are often used. Due to their widespread use (photocopying, printing, writing and archiving) paper properties have to meet certain requirements, such as water resistance, dimensional and optical stability. That is why appropriate substances are added during paper production. Except for cellulose fibres (virgin or recovered by their origin), there are many organic and inorganic components added – fillers, adhesives, pigments, binders, etc. (Plazonić, Barbarić-Mikočević, Džimbeg-Malčić, 2015).

Designing quality graphic products requires understanding the interactions between used materials. In our case these are the interactions between paper and adhesive in adhesive joint, but also the interactions between the basic components inside these two materials.

It is widely recognized that surface free energy of paper is important parameter affecting their performance in terms of liquid penetration rate and adhesion with other polymeric materials. Finding a reliable measurement of the surface free energy of paper sheets is a challenge. Contact angle methods, including the sessile drop method, are considered the most convenient for determining the surface free energy of paper sheets. Determining the surface free energy of paper from contact angle data for various liquids is not straight forward and the results can sometimes be misleading. Errors may arise from rapid penetration of liquid probes into the sheet or factors associated with roughness of the sheet. The surfaces of paper sheets are far from ideal for contact angle measurements due to their topographical and chemical heterogeneity. Despite the fact that some of the sources of error are well known, contact angle methods are still favoured for determining the surface free energy of paper sheets (Shen, Filonenko, Truong, Parker, Brack, Pigram, Liesegang, 2000).

After the calculation of the surface free energy of paper and adhesive by contact angle measurements, it is also possible to calculate the work of adhesion. The work of adhesion is the work which must be done to separate two phases in contact. Conversely, it is the energy which is released in the process of wetting. The work of adhesion is very useful parameter because it means that the optimal surface free energy of the adhesive can be calculated to create durable and quality products with sufficient strength of bonded joints. The quality of adhesive joints is highly complex issue as well as the theoretical relationship of the surface free energies of adhesive and substrate, but it certainly depends on the work of adhesion, which is therefore used to understand or predict in-process or end-use results of the particular adhesion ("Work of adhesion", 2016).

2. METHODS

2.1 Materials

Four office papers of the same grammage (80 g/m^2), all made from primary fibers but a different price range and from four different paper manufacturers reachable on Croatian market (Avery (A), Navigator Universal (B), IQ Premium (C), and Royal White (D)) were analysed. For better understanding the influence of inorganic fillers on PVAc - paper adhesion parameters, 5th analysed paper sample was filter paper (E) that does not contain any non-cellulosic components.
Used adhesive is Croatian company (Signoplast Ltd.) product and it`s commercial name is Signokol L. It is water dispersion of vinyl acetate homopolymers with polyvinyl alcohol with the addition of plasticizer. This adhesive has 45±2% solid content. According to the Signokol L material safety data sheet, the varying amount of water (0% (S1), 2.5% (S2) and 5% (S3)) was added to the used adhesive. Water based polyvinyl acetate adhesive was applied on polyvinyl chloride (PVC) strips (100 x 15 mm) under the same conditions, application method (brushing), film thickness (66 µm±1) and set time (48 h).

2.2 Determination of paper properties

All paper samples were analysed in the terms of roughness (ISO 4287-1), moisture (T412 om-94), $CaCO_3$ and ash content. Measurements were performed according to standard methods.
For ash content determination crucibles with test specimen were placed into the muffle furnace at 900 ± 25°C. After reaching the set temperature, crucibles were left at 900°C for about an hour. When the specimen was completely combusted, crucibles were cooled, removed from furnace, placed in a desiccator to reach room temperature and weight. Percent of ash content was calculated based on the moisture-free weight of the paper test specimen as follows (Equation 1) (TAPPI T 413 om-93):

$$Ash = \frac{m_{(ash)}}{m_{(specimen)}} \times 100 \text{ [\%]} \quad (1)$$

For determination of $CaCO_3$ content, five prepared paper samples were placed in an Erlenmeyer flask with 25 mL of distilled water and subjected to digestion in a known quantity of standardized hydrochloric acid (c_{HCl}=0,1 mol/L, V_{HCl}=20 mL). After heating up to the boiling point and cooling to a room temperature, back titration with standardized sodium hydroxide (c_{NaOH}= 1 mol/L) was used to determine the amount of consumed hydrochloric acid, with phenolphthalein as indicator. The percentage of calcium carbonate was calculated based on the moisture-free weight of the paper test specimen, assumed that all of the alkaline material neutralized was calcium carbonate (Equation 2) (TAPPI T 553 pm-92):

$$\omega(CaCO_3) = \frac{(c_{HCl} \times V_{HCl} - c_{NaOH} \times V_{NaOH}) \times 0.05}{m_{(specimen)}} \times 100 \text{ [\%]} \quad (2)$$

Combustion of paper samples in muffle furnace leads to the decomposition of $CaCO_3$ to CaO and CO_2 according to the following reaction (Equation 3).

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)} \quad (3)$$

Due to above reaction, obtained results for $CaCO_3$ and ash content, after comparison the amounts of substances and calculating the mass of $CaCO_3$ and CaO, the share of CaO can be calculated (Equation 4). After determination of CaO amount it is very easy to calculate the amount of inorganic fillers residue too.

$$\omega(CaO) = \frac{m_{(CaO)}}{m_{(ash)}} \times 100 \ [\%] \tag{4}$$

2.3 Determination of surface free energy and work of adhesion

The test specimens of five different papers were cut into strips (100 x 15 mm) for determination of surface free energy (SFE) using DataPhysics OCA 30 Goniometer, the Sessile Drop method. Stripes with PVAc adhesive were the same size. By measuring the contact angles (ϴ) between the solid surfaces and three different test liquids, with known surface tensions (demineralized water, diiodomethane and glycerol) (Table 1), free surface energies of analyzed paper and adhesive samples were evaluated via automatic calculation method integrated in the software (SCA20, Version 2.01). The volume of droplets was 1 µL. Contact angles were captured by CCD camera (Figure 2) and measured after the droplet has been in contact with the paper for about 1-2 s, immediately after the droplet was formed (TAPPI T 458cm-04):

Table 1: Surface tension (γ) of test liquids, their dispersive (γ^d) and polar components (γ^p)

TEST LIQUID	SURFACE TENSION [mJ/m²]		
	γ	γ^d	γ^p
Water	72.80	21.80	51.00
Diiodomethane	50.80	50.80	00.00
Glycerol	63.40	37.00	26.40

According to the Young equation, the contact angle of a liquid drop on an ideal solid surface is defined by the mechanical equilibrium of the drop under the action of the three interfacial tensions (Equation 5):

$$\gamma_{sg} = \gamma_{sl} + \gamma_{lg} \cos\theta \tag{5}$$

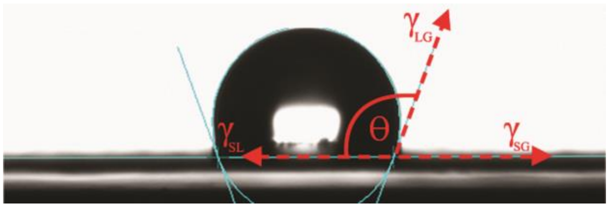

Figure 2: Wetting angle captured via CCD camera between B paper sample and water, forces of surface tensions

In order to enable adhesion of two materials, it is necessary to bring the adhesive into close contact with substrate surface to achieve strong bonds. The viscosity has to be such that on the one hand it can create adequate bond strength and on the other should not destabilize substrate. This is normally adjusted by varying the water content of the PVAc adhesive, according to the technical data sheet (0-5% of water).
The work of adhesion (W_{12}) is a measure of the strength of the contact between two phases. It is the work which must be done to separate two adjacent phases. When one phase is wetted by another, the two previously existing surfaces disappear, as a result of which energy is released due to the respective surface free energies γ_1 and γ_2. At the same time, work, which is referred to as surface free energy of interphase (γ_{12}), must be done in order to form the interface. The work of adhesion is given by the following (Equation 6) (Chaudhury, 1993; “Owens, Wendt, Rabel and Kaelbe (WORK) method”, 2016; Yuan, Randall Lee, 2011).

$$W_{12} = \gamma_1 + \gamma_2 - \gamma_{12} \tag{6}$$

The cohesion between two atoms and molecules which causes the surface free energy can be explained by different types of interactions. In particular, one can differentiate between dispersive and polar interactions. Interactions caused by temporary fluctuations of the charge distribution in the atoms/molecules are called dispersive interactions – van der Waals. Polar interactions comprised Coulomb interactions between permanent dipoles and between permanent and induced dipoles (e.g. hydrogen bonds). Because van der Waals interactions occur between all atoms and molecules there is no substance with a surface energy that solely consists of a polar part. On the other hand, there are substances which don't have any polar groups, such as alkanes that consist of hydrocarbon chains. Therefore, their surface energy is purely dispersive (“Dispersive and polar parts of the surface energy/tension”, 2016; Kaelbe, 1970).

3. RESULTS

Average values for paper roughness, moisture, ash and $CaCO_3$ content for all paper samples were calculated. Due to obtained results for ash and $CaCO_3$ content, the share of CaO was calculated to determine the share of inorganic fillers residue in all paper samples (Table 2).

Table 2: Paper properties for analyzed paper samples

PAPER SAMPLE	PAPER PROPERTIES					
	Roughness [µm]	Moisture [%]	Ash [%]	$CaCO_3$ [%]	CaO[%]	inorganic fillers residue [%]
A	2.83 ± 0.133	4.66	11.39	17.85	10.76	0.63
B	2.56 ± 0.001	4.78	13.67	20.55	13.33	0.34
C	2.83 ± 0.119	5.10	11.51	20.27	11.16	0.35
D	3.04 ± 0.005	4.40	16.63	30.01	16.60	0.03
E	5.33 ± 0.027	5.11	00.00	00.00	00.00	0.00

Average values of ten drops on different places of the same sample were taken and presented as mean ± SD (Table 3).

Table 3: Contact angle (ϴ) measurements on paper and PVAc adhesive samples

SAMPLE		CONTACT ANGLE [°]		
		Water	Diiodomethane	Glycerol
PAPER	A	113.4 ± 0.1	53.3 ± 0.7	102.1 ± 0.3
	B	110.9 ± 0.2	44.0 ± 0.5	89.0 ± 0.4
	C	105.4 ± 0.2	63.7 ± 0.9	104.8 ± 0.2
	D	112.2 ± 0.1	42.5 ± 0.6	94.3 ± 0.6
	E	0.0 ± 0.0	16.3 ± 0.2	21.1 ± 0.8
PVAC	S1	86.5 ± 0.2	37.7 ± 0.4	68.5 ± 0.4
	S2	83.6 ± 0.1	39.5 ± 0.1	72.3 ± 0.1
	S3	77.2 ± 0.1	41.0 ± 0.6	75.3 ± 0.3

Using two different calculation methods, Owens-Wendt & Kaelble (OW) and Wu`s harmonic mean (WU), the surface free energies of analyzed samples were obtained (Table 4), along with their polar (γ^p) – water attracting and dispersive (γ^d) - water repellent share and dispersive index (x^d).

Table 4: Surface free energy of paper and PVAc adhesive according to OW and WU methods

SAMPLE		SURFACE FREE ENERGY [mJ/m^2] OWENS-WENDT & KAELBLE (OW)				SURFACE FREE ENERGY [mJ/m^2] WU`S HARMONIC MEAN (WU)			
		γ	γ^d	γ^p	x^d (γ^d/γ) [%]	γ	γ^d	γ^p	x^d (γ^d/γ) [%]
PAPER	A	30.04	29.51	0.54	98.23	33.41	33.41	0.0	100.00
	B	37.32	36.77	0.55	98.53	38.12	38.12	0.0	100.00
	C	21.94	21.84	0.09	99.54	26.95	26.95	0.0	100.00
	D	36.83	36.02	0.81	97.80	38.40	38.40	0.0	100.00
	E	72.94	42.11	30.83	57.73	75.01	41.87	33.12	55.82
PVAC	S1	39.12	36.87	2.25	94.25	42.67	37.67	4.99	88.28
	S2	39.12	36.87	2.25	94.25	44.05	39.56	4.49	89.81
	S3	37.95	33.67	4.27	88.72	42.01	35.37	6.65	84.19

After determination of surface free energies of paper and PVAc adhesive samples, interfacial free energies were determined using two above listed calculation methods (Table 5).

OW model is an empirical model based on the assumption that the interfacial free energy is calculated based on the two surface free energies (γ_1 and γ_2) and the similar interactions between the phases. These interactions are interpreted as the geometric mean of a disperse part (γ^d) and a polar part (γ^p) of the surface free energy (Equation 7):

$$\gamma_{12} = \gamma_1 + \gamma_2 - 2\left(\sqrt{\gamma_1^d \times \gamma_2^d} + \sqrt{\gamma_1^p \times \gamma_2^p}\right) \tag{7}$$

The OW method is used when investigating the effect of polar and disperse interactions on wettability and adhesion.

Unlike OW model, WU model interpreted these interactions as the harmonic mean of a disperse part (γ^d) and a polar part (γ^p) of the surface free energy (Equation 8):

$$\gamma_{12} = \gamma_1 + \gamma_2 - 4\left(\frac{\gamma_1^d \times \gamma_2^d}{\gamma_1^d + \gamma_2^d} + \frac{\gamma_1^p \times \gamma_2^p}{\gamma_1^p + \gamma_2^p}\right) \tag{8}$$

The WU model is mostly used for polymers with low surface energy (up to 40 mJ/m^2). It must be emphasised that wetting performance and bonding strength depends on the interaction between adhesive and substrate. After the calculation of the surface free energies of paper and PVAc adhesive, work of adhesion and interfacial free energy for OW and WU methods were calculated too (Table 5).

Table 5: Adhesion parameters of paper and PVAc adhesive samples

SAMPLE	ADHESION PARAMETERS [mJ/m^2]			
	OW		WU	
	γ_{12}	W_{12}	γ_{12}	W_{12}
A + S1	0.98	68.18	5.26	70.82
B + S1	0.58	75.86	5.00	75.79
C + S1	3.41	57.65	6.78	62.84
D + S1	0.36	75.59	5.01	76.06
E + S1	16.60	95.46	21.01	96.67
A + S2	0.98	68.18	5.01	72.45
B + S2	0.58	75.86	4.52	77.65
C + S2	3.41	57.65	6.88	64.12
D + S2	0.36	75.59	4.51	77.94
E + S2	16.60	95.46	21.88	97.18
A + S3	1.91	66.08	6.70	68.72
B + S3	1.83	73.44	6.74	73.39
C + S3	4.42	55.47	7.78	61.18
D + S3	1.41	73.37	6.76	73.65
E + S3	12.63	98.26	18.17	98.85

4. DISCUSSION

All investigated paper samples have similar paper roughness (2.56 – 3.04 µm), except sample E – filter paper (5.33 µm). Although, surface roughness is often one of the most important adhesion parameter, in this study may be excluded because of its similarity (Packham, 2013). The highest share of $CaCO_3$ has sample D (30.01%), smallest sample A (17.85%), while paper samples B (20.55%) and C (20.27%) showed almost identical values. From Table 2 it can be observed that paper sample with highest $CaCO_3$ content contains the least amount of inorganic fillers residue (0.03%). Paper B (0.34%) and C (0.35%) have similar amounts. The highest amount has paper A (0.63). Of course, paper E does not contain any inorganic fillers. The moisture content in tested paper samples was similar, between 4.4 and 5.11%.

The contact angle indicates the wettability of a solid surface with selected liquid. The degree of wettability is determined by a force balance between adhesive and cohesive forces. Adhesive forces between a liquid and solid must be greater than cohesive forces within the liquid. Otherwise, the wetting will be low. High contact angles greater than 90° generally means that wetting of the surface is unfavourable, so the fluid will minimize contact with surface, form a compact liquid droplet and adhesion forces will be weak. Low contact angle less than 90° usually indicates that wetting of the surface is very favourable, and the fluid will spread over a large area of the surface. If contact angle is 0°, liquid will completely wet surface (Yuan, Randall Lee, 2013). Obtained contact angles presented in Table 3 show low wettability of A-D paper samples with water, which means that those papers have hydrophobic surfaces. While the hydrophobicity of samples A, B and D is almost same, sample C showed lowest hydrophobicity of these four samples. Water wets the sample E completely because polar interactions between water and cellulose fibers in sample E - filter paper. These polar interactions are hydrogen bonds between oxygen atoms from molecules of water and oxygen atoms from hydroxyl group in cellulose. Samples A-D showed high wettability with nonpolar liquid – diiodomethane, which confirmed hydrophobicity of those samples. From Table 3 it can be obtained that contact angles water - PVAc samples are lower than water – paper A-D samples. This means that PVAc is hydrophilic. Contact angles diiodomethane – PVAc are lower too. This can be explained by the existence of a hydrophobic phase in PVAc molecules which reduces the contact angle. By increasing the amount of water in PVAc adhesive its hydrophilic properties and diiodomethane – PVAc contact angle is also increasing. Based on obtained results, it can be concluded that paper samples A-D have hydrophobic coating on the surface.

Adhesion will be spontaneous only if surface free energy of the substrate is greater than surface tension of liquid. From Table 4, it is evident that samples A-D have low surface free energies (less than 40 mJ/m^2), and that sample E is polymer with high surface energy (72.94 mJ/m^2). Surface free energy of PVAc samples S1 – S3 is higher than surface free energy of paper samples A-D. Therefore, it can be expected that adhesion between PVAc and paper samples wouldn`t be spontaneous, except for filter paper. According to OW method, S1 and S2 have same surface free energy despite the varying amount of water. Because highest amount of water, S3 has a lower surface free energy, more similar to B and D paper samples. Therefore, this paper samples should show good wettability with S3. It can be assumed that paper sample C is the worst sample for quality adhesive paper – PVAc joint, and that adhesive sample S3 should ensure the best adhesion joint with all paper samples.

However, according to the two-component model, the interfacial tension depends on whether polar and dispersive parts can form interactions with corresponding parts of the adjacent phase. Considering that and OW method results, it can be noticed that S3 adhesive will not be the best choice for all paper samples. By comparison of dispersion and polar forces, or dispersion index, it is notable that sample S3 has the lowest index (88.72) due to polar interactions - hydrogen bonds between hydrogen atoms from water molecules, oxygen atoms from carbonyl group and oxygen atoms from the ester bond in PVAc structure. Dispersion index S1 and S2 adhesive is similar (94.25). If we take a look on dispersion indexes of paper samples, sample E has a lowest (57.73) due to its hydrogen bonds in cellulose chains, then sample D (97.80), sample B (98.53), sample A (98.23) and at the end is sample C (99.54). Comparing the ratio between the dispersive and the polar part of the surface free energy for two phases allows for a prediction of the adhesion between these two phases (Figure 3). The closer ratios match the more interactions are possible between the phases and the higher the adhesion is to be expected. A high potential for interactions between two phases also leads to a small interfacial energy ("Dispersive and polar parts of the surface energy/tension", 2016; Kaelbe, 1970; "Owens, Wendt, Rabel and Kaelbe (WORK) method", 2016).

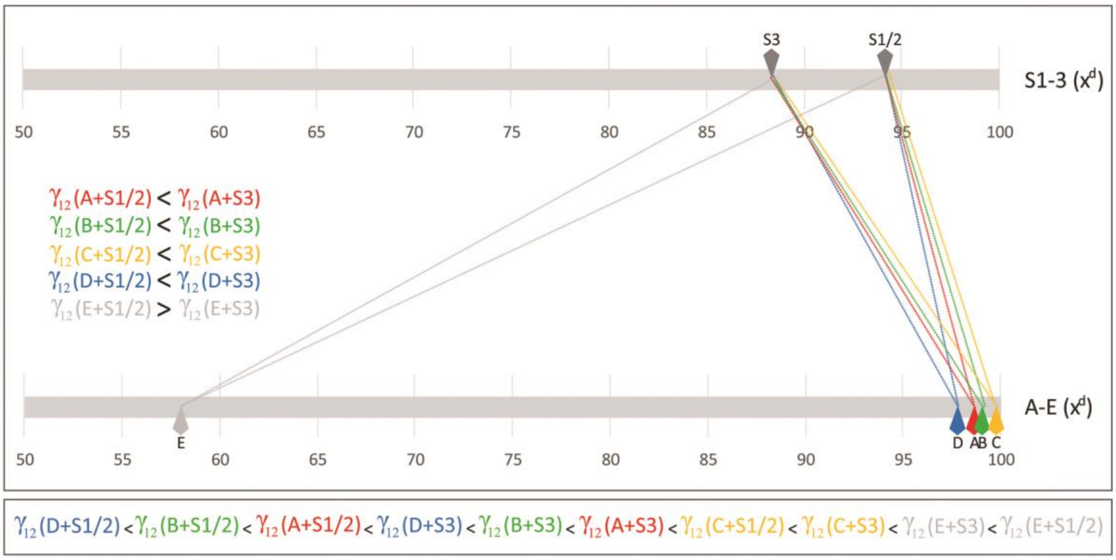

Figure 3: Comparison of interfacial energies (γ_{12}) based and dispersion index (x^d) – paper and PVAc samples

To ensure optimum adhesion, the work of adhesion must be as large as possible, i.e. maximum and interfacial free energy must be as close as possible to zero, i.e. minimum. From Table 5 it can be observed that work of adhesion is highest for samples E, B and D, as expected due to their larger SFE. The lowest work of adhesion was obtained for sample C, regardless of used adhesive sample. The lowest interfacial energy is: D, B, A, C and E.

Figures 4 and 5 show the impact of all observed parameters on adhesion efficient (roughness, $CaCO_3$ content, SFE, W_{12} and γ_{12}). Figure 4 refers to the quality of the adhesion between all tested paper samples (A-E) with PVAc adhesive samples S1 and S2. Figure 5 refers to the quality of the adhesion between all tested paper samples (A-E) with PVAc adhesive sample S3. By comparing the area of obtained polygon shapes (pentagons), it is possible to determine which paper sample will give the best adhesion results with selected adhesive. For all adhesives filter paper should be the best. Due to the fact that filter paper does not belong to the same category as the rest of the tested samples, more interesting is the order of the office paper group: D, B, A and C.

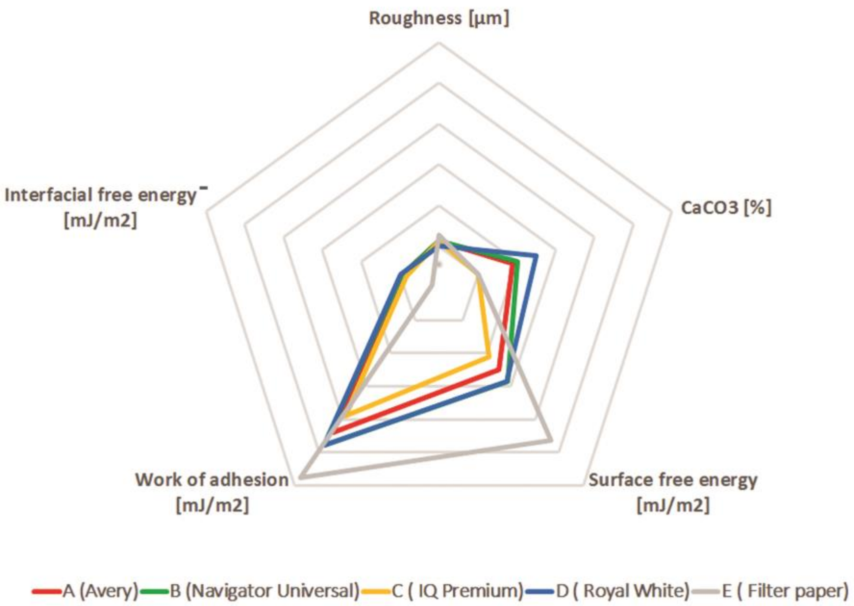

Figure 4: Comparison of adhesive joint strength - all paper samples (A-E) with S1/2 adhesive (OW method)

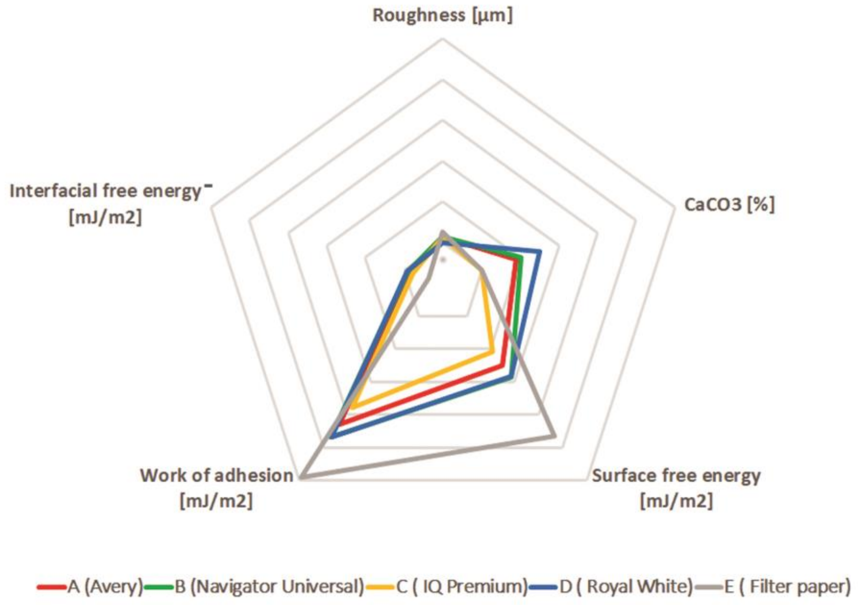

Figure 5: Comparison of adhesive joint strength - all paper samples (A-E) with S3 adhesive (OW method)

5. CONCLUSIONS

In response to environmental regulations, adhesives based on water emulsions and dispersion are becoming increasingly important. This trend has been driven by restrictions on the use of volatile organic compounds (VOC), which include solvents that are realised into atmosphere and contribute to the depletion of ozone. In this study, the influence of several parameters on adhesion between polyvinyl acetate and office paper samples were investigated. The main aim of investigation was influence of surface free energy, the work of adhesion and interfacial free energy between phases. Also, influence of inorganic fillers, especially $CaCO_3$ in paper samples A-D on adhesion was investigated too.

Although obtained results for above listed parameters (Tables 4-5), for OW and WU methods were almost identical, analysis of the results was made according the OW method, which is used when investigating the effect of polar and dispersive interactions on adhesion.

In the formation of an adhesive bond, a transitional zone arises in the interface between adherend and adhesive – the interphase. In this zone, chemical and physical properties of the adhesive may be considerably different from those in the noncontact portions.

Despite the order based on work of adhesion (E, B, D, A, C), considering dispersion index and interfacial energy it can be concluded that filter paper with PVAc S3 (5% water amount) would make best adhesive joint. Also, it can be predicted that paper sample D with adhesive S1 or S2 would make best adhesive joint comparing it to the tested office paper samples. Next is sample B, then A and at least C, all three with adhesive S1 or S2. S1 and S2 proved to be better adhesives for office papers (A-D) because of its dispersion index which is numerically closer to dispersion indexes of paper samples A-D (Figure 3). S3 is numerically closer to filter paper dispersion index i.e. to papers with higher amount of cellulose fibres and without any inorganic fillers. Thus influence of the ratio between polar and dispersive part on decreasing or increasing interphase free energy has been proven. Interphase energy controls the durability and strength of an adhesive joint and is primarily responsible for the transference of the stress from one adherent to another. Analysing the amount of calcium carbonate and other inorganic fillers in tested paper samples, it can be assumed that the increase of the amount of the $CaCO_3$ in paper can reduce interfacial energy between these two phases, due to ion-dipole interactions. To reduce the consumption of PVAc adhesive, small amount of water can be added to the dispersion (about 2.5%), without reducing the strength of the PVAc – office paper adhesion joint.

The strength of adhesive joints is usually determined by destructive tests which measure the stresses set up at the point of line of fracture of the test piece (peel, tensile lap shear cleavage). An alternative

method that was used in this study, was characterization of an adhesive joints by determining the energy expended in cleaving apart the unit area of the interphase. Although, the conclusion derived from such energy calculations are, in principle, completely equivalent to those derived from stress analysis, plans for further research are attached to expanding this study with peel strength test – to be completely sure in obtained results and derived conclusions.
The quality of adhesive joints is generally highly complex issue. Speaking of PVAc – paper adhesive joint there is a lot of interactions, a lot of interdependences between examined parameters and several disadvantages associated with the used methods, so it is not easy to make a simple and an unambiguous interpretation of obtained results. Also, paper samples A-D, besides the cellulose and calcium carbonate, are containing different amounts of various binders, fillers and pigments that cannot be precisely defined. Plans for further research of this topic, with this preliminary research and above mentioned destructive tests, certainly include the determination of cellulose content in already tested samples and production of laboratory hand-sheet paper containing only cellulose with different amounts of calcium carbonate.

6. ACKNOWLEDGMENTS

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DECOLOURIZATION OF AN ANTHRAQUINONE DYE WITH NANO ZERO VALENT IRON SYNTHETIZED BY USING KRAFT (SULPHATE) LIGNIN

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Abstract: *In this study, nano zero valent iron synthetized with the Kraft sulphate lignin was used in Fenton system to decolourize Reactive Blue 4 solution. Optimization was carried out by response surface methodology (RSM) when varying nano zero valent iron dosage, hydrogen-peroxide concentration, pH value and initial dye concentration. Experimental variables with the highest influence on the process efficiency were pH value and nanomaterial dosage. During the experiment high decolourization efficiencies were achieved (>90 %). UV-Vis spectra of decolourized solutions (for each experiment) indicated that not only the chromophore group was destroyed but also the complete dye molecule. Mineralization degree was established by determining chemical oxygen demand (COD) before and after the applied process. Achieved mineralization was >70 %. Also these measurements indicated that Fenton process also caused the mineralization of aromatics present in the lignin solution. The sum of all results indicated on the potential application of this material, in Fenton process, for heavily degradable molecules removal.*

Key words: Fenton process, sulphate lignin, anthraquinone dye, nano zero valent iron

1. INTRODUCTION

Dyes are an important source of water pollution and their degradation products can be carcinogenic and toxic to mammals. It is estimated that about 15% of the total produced dye is lost and discharged via the effluent during the dye manufacturing as well as during dying processes.

Azo and anthraquinone dyes represent the two largest dye groups that are used in the textile industry and are considered to be very stable and non-biodegradable molecules. The used processes for this kind of waste waters are physical, chemical and biological in nature (Al-Amrani et al, 2014). Conventional treatments do not have sufficient efficiency in removing these kinds of pollutants. Advanced oxidation processes (AOPs), which are characterized by *in situ* generation of reactive species, primarily hydroxyl radicals, have been recognized as one of the potential technologies for the treatment of organic pollutants in different waste waters. Intensive research in the field of application of various types of advanced oxidation process lasts for more than three decades. The main disadvantage, characteristic for all AOPs processes, is the high maintenance costs, which somewhat limits the application of these extremely powerful technologies. Fenton process is a very effective treatment for the degradation of a wide range of dyes. It is easy to perform compared to other advanced oxidation processes. Fenton process is based on the addition of Fenton reagent which includes the addition of iron ions and hydrogen peroxide, wherein the iron acts as a catalyst in the production of hydroxyl radicals. There is a great interest, in recent years, regarding the development of dye degradation using Fenton system with particles of nano zero valent iron (nZVI), because they are relatively inexpensive, environmentally safe, easy to use and they do not burden the water high concentrations of iron (Choi and Lee, 202). However nZVI particles are reactive and tend to agglomerate, resulting in a significant loss of reactivity. In last few years more favorable ecological mode of nZVI production is developing. This approach is based on the use of natural products (usually the plant and waste material) that have large natural antioxidant capacity (Prasad et al, 2014).

The aim of this study was to investigate and optimize the decolourization process of anthraquinone dye Reactive Blue 4 (RB4), with application of nano zero valent iron synthesized using broadleaf Kraft (sulphate) lignin in the Fenton process.

2. METHODS

This study involved the optimization of RB4 decolourization, with varying parameters such as dose of prepared nanomaterial, hydrogen-peroxide concentration, pH values and initial dye concentration. Also characterization of the resulting solution after applied Fenton process was performed.
All chemicals used in the experiment were pro analisy and were used without further purification.

2.1 nZVI synthesis

Broadleaf Kraft (sulphate) lignin is obtained by precipitation from black liquor produced in the cellulose manufacture in pulp and paper factory "Matroz" in Sremska Mitrovica, Serbia. 5 g of lignin is measured in Erlenmeyer flask of 300ml, 250 ml of DI was added and stirring is maintained on a magnetic stirrer for 20 min at 80˚. After stirring the mixture was filtered through a Buchner funnel, and the filtrate (extract) was used for preparing nZVI. Extract was mixed with 0.1 M ($FeCl_3 \cdot 6H_2O$) in ratio 3:1.

2.2 Optimization of operating conditions in dye solution degradation

In order to reduce the number of analysis Response Surface Methodology (RSM) was applied as an instrument for efficient testing of RB4 solution decolourization using nZVI synthesized with lignin in Fenton process.
Tests were conducted through a series of experiments on the jar test apparatus (for 60 min) and included testing of the following operating conditions: nZVI and H_2O_2 concentration, pH, and the influence of the initial dye concentration in the solution. The solutions absorbance (A) was measured at a wavelength, λmax= 595 nm, using a UV-VIS spectrophotometer 1800 (Shimadzu, Japan). The efficiency of dye decolourization was obtained by the application of the following formula (1):

$$(A_0-A_t)/A_0 \times 100 = \textit{Decolourization efficiency (\%)} \tag{1}$$

where: A_0 - initial absorbance of the dye solution
At - the absorbance of the dye solution after the treatment at a particular time t.

Mineralization efficiency was performed by COD measurement (SRPS ISO 6060:1994). Obtaining effluent toxicity was measured by luminescence inhibition test (*Vibrio fischeri*) (ISO 11348-1:2007).

3. RESULTS AND DISCUSSION

3.1 Optimization of decolourization process

Optimization of dye decolourization process was carried out in blocks with varying selected process parameters. Based on the model results and the value of P factor (which has a lower value if the variable has a greater influence on the process) have shown that the influence of investigated parameters on the decolourization efficiency decreased in the following order pH> $[Fe^0]$> $[RB4]_0$> $[H_2O_2]$ with P values of 0.000; 0.029; 0,121; 0.396 respectively. The effect of pH on the decolourization efficiency has been tested with values 2, 5 and 8. According to the results this is the parameter that had the biggest impact on the whole process (Figure 1). Efficacy of the process increases with lowering the pH values. From the contour plots it can be concluded that the used concentration of nZVI has a large influence on the process. Concentration increase of iron ions in the Fenton process caused a greater production of HO• radicals (Daud and Hameed, 2010). The effect of initial dye concentration also has influence on the decolourization efficiency. With increasing dye concentration, the process efficiency decreases. The increase in the dye concentration implies increasing the number of dye molecule at the same amount of HO• radicals which causes this effect (Chen et al, 2008).

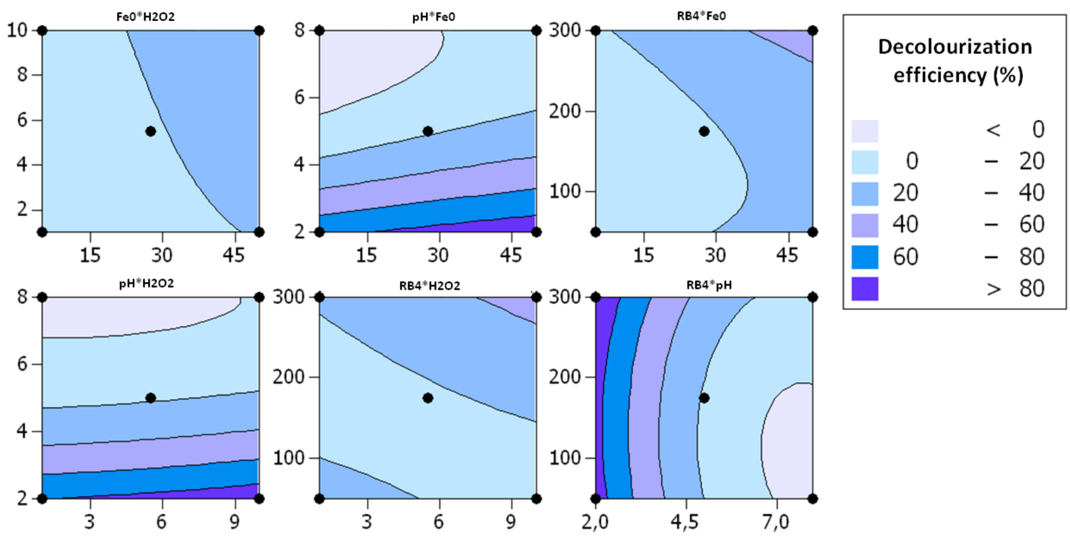

Figure 1: Contour plots of examined parameters at hold values: Fe^0-27.5 mg/l, H_2O_2-5.5mM, pH-3, Initial dye concentration-175 mg/l

Furthermore, when one of the variables is hydrogen-peroxide concentration, it is concluded that the increase in its concentration has no significant effect on the solution decolourization. At low initial hydrogen-peroxide concentrations, there is also low concentration of HO• radicals, resulting in a small increase in the dye solution decolourization. Also, with its excessive amount, H_2O_2 can acts as a scavenger of HO• radicals leading to the inhibition of the process (Muruganandham and Swaminathan, 2004).

One set of experiments was carried out to examine the possibility of lignin extract dilution when synthesizing nano zero valent iron, in order to reduce the intake of chemical species from this extract in Fenton system and to improve the effluent characteristics after the process. In the experiments nZVI was synthesized with lignin extract diluted four, six and ten times and corresponding decolourization efficiencies were: 4x = 94.01%, 93.5%= 6x, 10x= 73.1%, respectively (Figure 2). Decolourization efficiency when undiluted solution is applied was NR= 95%. The differences between the decolourization efficiency when applying nZVI synthesized with non-diluted and four and six times diluted lignin extract can be disregarded, and for further research material that is six times diluted was used. It is estimated that lignin extract diluted six times still has enough reduction power and antioxidant capacity for the efficient synthesis of nZVI while in further dilution loses this power.

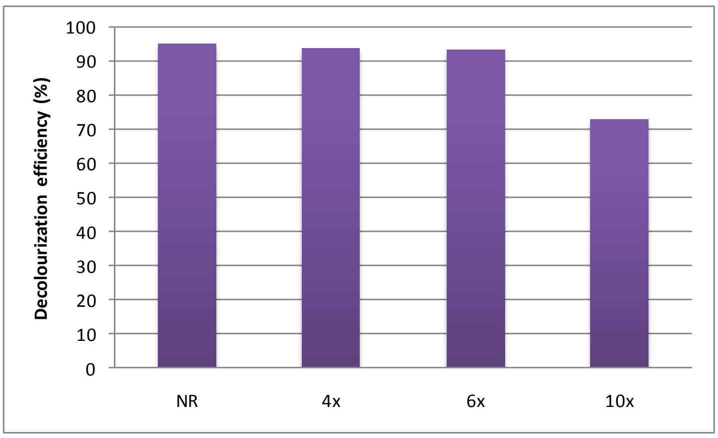

Figure 2: Decolourization efficiency at different dilution of lignin extract used for nZVI synthesis

3.2 Characterization of effluent after decolourization

The mineralization degree of treated effluent after Fenton process with nZVI, was determined by measuring the chemical oxygen demand (COD). During the Fenton process, decolourization of solution is caused by the destruction of chromophore group of dye molecule, while COD reduction depends on the degree of complete molecule mineralization. COD was measured in initial dye solution with dye concentration of 300 mg/l, in the same effluent after the applied Fenton process (under optimal conditions) with nZVI generated with non-diluted and six time diluted lignin extract as well as in sample with initial dye concentration of 50 mg/l after Fenton process using nZVI generated with six time diluted lignin extract (Table 1).

Table 1: COD values in examined samples

Sample type	COD (mgO_2/l)
Initial dye solution, $[RB4]_0$-300 mg/l	361
Sample after applied process, $[RB4]_0$-300 mg/l	94.0
Sample allied after process, $[RB4]_0$-300 mg/l, (lignin extract diluted 6 times)	47.7
Sample allied after process, $[RB4]_0$-50 mg/l, (lignin extract diluted 6 times)	12.4
Lignin extract	155

Based on the obtained results it can be concluded that the degree of mineralization can be considered significant (~70 %). Fast decolourization followed by a slower reduction in COD values is an indicator of the formation of stable intermediates in the reaction medium which contribute to the higher value of this parameter.

Furthermore, the lower COD value for sample after the decolourization compared to the COD for lignin extract shows that during the Fenton process, not only the destruction of the dye molecule occurs, but also to the decomposition of the aromatic structures originating from lignin. Complex oxidation reactions lead to depolymerization of lignin (Kalliola et al, 2010). Greater oxygen demand, in this case, is caused by decomposition reactions of resulting degradation product, which in this case explains the high value for COD of lignin extract.

Further characterization of obtained effluents included the assessment of their toxicity on the basis of bioluminescence inhibition test of marine Gram-negative bacteria *Vibrio fischeri* (Parvez et al, 2009). Lignin extract alone proved to be extremely toxic, as well as the reaction mixture after the Fenton process when nZVI produced with non-diluted lignin extract were used. Further examination included the reaction mixture after completing the Fenton process (with nanomaterial synthesized with a diluted lignin extract) at different initial dye concentrations. When the initial dye concentration was 300 mg/l, after decolourization, the effluent showed high toxicity, and when the lower initial dye concentration was applied (50 mg/l) toxicity significantly reduced (Table 2).

Table 2: Toxicity results of samples tested on organisms Vibrio fischeri

Sample type	Inhibition (%)
Sample allied after process, [RB4]0-300 mg/l, (lignin extract diluted 6 times)	96.39
Sample allied after process, [RB4]0-50 mg/l, (lignin extract diluted 6 times)	28.55

These results can be interpreted from many aspects. Namely, as the only variable in these experiments was the initial dye concentration, it can be concluded that the complete decomposition of dye contributes to the reduction of toxicity. On the other hand, since in the both samples there is the same amount of iron and hydrogen peroxide, so there is equal amount of generated hydroxyl radicals, the toxicity may originate also from lignin residues. This is especially the case in the first sample, due to the larger system load as greater amount of dye molecules is present. In this case, hydroxyl radicals are used both for the dye and lignin degradation, which is also observed in the mineralization measurement.

4. CONCLUSIONS

In this research decolourization of Ractive Blue 4 was performed using Fenton process with nano zero valent iron particles synthesized using Kraft (sulphate) lignin. The study involved the optimization of decolourization conditions and testing the degree of mineralization and toxicity. Optimization is performed via response surface method RSM, which proved to be simple method to investigate the influence of independent process parameters on decolourization efficiency. Parameter with the most influence on investigated process was pH value followed by nanomaterial (iron) dose, initial dye concentration and hydrogen-peroxide in descending order. Also, it has been proven that the obtained lignin extract can be diluted six times before the synthesis of nanomaterial with no significant impact on the decolourization efficiency, as this extract still has enough reduction power and antioxidant capacity for the efficient synthesis of nZVI while with further dilution this ability declines. The degree of mineralization is significant, amounting to about 70%. Also, it was concluded that the applied Fenton process has caused not only the degradation of dye molecule but also the degradation of aromatic lignin structure. Toxicity test pointed out that it is necessary to use diluted lignin extract for nZVI production and that toxicity largely depends on the destruction degree of dye molecules, where complete decomposition contributes to the toxicity reduction. Generally, all the results showed that the nZVI synthesized with the help of Kraft (sulphate) lignin extract is an efficient catalyst and a source of iron in the Fenton process.

5. ACKNOWLEDGMENTS

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INFLUENCE OF SAMPLE-SIZE VARIATIONS ON THE IN-PLANE TENSILE STRENGTH OF UNCOATED PAPER

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Abstract: *Tensile properties of different printing substrates, such as papers and paperboards, can deliver useful information about the substrates` usability in the converting process and end-use. Therefore, the in-plane tensile testing is one of the crucial material characterization methods. For the needs of tensile testing, specimens have to be prepared according to the corresponding international standards, which among other parameters, strictly define the sample` size. However, in some cases the requirements concerning sample size cannot be fulfilled, due to the specimen`s special properties or its preparation process. In this investigation, uncoated, wood-free offset papers were examined by tensile test where sample width and length was varied in order to investigate the influence of the sample-size variation on the in-plane tensile strength and elongation at break distribution. The obtained results show differences in measured tensile strength values, but also in the elongation at break according to the sample length to width changes.*

Key words: tensile testing, sample-size, uncoated paper

1. INTRODUCTION

Tensile tests are the fundamental tests within material science and they are performed on more or less all materials including different types of paper and paperboard. Information about the in-plane properties of the paper, derived from the tensile tests, have significant role in the field of new material development process, but also in the graphic production and the finished product`s end-use, as well. Since printing and converting processes are today usually done on highly automated machines, the controlled tensile properties play crucial role when the substrates (papers and paperboards) are fed through machines at very high speeds (Liebau and Heinze, 2001; Harman, 2016). For the needs of tensile testing several international standards have been established. These standards describe the specimen`s preparation parameters (i.e. dimensions, fiber orientation, number, etc.), testing procedure (i.e. tensile testing machine requirements, clamping pressure, clamp separation rate, measurement accuracy and repeatability, etc.) but also all the needed definitions and calculus of different in-plane measures (i.e. tensile strength, stretch, tensile energy absorption, tensile stiffness, etc.) (Hernádi, 1980; ISO 1924-2; TAPPI 494-om-1; Davis, 2004). Although these standards have widespread application, in some cases, these requirements cannot be respected. Different specimen sizes and geometries could be used in tensile testing driven by the need for keeping the test specimens similar in size to the end-use components or to reliably predict the materials performance on different scale (macro and micro) with local and global properties. Sometimes, deviations in specimens` dimensions are more prose problems, they depend on the availability of materials to be tested (Sergueeva et al, 2009). In that case it is natural to ask the question whether the tensile properties obtained by using such non-standard specimens could be comparable to standard tests and would be representative of the material properties (Zhao et. al, 2008). Numerous investigations have been performed on different papers and paperboards with various specimen lengths, widths, width-to-length ratios to define the sample-size effect on different in-plane tensile properties and they results and conclusions were briefly summarized by Hagman and Nygårds (2012).

In this paper, tensile properties (tensile strength and elongation at break) of uncoated wood-free paper were analyzed in terms of sample geometry effects on mechanical characteristics using regular tensile tests. Additionally, in order to get more insight into the sample-size influence, detailed statistical analyses have been conducted (a set of four one-way between-groups analysis of variance with two categorical independent variables, tensile strength and elongation at break).

2. MATERIALS AND METHODS

For the purpose of the conducted research commercially available, uncoated wood-free offset paper was chosen (MAESTRO® PRINT, Mondi SCP, Slovakia). The selected paper is commonly used for printed products such as books, magazines, brochures, stationery, annual reports, etc. Its dimension stability, surface properties and smoothness allow trouble-free print and postpress processing (i.e. folding, embossing). The basic properties of selected paper are presented in Table 1 (Mondi SCP, 2016).

Table 1: Basic properties of selected paper

Parameter	Value
Basis weight [g/m^2]	80
Thickness [µm]	103
Bulk [cm^3/g]	1,29
Roughness by Bendtsen [ml/min]	225
Humidity [%]	6,2
CIE Whiteness	145

In order to investigate the effect of sample geometry on the in-plane tensile strength of the selected paper, the measurements were performed on two different sets of specimens. The initial specimen parameters were prepared based on the recommendations of the tensile testing standard TAPPI T494-omo-1. It defines a 25 mm wide specimen with a 180 mm clamp length and a constant speed of traction displacement at speed of 25 ± 5 mm/min. For the first specimen group the clamp length was constant (180 mm) while the sample width was varied: 25, 20, 15, 10 and 5 mm. Specimens in the second group had constant sample width (25 mm) with variable sample length (180, 150, 120, 90 and 60 mm). 20 specimens were prepared for each size combination and in both paper grain direction (MD/machine direction and CD/cross direction). The tensile strength tests were performed on a table top, single column, electromechanical universal testing machine Shimadzu EZ-LX (Shimadzu, Japan) using a high-precision load cell (capacity of 500N, ISO 376 accuracy class 00) and non-shift wedge tensile grips (capacity of 5kN). The speed of traction displacement was constant for all specimens' size combinations (25 mm/min), sampling frequency of 10msec, and break detection at 50% of maximum load. All these testing parameters were monitored and controlled by TRAPEZIUM X software (version 1.4.2, Shimadzu, Japan) in the Single test mode (Shimadzu, 2012). During test, rupture of specimens occurred at various points of the specimen length between the grips. None of the specimens failed immediately at the grips. All measurements were conducted in a controlled environment (at room temperature and standard relative air humidity) and the samples were conditioned for more than 48h prior to testing.

Based on the obtained test data and the different specimens sizes (lengths and widths) values of tensile strength [kN/m] and elongation at break [%] were calculated. It has to be mentioned, that the tensile strength measured in paper industry is not a true material tensile strength, load per unit area, rather the load (breaking force) per unit width. It is due to the porosity of paper structure and, for the ordinary purposes, tensile strength, as measured in paper industry, is enough indicative of the utility of the paper, since the paper is generally used in sheet forms.

Mean values and standard deviations of obtained tensile strength and elongation values have been calculated for each specimen size and paper grain combination. In order to determine the statistical significance of the differences in the gained tensile strength and elongation data depending on the various sample dimensions, detailed statistical analyses were done by one-way ANOVA and corresponding post-hoc test (Tukey's HSD). Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homogeneity. All the statistical analyses were done using IBM SPSS statistics software (version 20), with a significance level of $p<0.05$. Beside statistical significance, the effect size (the practical significance) is also calculated for each test using partial eta squared, where Cohen classifies 0.01 as a small effect, 0.06 as a medium effect, and 0.14 as a large effect (Pallant, 2005).

3. RESULTS AND DISCUSSION

Figures 1 and 2 show typical force [N] - displacement (stroke) [mm] curves for both set of specimens, i.e. with constant length and width, respectively. In order to preserve the diagram`s clarity, 10 representative curves have been selected from each sample group. Dashed lines indicate individual curves, while solid lines the average ones.

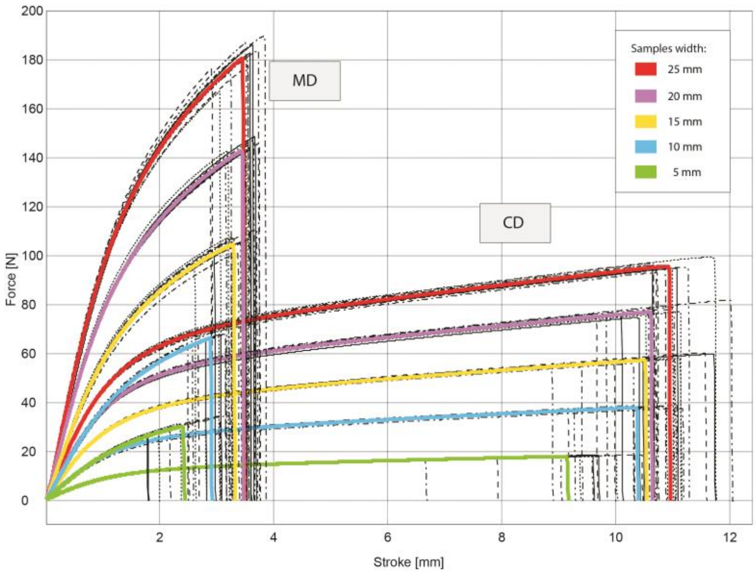


Figure 1: Force-stroke curves for specimen set 1 - constant length (180 mm) with varying widths

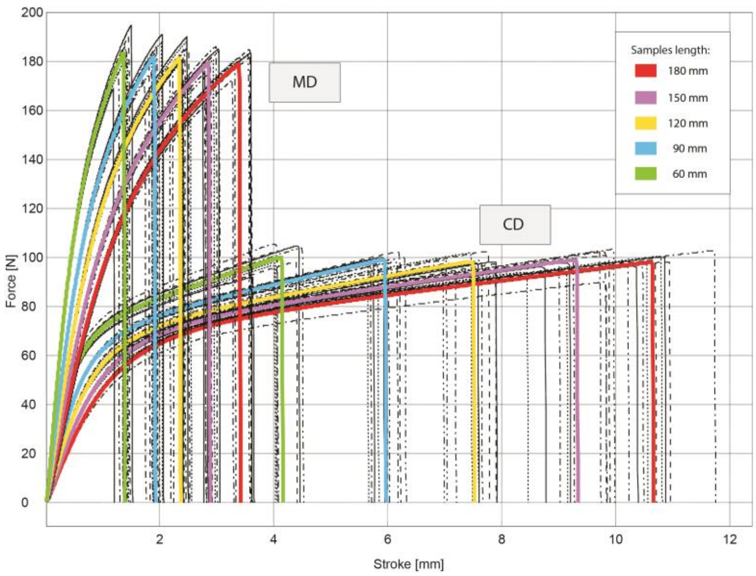
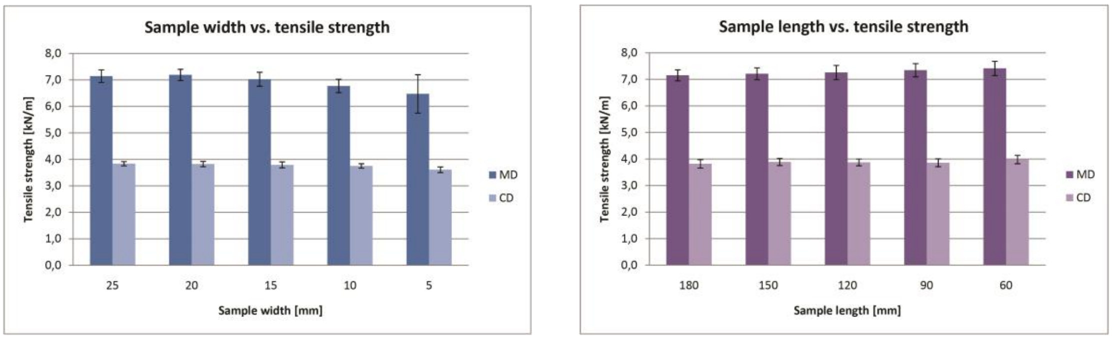


Figure 2: Force-stroke curves for specimen set 2 - constant width (25 mm) with varying lengths

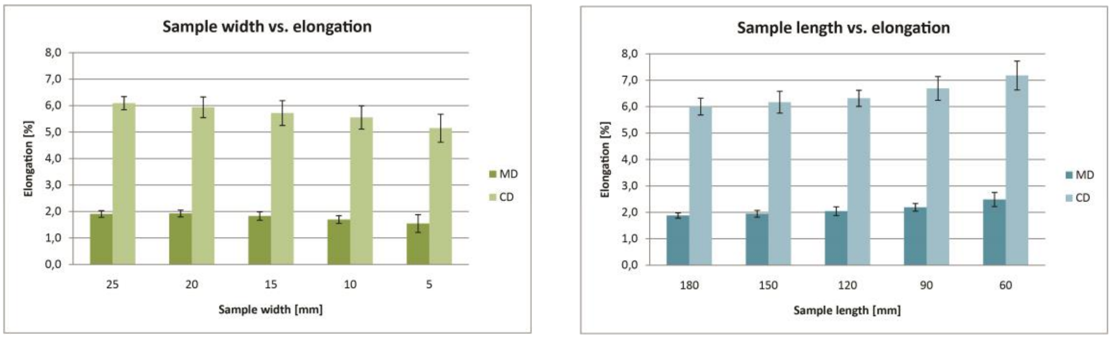
As it was expected based on the samples geometry, the maximum force during the tensile testing had clear decreasing tendency by reducing the samples` width in both paper grain directions (Figure 1). Displacement values were similar within one paper grain group (MD or CD), except samples with 5 mm width in both principal directions, where noticeably lower displacements were recorded during the measurement procedure. In the case of different sample lengths, again as it was expected based on the samples sizes, the obtained results of displacements values show distinct decreasing tendency by shortening the samples` length regardless of the paper grain direction (Figure 2), while for the maximum forces similar values were gathered. The mean values and standard deviations of the calculated tensile strength [kN/m] and elongation at break [%] values are presented in Figures 3a-b and 4a-b, respectively. Considering the tensile strength values by varying the samples width (Figure 3a), decreasing tendency can be noticed, just like for the maximum force values, but with different magnitude, since the obtained results varied in narrow range (from 7.14 kN/m to 6.47 kN/m in MD, and from 3.84 kN/m to 3.61 kN/m in CD). Unlike them, the samples length results (Figure 3b) show increasing tendency, however the differences between the mean values are not that noticeably expressed (7.15 kN/m ÷ 7.42 kN/m in MD, and 3.82 kN/m ÷ 3.98 kN/m in CD). Very low values of standard deviation indicate high consistency of measured values. Similar situation can be noticed for the results of the elongation at break: by decreasing the samples` width the elongation is also decreasing (Figure 4a), while with the decreasing samples length elongation shows increasing tendency

(Figure 4b). The obtained results show that the impact of the differences in specimens’ size (width or length) on elongation at break was higher in MD (mean values were from 1.91 % to 1.55 % for samples` width changes and 1.88 % ÷ 2.49 % for variation in sample length) than in CD (mean values were in the range 6.10 % ÷ 5.15 % for samples` width changes and 6.01 % ÷ 7.18 % for variation in sample length). The obtained results are in line with the literature findings (Setterholm and Kuenzi, 1956; Hernádi, 1980; Hangman and Nygårds, 2012).



a) *b)*

Figure 3: Tensile strength values for different specimens’ width (a) and length (b)



a) *b)*

Figure 4: Elongation at break values for different specimens’ width (a) and length (b)

Albeit, the presented graphs can deliver useful information about the trends of the changes in tensile strength and elongation, but they do not set out whether these changes are statistically significant. In order to explore the impact of the samples` dimension variations on the tensile strength and elongation at break of the selected paper, a set of four one-way between-groups analysis of variance with two categorical independent variables (tensile strength and elongation at break) was conducted. The results of one-way ANOVA indicated statistically significant difference at the $p<0.05$ level in tensile strength and elongation at break for both dimensions changes (width and length), regardless the paper grain direction.

In case of tensile strength there was a statistically significant main effect for sample length as well as sample width changes with following large effect size: sample length in MD [$F(4, 95)= 4.406$, $p=0.003$, partial eta squared=0.17], sample length in CD [$F(4, 95)= 3.908$, $p=0.006$, partial eta squared=0.14], sample width in MD [$F(4, 95)= 12.789$, $p=0.000$, partial eta squared=0.35], sample width in CD [$F(4, 95)=17.771$, $p=0.000$, partial eta squared=0.43].

Post-hoc comparisons using the Tukey’s HSD test indicated that in the case of sample length changes in MD, only the mean values of tensile strength for sample length 90 mm and 60 mm (M=7.34, SD=0.25 and M=7.41, SD=0.27) differ significantly from the mean value of 180 mm samples` length (M=7.15, SD=0.21). In case of sample length changes in CD, only sample length of 60 mm (M=3.98, SD=0.16) differs significantly from the 180 mm long sample (M=3.82, SD=0.16). In the case of sample width changes in MD, the mean value of tensile strength for sample width of 5 mm (M=6.47, SD=0.72) differ significantly from the mean value of 25, 20 and 15 mm wide samples (M=7.14, SD=0.24; M=7.19, SD=0.21 and M=7.03, SD=0.26, respectively), while the mean value of tensile strength for samples width of 10 mm (M=6.77, SD=0.25) differ significantly from the 25 and 20 wide sample (M=7.14, SD=0.24 and M=7.19, SD=0.21). For sample width changes in CD, only the mean value of tensile strength for 5 mm wide samples (M=3.61, SD=0.11) was significantly different from the mean values of all other sample widths (25 mm: M=3.84, SD=0.08; 20 mm: M=3.83, SD=0.10; 15 mm: M=3.79, SD=0.11; 10 mm: M=3.75, SD=0.08). Additionally, results for 10 mm wide samples (M=6.31, SD=0.36) also differ significantly but only from the widest samples, 25 mm (M=3.84, SD=0.08). In all other cases, the mean values did not differ significantly.

Results of one-way ANOVA for elongation at break showed, like in the case of tensile strength, that the actual differences in mean values were large with the following eta squared values: different length in MD [F(4, 95)= 39.433, p=0.000] the partial eta squared was 0.62 and in CD [F(4, 95)= 25.372, p=0.000] it was 0.52, while different width in MD [F(4, 95)= 13.934, p=0.000] the effect size was 0.37 and in CD [F(4, 95)=14.804, p=.000] it is calculated as 0.38.

Based on Tukey's HSD post-hoc tests, in the case of elongation at break just for few group pairs statistically significant difference in the mean values was not established. There were as follows: by changing the samples` length in MD, the mean value of elongation at break for 150 mm long samples (M=1.95 SD=0.13) did not differ significantly from the mean value for samples with 180 mm length (M=1.88, SD=0.10) and 120 mm (M=2.04, SD=0.16), which also did not differ from mean values for 90 mm length samples (M=2.19, SD=0.15). Length variations in CD caused no statistical significant difference between the mean value of 180 mm long samples (M=6.00, SD=0.31) and the mean values of 150 mm (M=6.17, SD=0.41) and 120 mm long samples (M=6.32, SD=0.30). Additionally, the mean values for 150 mm and 120 mm long samples did not differ either. In case of sample width variations, for MD testing the mean value for 15 mm width samples (M=1.83, SD=0.16) did not differ significantly from the 25, 20 and 10 mm wide samples (M=1.91, SD=0.12; M=1.93, SD=0.13 and M=1.69, SD=0.15, respectively). Additionally, the mean value for 25 mm wide samples did not differ from the 20 mm wide samples, and 10 mm wide samples (M=1.69, SD=0.15) from 5 mm wide ones (M=1.55, SD=0.36). Results in CD showed that the mean value of 15 mm width samples (M=5.72, SD=0.47) did not differ significantly from the 25, 20 and 10 mm wide samples (M=6.09, SD=0.25; M=5.94, SD=0.39 and M=5.55, SD=0.44, respectively), but also the 25 mm from 20 mm wide samples. In all other cases, the mean values differ significantly.

The results of obtained ANOVA and post-hoc tests imply that changes in sample length and width influence significant changes in tensile strength, but only for lower values (90 mm and 60 mm for the sample length, 10 mm and 5 mm for sample width). Considering the results for elongation at break significant differences were observed in more cases that for the tensile strength, but also for the lower length and width values (120 mm, 90 mm and 60 mm for the sample length, 10 mm and 5 mm for sample width).

4. CONCLUSIONS

In-plane tensile testing is one of the crucial material characterization methods in paper and printing industry, since it can deliver useful information about the substrates` usability in the converting process and end-use. This paper is dealing with tensile properties (tensile strength and elongation at break) of uncoated wood-free paper examined by tensile test with variable specimens` width and length. The obtained results of tensile strength show increasing tendency as the specimen length decreases, but decreasing tendency with the sample width reduction. This difference might be attributed to the fact that a shorter specimen has fewer chances for a flaw to occur within the area being tested, but at the same time wider samples reduce the risk of weak spots and the damage behavior in these spots. There was similar effect on the elongation at break caused by the size changes of the tested sample, but in comparison with the tensile strength, elongation at break is influenced in much higher degree. Discovered significant influences on the examined mechanical characteristics imply the importance of specifying the sample-size deviations in the case of non-standard testing conditions.

5. ACKNOWLEDGMENTS

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Print quality

EFFECT OF THE POST-TREATMENT OF PRINTING PLATE ON THE QUALITY OF FINE PRINTED ELEMENTS IN FLEXOGRAPHY

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Abstract: *With the increasing qualitative requirements present for the products printed in flexography, various improvements in the workflow of flexographic printing are being expolred and utilized. The aim of this paper is to propose and present a method for increasing the quality of fine printed elements in flexography with the post-treatment of the printing plate seen as a tool for improving the definition of the printed features. In the experimental part, two types of flexographic printing plates were used: one solvent-washable photopolymer CtP plate, and one water-washable photopolymer CtP plate. Samples were produced using the procedure recomended by the manufacturer, and by applying the same compensation curves for both types of printing plates. The durations of UVA and UVC post-treatments were varied in order to influence the properties of the printing plates that will affect the transfer of the ink to the pritning substrate. On the printing plates, formed printing elements were monitored by 3D microscopy in order to assess the initial quality of the image transferred onto different types of photopolymer materials. Samples of the post-treated printing plates were then evaluated by the hardness measurements and surface free energy calculations. Test prints were produced by means of the modified printing plate samples, and the quality of the reproduction of fine elements was monitored by optical methods (microscopy, measurement of coverage values). Results of the research proved that the modifications of both UVA and UVC post-treatments significantly affect the quality of the fine printed elements. Specifically, UVA and UVC post-treatments have proven as a useful tool for improving the definition of the thin printed lines due to the combined effect of the changes in the hardness and surface free energy of printing plates. Furthermore, sufficiently increased hardness of the printing plate together with the specific adjustment of the surface free energy of the printing plate enables the adjustment of the dot gain in the shadow areas of the print (90% - 100% coverage value). Therefore, the post-treatment of the flexographic printing plates can be used as a workflow-incorporable method for the fine adjustment of the qualitative properties of the flexographic print.*

Key words: flexography, photopolymer, UV post-treatment, surface modification, hardness.

1. INTRODUCTION

Flexography is a printing technique of high complexity. In the 1960s, used mostly for printing on the corrugated board, this technique has developed and is nowadays applied in printing of various packaging materials and printed electronics (Brajnović, 2011). Modern flexographic printing plates can be solvent-washable or water-washable and are based on the effect of crosslinking of copolymers and monomers as a result of the exposure to UVA wavelengths that initiate crosslinking and UVC wavelengths that terminate it, thus giving polymeric molecular structures insoluble in the defined developing solution. Composition of this type of printing plates includes different types of copolymers, most common styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS) block copolymers, polyurethane-methacrylate compounds, photoinitiators sensitive to UV radiation, plasticizers which provide elastic properties, colorants and other additives (Knoll, 2002).

With the development of new photopolymer materials for printing plate production, boundaries of the printing plate qualitative properties were pushed even further. Nowadays, optimal surface properties of the flexographic printing plate can be achieved by number of technologies in order to enable high-qualiy printing on various substrates and for various applications (Tomašegović et al, 2014).

Today, the production of the flexographic printing plates is based on the digital, Computer to Plate (CtP) technology. Laser Ablation Mask Layer (LAMS) technology is the most common and widely adoped principle used in the printing houses for production of flexographic printing plates (Brajnović, 2011).

However, although the LAMS-based flexographic plate production process enables the production of the plates and prints of high quality, during the period of laser ablation of the mask and the period of UV radiation, photopolymer material is exposed to the destructive influence of the oxygen. Oxygen disables the crosslinking, which results with the solubility of the tops of printing elements in the rinsing solution

(Andzejewska, 2001). The results are poorly and incompletely formed fine printing elements such as lines which will be unable to transfer the printing ink to the printing substrate correctly. Therefore, it is important to be well acquainted with the formation of the printing elements in a specific photopolymer material and apply necessary corrections of the digital information to be transferred to the printing plate surface. Printing plates in flexography can be divided based on the type of the rinsing agent: solvent-washable and water-washable. Solvents used in the washing process are organic-based volatile solutions. Ecologically, water-washable printing plates are more acceptable and do not require stabilization period as solvent-washable plates. They do not swell significantly in the water, such as solvent-washable plates do in the developing agents (Theopold et al, 2012). However, since water-washable printing plates are relatively new to the market, they have not been integrated in the commercial workflows as much as solvent-washable plates. Furthermore, their properties can differ from the solvent-washable printing plates to some extent. Therefore, their application would require certain adjustments in the digital file workflow and the printing process.
Furthermore, the baseline for the production of printing elements in the photopolymer materials used in modern flexography is radical photo-initiated crosslinking. Specifically, when exposed to UV wavelengths, photoinitiator activates, and the process of radical crosslinking occurs (Yagci et al, 2010):

Initiation:

$$\mathit{Initiator} + h\upsilon \rightarrow R^* \quad (1)$$

$$R^* + M \rightarrow RM^* \quad (2)$$

Propagation:

$$RM^* + M_n \rightarrow RM_{n+1} \quad (3)$$

Termination:

$$R\,M_n^* + {}^*M_mR \rightarrow RM_nM_mR \quad (4)$$

where *R* presents radical, *M* monomer, while *n* and *m* present the numbers of repeating units. UVA radiation initiates (1) while UVC completes (4). Specifically, the duration of the UVA and UVC post-treatments in the flexographic prinitng plate production defines the final surface and even mechanical properties of the pritning plate (Tomašegović et al, 2013).
The object of this research is the analysis of the quality of the formation of printing elements on different flexographic printing plate materials and their resistance and behavior when exposed to varied durations of the UV post-treatments. The aim is to analyze the influence of the modified properties of different printing plates on the transfer of the coverage values from the printing plate to the printing substrate and on the shape and definition of printed fine lines. By defining the relations between the modified printing plate parameters and their significance for obtaining the optimal print quality, it is easier to adjust and optimize the printing plate processing parameters necessary for the highest possible quality of the output (Tomašegović, 2016).

2. EXPERIMENTAL

2.1 Preparation of samples

In this research, two different photopolymer materials were tested in terms of their surface and mechanical properties which are subject to change due to the variations in the post-treatment process. Both types of printing plates were LAMS-based, with digital (CtP) production procedure. One type of printing plate was solvent-washable Flint ACE Digital pritning plate, and the other type was water-washable Toyobo Cosmolight QS printing plate.

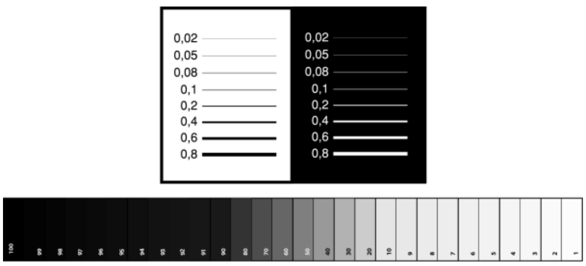


Figure 1: Test image transferred to the surface of the printing plate samples

Samples of both types of printing plates were produced by the standard procedure recommended by their manufacturer up to the post-treatment process. The test image transferred to the printing plate surface consisted of the control strip and the fine lines (Figure 1). FlexoSync 56 compensation curve was applied to both types of pritning plates. Produced printing plate samples were exposed to different durations of UVA and UVC post-treatments. The duration of the post-treatments was varied from 0 to 20 minutes, with the step of 1 minute.
The purpose of this research was to maintain the necessary functional properties of the flexographic printing plate. Therefore, both post-trestments were performed on the samples (except the first, referent sample without any post-treatment), but the duration of one of them was varied. The duration of the post-treatment that was kept constant was an optimal duration recommended by the manufacturers (10 minutes of UVA and UVC radiation for ACE Digital printing plate and 10 minutes of UVA and 5 minutes of UVC for Cosmolight QS printing plate).
Samples of test prints obtained by means of the printing plate samples were produced in printing house Rotoplast d.o.o. under their standard production conditions. ISO 9001:2008 and ISO 14001:2004 standards were respected. The characteristics of used anilox were 400 lcm^{-1}, with cell volume of 4.5 cm^3m^{-2}. Printing speed was 200 $mmin^{-1}$.

2.2 Measurement and analysis methods

For the analysis of the pritning elements' formation, 3D microscope AniCAM was used. AniCAM microscope can be used for the flexographic pritning plate, gravure printing cylinder and the anilox roller analysis. It was used to display the 3D image of the surface by capturing its layers based on changes in focus, and then merge them (Troika Systems, n.d.).
Surface free energy was calculated using OWRK method, applicable for polymer, aluminium and coatings characterization (Owens et al, 1969). After obtaining the values of contact angles for each probe liquid, mean values of contact angle for each sample were calculated. Results of the contact angle measurements enable calculation of the surface free energy, its polar and dispersive component (5):

$$\frac{(1-\cos\theta)\cdot\gamma_s}{\sqrt[2]{\gamma_l^D}} = \sqrt{\gamma_s^P}\sqrt{\frac{\gamma_l^P}{\gamma_l^D}} + \sqrt{\gamma_s^D} \qquad (5)$$

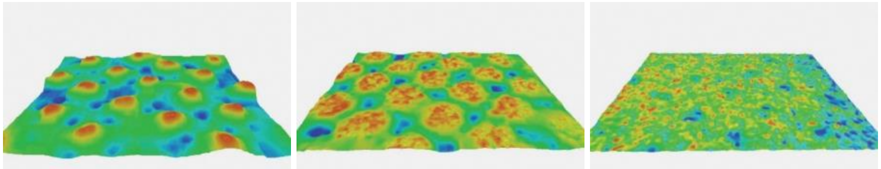
where γ_s is surface tension of the solid, γ_l is the surface tension of the liquid, γ^d disperisve part of surface tension, γ^p polar phase of surface tension, and ϑ is the contact angle.
Hardness of the printing plate samples that changed due to the varied UV post-treatments was measured ten times on each sample by means of durometer Zwick Roell, suitable for the measurement of the hardness at Shore A and Shore D scale.
IC Plate II was used for the measurement of coverage values on the prints (X-Rite, n.d.). Although it is a portable device primarily intended for the offset printing plate measurements, it has an integrated mode for measurement on the printing substrate as well. Its precise measurement of coverage values on test prints examined in this research enabled obtaining precise results even in the coverage area higher than 95%. Coverage values on prints were measured on differents spots 20 times to ensure correct calculations of the error. Results of the measurements were used to identify the influence of printing plate parameters, subjected to change during variations of the UV post-treatment process, on the quality of prints.
Images of the fine lines on test prints were observed by Olympus BX51 microscope (Olympus, n.d.). Fine ines on test prints were observed in order to examine their regularity and shape as a consequence of different durations of UV treatments.

3. RESULTS AND DISCUSSION

3.1 3D microscopy of printing elements on the printing plates

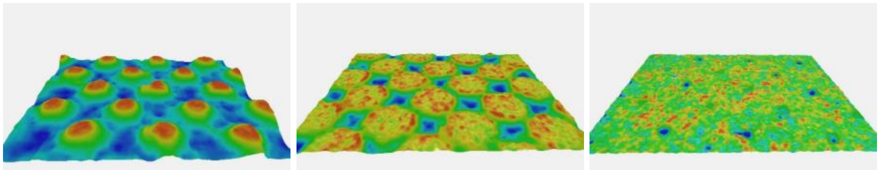
Images presented in Figures 2 and 3 were obtained by AniCAM 3D microscope. Fields of 5%, 50% and 95% surface coverage on printing plates treated with the optimal durations of the UV post-treatments (according to the manufacturer) were scanned in order to observe the surface of the halftones on different printing plates. Despite the same compensation curve applied to all printing plate samples, one

can notice the differences in the shapes and sizes of the printing elements at 5% coverage value - Figures 2a) and 3a). The shape of the printing element top is influenced by the oxygen in the main exposure process, and the size (area) of the printing element is then determined by the bump curve, adjusted to each type of photopolymer material specifically.
Furthermore, the difference in topography of the printing elements in the area of 50% coverage is visible as well (Figures 2b) and 3b). With the increase of the coverage value, visual differences on the surface become less apparent (Figures 2c) and 3c).



a) b) c)

Figure 2: 3D scans of printing elements on ACE Digital printing plate at: a) 5% coverage value, b) 50% coverage value, c) 95% coverage value



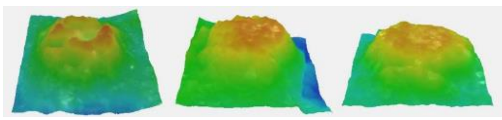
a) b) c)

Figure 3: 3D scans of printing elements on Cosmolight QS printing plate at: a) 5% coverage value, b) 50% coverage value, c) 95% coverage value

In order to observe the printing elements formed in the highlight area, the shape of elements from the fields of DFTA control strip (Figure 4) were scanned with AniCAM 3D microscope as well (Figures 5 – 6). Observed printing element areas in highlights on the printing plates were image areas of C, H and P fields transferred from the DFTA control strip to the printing plates' surfaces. Field C corresponds to the area of 4 pixels ablated on the mask layer on the printing plate, field C to 14 pixels ablated on the mask layer on the printing plate, and field P to 30 pixels ablated on the mask layer on the printing plate.

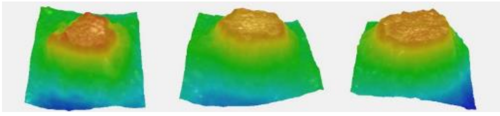
Figure 4: DFTA control strip

Figures 5a) and 6a) display printing elements on field C of DFTA strip, which was supposed to be the first field with stable and correctly formed printing elements after the application of correction curves. However, it is visible that not all the elements formed correctly. Printing element in Figure 5a) formed with the higher edge than the inside area of the element top. This occurrence is often connected to the relaxation after the compression of the photopolymer material during the exposure on printing plates produced by technology that includes the oxygen-protection layer attached to the plate before and during the exposure (for example, Kodak NX technology with TIL film, MacDermid LUX ITP technology) (Kodak NX technology, n.d.; MacDermid Printing Solutions, 2015).



a) b) c)

Figure 5: 3D scans of fields on DFTA strip transferred to ACE Digital printing plate: a) field C – 4 px, b) field H – 14 px, c) field P – 30 px



a) b) c)

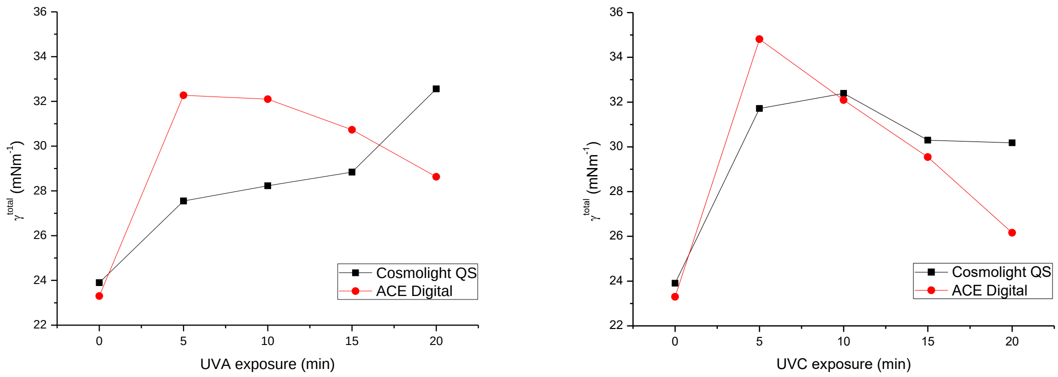
Figure 6: 3D scans of fields on DFTA strip transferred to Cosmolight QS printing plate:

a) field C – 4 px, b) field H – 14 px, c) field P – 30 px

However, printing plate samples in this research were not produced using that type of technology. Furthermore, in other figures (Figures 5 - 6, b) and c) correctly formed elements with generally flat top are visible. Besides that, photopolymers usually contract during the crosslinking process due to the increased network density (Lindén et al, 2001). Therefore, the reason for the incorrectly formed elements on field C could be the diffraction of light passing through the ablated areas of small dimensions and different sensitivity of photopolymer materials to the UV radiation.
The differences in printing elements formed in different photopolymer materials for fields H and P are apparent in the printing elements' areas. Therefore, when choosing the printing plate for the specific purpose, especially in functional and/or high-quality printing, one should, beside the implicated physicochemical properties, have in mind the reproductive limitations of the material, as well.

3.2 Surface free energy of modified printing plates

Calculations of the surface free energy (γ^{total}) and it dispersive (γ^{d}) and polar (γ^{p}) components showed that the variations in UVA and UVC post-treatments have different trend of the effect on the photopolymer material samples (Figures 7 – 9). However, changes in components of γ caused by prolonged UVC post-treatment are more expressed than changes caused by UVA radiation, since UVC radiation carries more energy. Setting the duration of the UVA post-treatment of the photopolymer material from 0 to 20 minutes causes the increase of γ^{total} from 23.9 mNm^{-1} to 32.56 mNm^{-1} for Cosmolight QS samples (Figure 7a). However, γ^{total} for ACE Digital samples reaches maximal value of 32.27 mNm^{-1} at 5 minutes of UVA post-treatment and then decreases to 28.63 mNm^{-1} for 20 minutes of UVA post-treatment (Figure 7a).
Specifically, the trends of changes of γ^{total} after prolonged UVA radiation are primarily caused by the changes of γ^{d} (Figure 8a).



a) b)

Figure 7: Total surface free energy of printing plate samples exposed to:
a) varied UVA post-treatment, b) varied UVC post-treatment

The increase of γ^{d} and γ^{total} of photopolymer material can be explained by further crosslinking which occurs in the photopolymer material and indicates that, even after the printing plate is considered to be finished in its production process, further crosslinking caused by UVA radiation takes place.
The point of inflexion at 5 minutes of UVA post-treatment for γ^{total} and γ^{d} for ACE Digital sample can be explained by the weaker intermolecular forces in the polymer network with prolonged UVA post-treatment due to the possible start of the material degradation (Krásný et al, 2012).
Furthermore, changes of γ^{p} are not as expressed as changes of γ^{d} (Figure 8a and 9a). Therefore, UVA radiation can be used as a tool to adjust γ^{d} of ACE Digital photopolymer material, but not as a tool to enhance significantly the adsorption of polar inks and coatings.

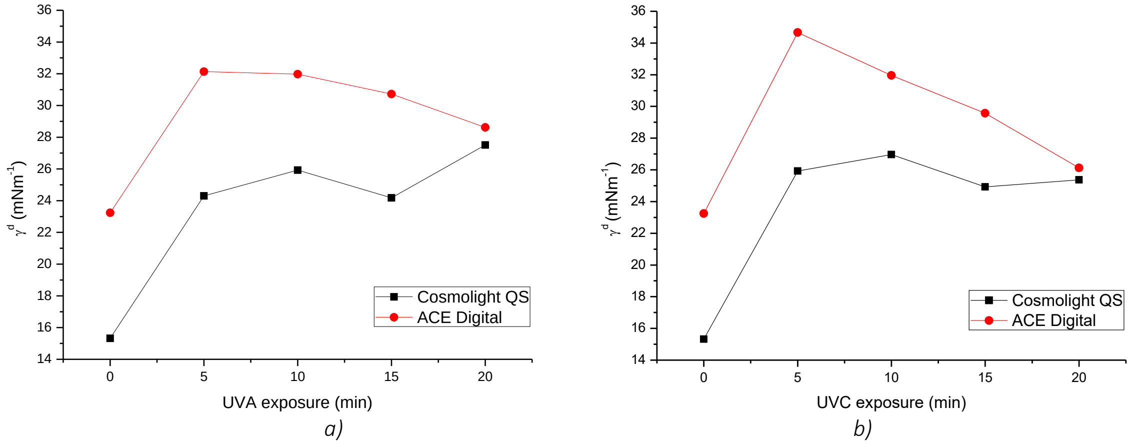


Figure 8: Dispersive component of surface free energy of printing plate samples exposed to:
a) varied UVA post-treatment, b) varied UVC post-treatment

UVC post-treatment (Figures 7b), 8b) and 9b) has a more distinct effect on all components of γ. When performing the variation of UVC radiation from 0 to 20 minutes, γ^{total} of the photopolymer surface for ACE Digital samples reaches maximal value of 34.81 mNm^{-1} at 5 minutes of UVC post-treatment and then decreases to 26.16 mNm^{-1} for 20 minutes of UVC post-treatment (Figure 7b). Cosmolight QS samples display similar behavior, reaching maximal value of γ^{total} of 32.39 mNm^{-1} at 10 minutes of UVC post-treatment and then decreasing to 30.18 mNm^{-1} for 20 minutes of UVC post-treatment (Figure 7b). These changes, just like the increases of γ^{total} and its components caused by UVA post-treatment, are significant for the graphic reproduction process because of the changes in the adsorption of the printing ink on the printing plate. Furthermore, even though γ^{d} is a dominant component influencing γ^{total} (Figure 8b), changes in γ^{p} have an interesting trend. γ^{p} for both printing plate samples displays an inflexion point after initial increase after which it decreases to a certain level, depending on the photopolymer material (Figure 9b).

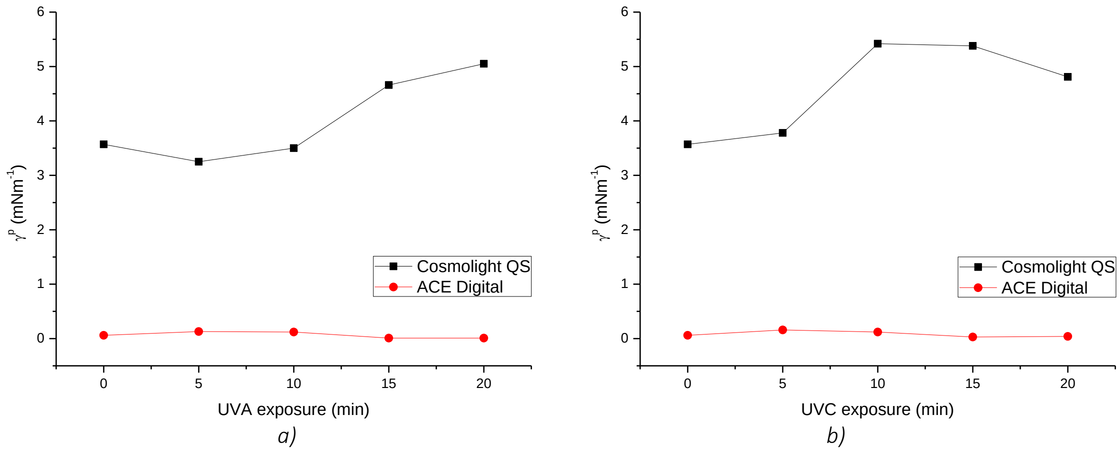


Figure 9: Polar component of surface free energy of printing plate samples exposed to:
a) varied UVA post-treatment, b) varied UVC post-treatment

Initial increase of γ^{p} is caused by the integration of the oxygen in the surface layer of photopolymer material. However, the decrease of γ^{p} after the certain duration of UV post-treatment can be explained by the process of migration of non-polar carbohydrate compounds of low molecular weight (such as protective waxes added to these types of photopolymers) to the surface of the material and by the changed orientation of the polar molecular structures in the surface of the material (Knoll, 2002).
Therefore, when needing to adjust γ^{p} of the flexographic printing plate surface, initial test needs to be performed in order to detect the inflexion point with maximal γ^{p}.
However, since UVA radiation initiates the crosslinking reaction, and UVC terminates it due to the higher energy and generation of ozone, one should use both post-treatments and combine their duration in

order to achieve desired γ, but at the same not diminish the functionality of the photopolymer printing plate in the reproduction process (Kramer et al, 2012); (Cataldo, 2001).

3.3 Hardness of modified printing plates

Results of hardness measurements of photopolymer printing plates are displayed in Figure 10. Results show the increasing trend, which was expected due to the further crosslinking in the material volume and therefore increased network density (Tomašegović, 2016) Increased hardness of the printing plates will result with lower deformation of the printed elements during the engagement in the reproduction process. Specifically, UVC post-treatment causes more expressed increase in printing plate's hardness than UVA post-treatment.

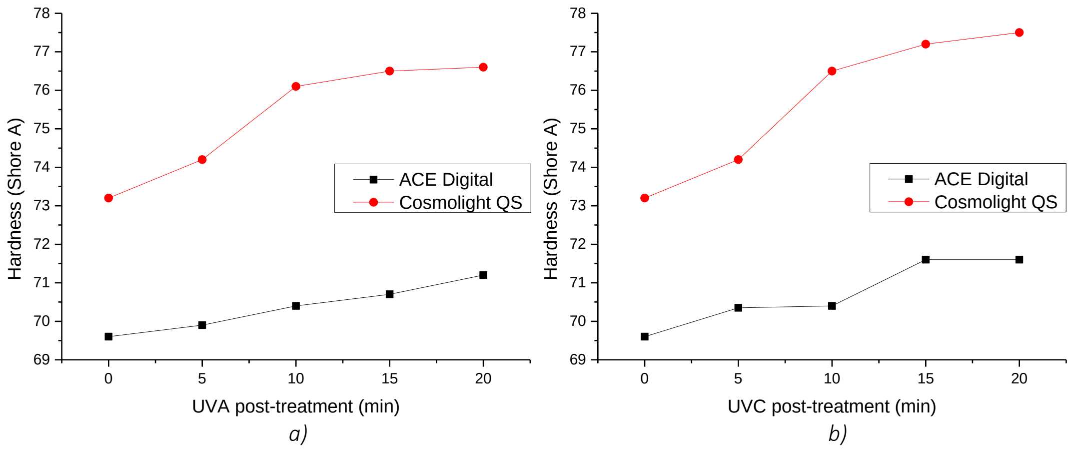
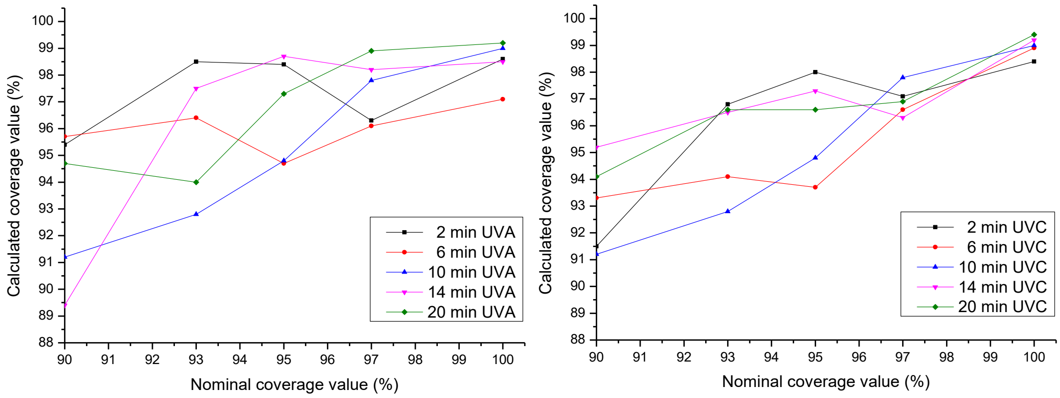


Figure 10: Changes of printing plate hardness in dependence on the duration of:
a) UVA post-treatment, b) UVC post-treatment

ACE digital printing plate displays higher resistance to UV post-treatments in relation to the changes in hardness, with maximal increase of 1.4 according to Shore A scale (Figure 10b). This result supports the the statement that excessive UV radiation causes the migration of protective waxes to the surface, which will minimize the influence of the post-treatment on the core of the material. Maximal increase of the hardness for Cosmolight QS printing plate is 4.2 on Shore A scale, caused by UVC radiation (Figure 10b). Changes in hardness of the photopolymer material are relevant because they can, together with the changes of the printing plate's surface properties, have an effect on the quality of fine printed elements. Obtained results point to the conclusion that prolonged UV post-treatments, although causing different types of changes in photopolymer surfaces, have a similar impact on the core of the material.

3.4 Features of the test prints

Results of coverage values measured on prints obtained by UV post-treated printing plates are presented in Figures 11 and 12. Noticeable changes were detected in high coverage area, where the deformation of the printing plate and excessive dot gain in the printing process can cause the loss of shadow area on the print, i.e. printing a solid tonal patch in the halftone area.
Figure 11 presents the changes in high coverage area on prints obtained by UV post-treated ACE Digital printing plates. There is no visible trend of the influence of the duration of UVA and UVC post-treatment on coverage values, except the general increase. ACE Digital is a printing plate with relatively low initial hardness compared to Cosmolight QS printing plate (maximal hardness of ACE Digital printing plate is 71.6 on Shore A scale, while Cosmolight QS's 77.5 on Shore A scale).



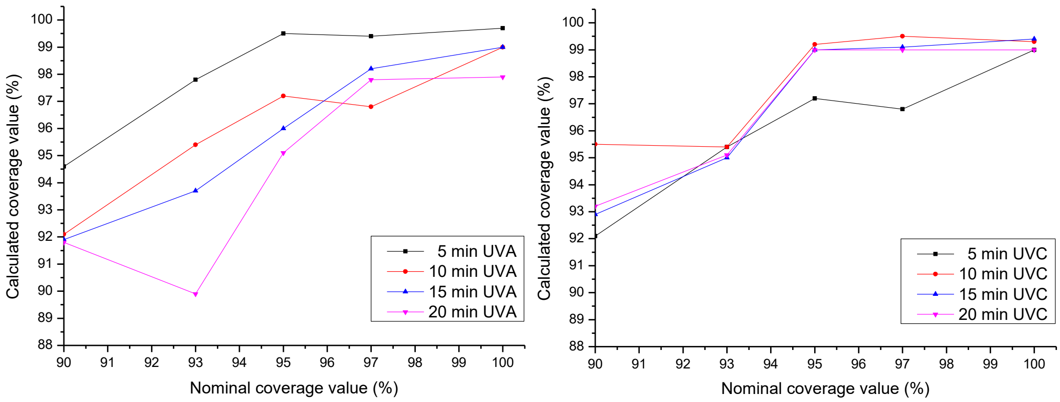
a) *b)*

Figure 11: Changes in high coverage area on prints obtained by UV post-treated ACE Digital printing plates: a) with variation of UVA post-treatment, b) with variation of UVC post-treatment

Higher hardness of Cosmolight QS printing plates, and therefore increased stability in terms of elastic deformation in the printing process (Yusof et al, 2008); (Bould et al, 2004), results with the visible effect of varied UV post-treatments on the halftones in high coverage area (Figure 12).

Specifically, with prolonged UVA post-treatment (Figure 12a), coverage values in the shadow area decrease, primarily because of the increasing hardness and therefore decreased deformation of the printing plates during the engagement.

This decrease in high coverage area on prints for Cosmolight QS printing plate is significant (from 97.8% to 89.9% for Cosmolight QS printing plates, at nominal coverage value of 93%).

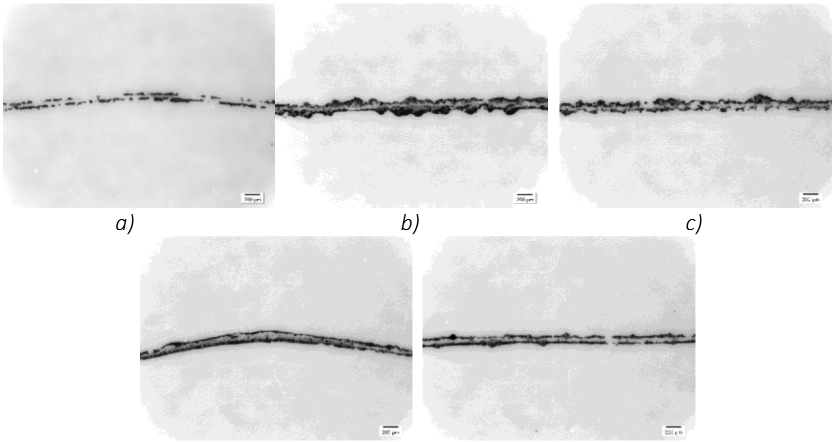


a) *b)*

Figure 12: Changes in high coverage area on prints obtained by UV post-treated Cosmoight QS printing plates: a) with variation of UVA post-treatment, b) with variation of UVC post-treatment

On the other hand, UVC post-treatment results with the opposite trend of changes in high coverage area (Figure 12b) for the prints obtained by Cosmolight QS printing plate. Trends of the changes in measured coverage values on prints follow the similar trends as the changes in printing plates' γ^p (Olson et al, 2006). Therefore, if initial hardness of the printing plate is sufficient to eliminate excessive deformations during the engagement, duration of UVA post-treatment can be used to decrease the coverage values in shadow area due to the increasing hardness, while the duration of UVC post-treatment (adjusted to the application of the specific printing ink) can be used to adjust the coverage values on prints to the desired levels, as well.

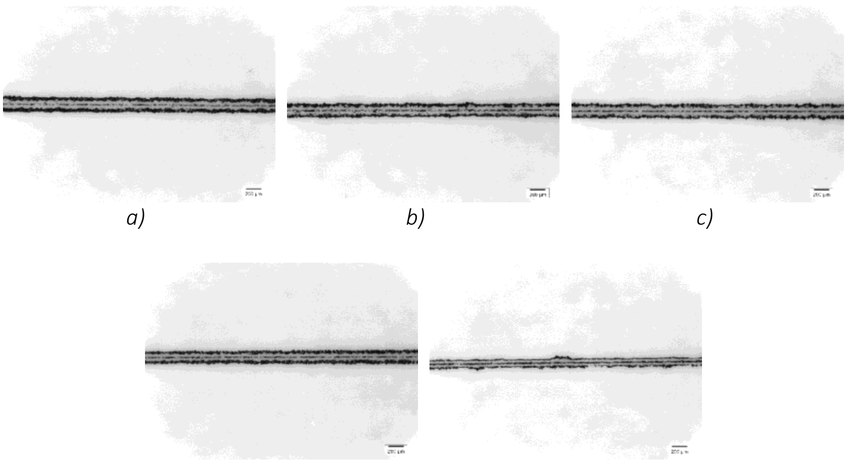
The results of the microscopic analysis are displayed for the fine printed lines, with nominal width of 20 µm (Figures 13 and 14). Microscopic images of screen elements of different coverage values didn't display any significant visual changes in quality. This points to the conclusion that the variation of one type of UV post-treatment (UVA or UVC), while keeping the other one constant at optimal value, results with printing plate of functional properties which is able to perform correctly when printing halftones. Images of printed lines obtained by UV post-treated ACE Digital samples are presented in Figure 13. It is visible that the print obtained by printing plate exposed to 2 minutes of UVA post-treatment (Figure 13a) prints the inconsistent line, primarily because of the insufficient hardness of the printing plate.



a) b) c) d) e)

Figure 13: Lines with nominal width of 20 µm (magnification of 50x) on prints obtained by ACE Digital printing plates exposed to varied UV post-treatments: a) 2 min UVA post-treatment, b) 10 min UV post-treatment, c) 20 min UVA post-treatment, d) 2 min UVC post-treatment, e) 20 min UVC post-treatment

10 minutes of UV post-treatment (Figure 13b) results with thicker printed line, but its edges are not well defined, due to the poor wetting of the printing ink on the printing plate. In general, ACE Digital printing plate does not enable the optimal quality of printed thin lines, since its γ decreases with prolonged UV post-treatments. However, increased hardness of the printing plate will improve the quality of the prints (Figure 13e), but the end result is still not good enough for high-quality prints of specific motives.
Figure 14 displays fine lines printed by Cosmolight QS printing plates. Printed fine lines are straight, regardless of the duration of UV post-treatments, pointing to the stable and correctly formed fine printing elements on the printing plate.



a) b) c) d) e)

Figure 14: Lines with nominal width of 20 µm (magnification of 50x) on prints obtained by Cosmolight QS printing plates exposed to varied UV post-treatments: a) 2 min UVA post-treatment, b) 10 min UV post-treatment, c) 20 min UVA post-treatment, d) 2 min UVC post-treatment, e) 20 min UVC post-treatment

It is visible that 5 minutes of UVA post-treatment (Figure 14a) results with the increased ink amount on the print compared to prolonged UVA and UVC post-treatments. The reason is poorer wetting (because of the lower γ) than for printing plates exposed to prolonged UV post-treatments. Prolonged UVC post-treatment (Figure 14e) can be used as a tool to decrease the width of the printed line.
Moreover, it is important to notice that neither ACE Digital, nor the Cosmolight QS printing plates give optimal results regarding the consistency of the fine printed line. The deformation specific for flexographic printing plate results in absence of the printing ink transfer in the center of the printed

element (screen element, line, etc.). Therefore, if printing with conductive inks, where the uniformity and coverage of the whole line/element surface is of crucial importance, nominal width of the line must be adjusted to the specific printing plate if possible (Deganello et al, 2010); (Baker et al, 2014). Alternatively, the choice of different type of photopolymer flexographic printing plate must be made.

4. CONCLUSION

In this research, the properties of two different types of photopolymer flexographic printing plates were analyzed in relation to varied exposure to UVA and UVC wavelengths in the post-treatment process of the printing plate production workflow. The aim was to define and interconnect the changes that occur in mechanical and surface properties of printing plates during the UV post-treatments, in relation to the modified properties of prints.

Since the primary purpose of this research was to retain the functional properties of printing plates in the reproduction process throughout all modifications, all procedures in the printing plate production workflow prior to post-treatment needed to be kept constant and standardized, in order to initially result with functional printing plate. The post-treatment process, as the last step in flexographic printing plate production workflow, is of crucial importance for defining printing plate’s surface properties. Furthermore, the post-treatment process is easily alterable in the real systems and is not completely standardized by printing plate manufacturers – its duration is often defined by the recommended range.

From the results of measurement, analysis and calculation methods performed in this research, the following conclusions can be made:

It was proved that the in the dispersive and polar component of the surface free energy of photopolymer materials (γ^d and γ^p) due to the varied UVA and UVC post-treatments, are primarily caused by oxygen inhibition and the crosslinking propagation and termination. This points to different crosslinking propagation and termination mechanisms in solvent- and water- washable photopolymer materials, as well as to different sensitivity to the oxygen and the potential to modify γ^d or γ^p of printing plate without damaging the surface.

It was confirmed that the changes in the surface properties (γ^d and γ^p) of printing plates caused by varied UVA and UVC post-treatment cause the changes in the quality of prints, as well. Coverage values in shadow area display the changes directly connected to the changes of hardness and γ^d and γ^p, which demonstrates that UVA and UVC post-treatments can be used as tools to adjust the print properties.

Therefore, UVA and UVC post-treatments have been specifically recognized as a significant step for obtaining maximal possible quality in the reproduction process.

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Original scientific paper

EXPERIMENTAL STUDY OF THE DEFORMATION OF PRINTING BLANKETS BY MEANS OF AN OPTICAL ANALYSIS

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Abstract: *The aim of this experimental study was to determine displacement and elastic strain of separate layers of different compressible printing blankets due to a uniaxial static plane pressure (plane-plane) using custom optical analysis methods. Compressible blankets are viscoelastic laminated compound structures composed of outermost incompressible printing rubber surface, several various stretch resistant supporting fabrics, and at least one compressible layer comprising a foamed rubber that may consist of voids or micro spheres. Depending on their mechanical characteristics, there are substantial differences in how these individual layers deform due to indentation by the plate or the impression cylinder in nip. In order to investigate these deformations, special equipment was built and techniques developed that allow precise contactless measurement of micro displacements. Series of microscopic images of a cross-section of blanket samples during gradually increasing plane indentation are acquired and the profiles of average Y-values of acquired images were plotted. Displacements of layer joints were defined exactly by the custom mathematical function using means of a maximum gradient search and strains were calculated according to the obtained results. Five different compressible blankets were studied and the results indicated that, in percentage rate, the top rubber layer of some blankets got more deformed than the rest of the blanket. This finding leads to the conclusion that some top rubber layers are more resilient than rest of layers.*

Key words: printing blanket, deformations in nip, strain measurement, optical analysis

1. INTRODUCTION

Thanks to the modern mechanical engineering, offset printing today stands for a relative stable and predictable printing process in which the most important parameters of machines are firmly defined or easily adjustable. There is a variety of printing blankets in use but some important characteristics that could help printers achieving desired results are not clearly declared. Because of their non-uniformity and inhomogeneity, blankets can have different characteristics in print. In several studies, the blankets were observed as homogeneous material, and this paper shows analysis of individual layers of blankets.

1.1 Offset printing

Offset printing is an indirect printing technology in which the printing ink is transferred from an offset plate to the blanket and then to the printing substrate (DIN 16529, 1982). There are sheet-fed and web-fed offset printing techniques. The centerpiece of every offset printing machine consists of three coupled cylinders: plate cylinder, blanket cylinder and impression cylinder (Figure 1a). The blanket cylinder is covered with the printing blanket in order to transfer ink from the plate to the substrate due to indentation in nip (Figure 1b) and therefore has a direct influence on print quality.

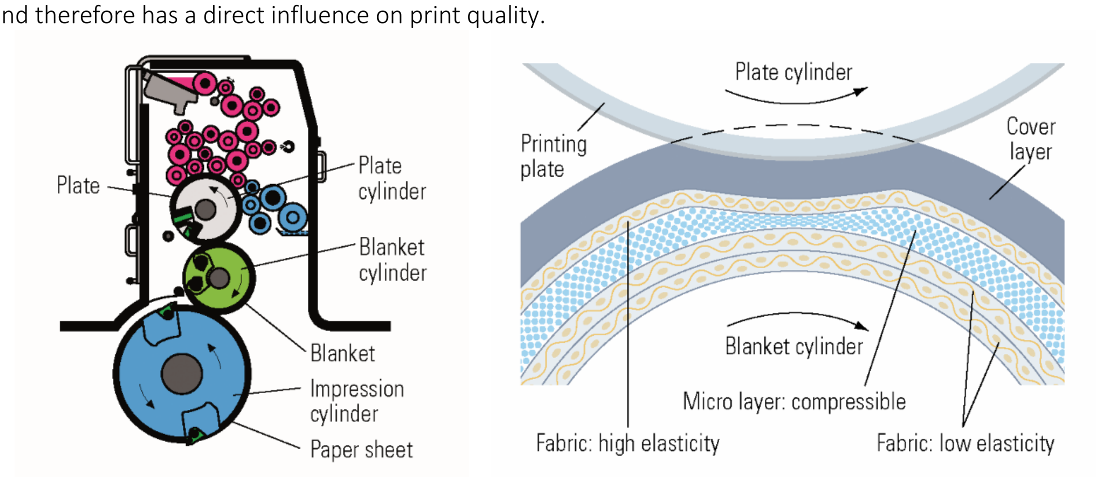


Figure 1: Cross-section of offset printing machine: a) offset printing unit (Kipphan,2001) b) blanket in nip (ContiTech)

1.2 Printing blankets

Incompressible and compressible blankets (Figure 2a) have to be distinguished and in this experimental study, several compressible blankets were investigated. Compressible blankets are compound laminated viscoelastic structures 1,65 to 1,95 mm thick (Walensky, 1993), composed of outermost incompressible rubber surface, multiple stretch resistant fabric plies and at least one compressible layer comprising a soft and resilient foamed rubber (Figure 2b). The latter one may consist of voids or micro spheres. Compressible blankets displace less rubber in nip than conventional ones, thus contributing to the attainment of true rolling or absence of tangential force and consequently less slippage (Riedl et al, 1989).

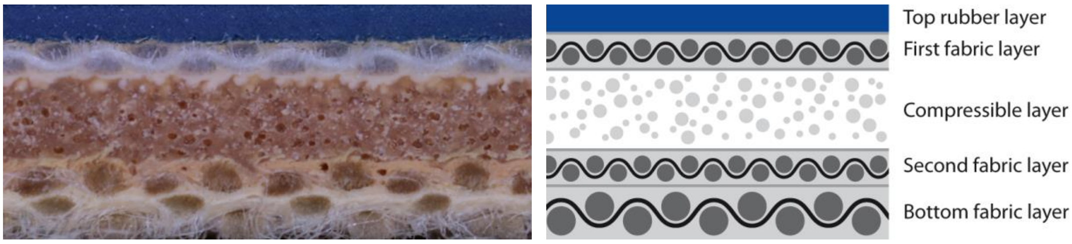


Figure 2: Structure of blanket: a) cross-section of compressible blanket b) layers of compressible blanket (One mostly used general model is displayed, variety of different blanket models are possible)

Depending on mechanical and viscoelastic characteristics of the individual layers, there are substantial differences in how these layers deform in nip due to indentation of neighbouring cylinders (Figure 3).

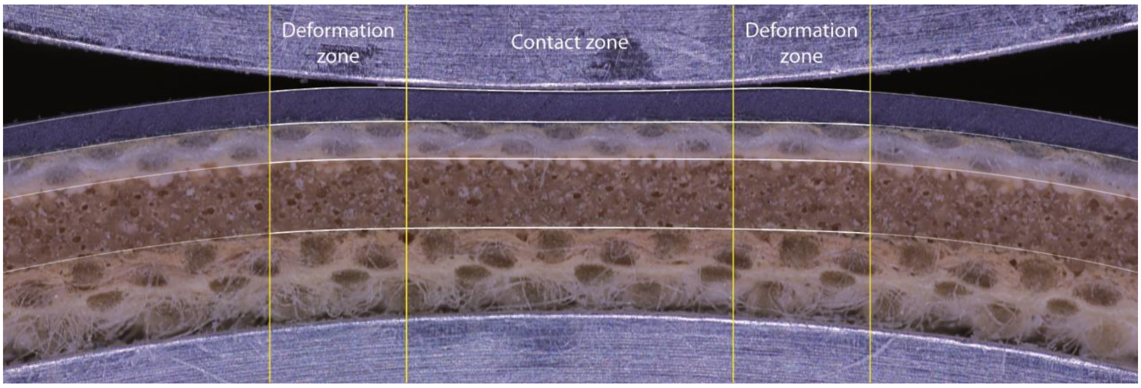


Figure 3: Cross-section of compressible printing blanket under indentation in simulated static nip (First two layers are relatively rigid and the radial displacement starts wide before and after the contact zone)

1.3 Viscoelasticity

Viscoelasticity is the property of material to exhibit simultaneously elastic and viscous characteristics. Their behavior may be represented by means of mechanical or rheological models composed of elastic and viscous elements (Hying, 2003). The mechanical behavior of an ideal elastic body obeys the Hooke-Law of elasticity E and is modeled with a linear elastic spring (Figure 4a) with a stress σ dependent and time t independent strain response ε (Figure 5a). The mechanical behavior of a viscous material is determined by the Newton-Law of viscosity η and is modeled with an ideal damping element (Figure 4b) that extends proportionally to the stress with a strain independent but time dependent response (Figure 5b). Maxwell viscoelastic model (Figure 4c) can be represented by an elastic spring and viscous damper connected in series, with a strain and time dependent response (Figure 5c). Kelvin–Voigt viscoelastic model (Figure 4d) consists of a Hookean elastic spring and a Newtonian damper that are connected in parallel, with a strain and time dependent response (Figure 5d). These two are the simplest viscoelastic models so that more realistic viscoelastic responses can be modelled using more elements (Kelly, 2016).

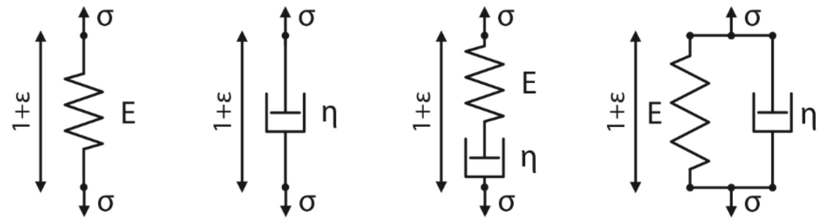


Figure 4: Mechanical element of elasticity and viscosity and models of viscoelasticity
a) Hooke-Element b) Newton-Element c) Maxwell model d) Kelvin–Voigt model

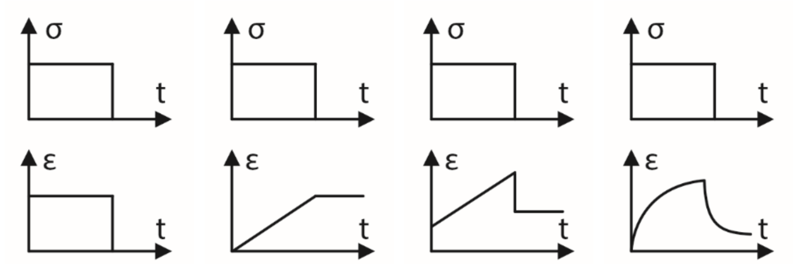


Figure5: Stress-strain responses of elastic and viscos element and viscoelastic models
a) Hooke-element b) Newton-element c) Maxwell model d) Kelvin–Voigt model

1.5 Blanket model

Blankets are viscoelastic compounds and should be simulated with a couple in series and parallel connected viscoelastic models (Figure 6a). In this study, all experiments were static so the viscous component was neglected and blankets were modeled as ensemble of ideal springs in series (Figure 6b).

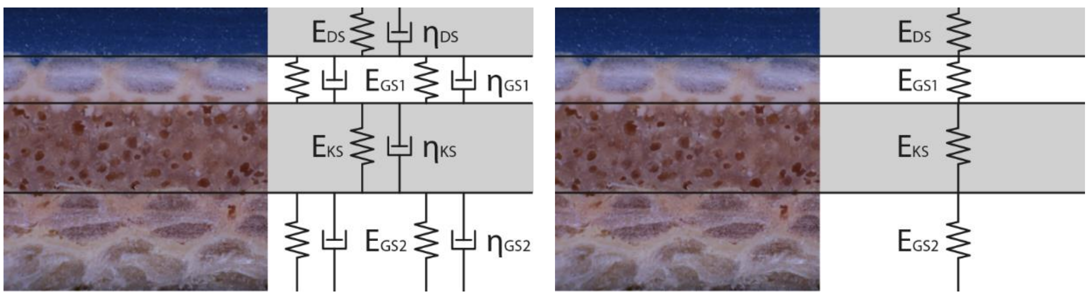


Figure 6: One-dimensional models of blanket: a) viscoelastic model b) simplified elastic foundation model
(Blanket model in Figure 6b is only allowed if the system is considered as static and thus is examined)

For the springs in series, the stress applied to the ensemble gets equally applied to each spring, and the amount of strain is the sum of the strains of the individual springs. For parallel springs, the strain of the ensemble is their general strain and the stress of the ensemble is the sum of their stresses (Table 1).

Table 1: Stress and strain equations of springs in series and in parallel

	Springs in series	Springs in parallel
Strain	$\varepsilon = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \varepsilon_N$	$\varepsilon = \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = \varepsilon_N$
Stress	$\sigma = \sigma_1 = \sigma_2 = \sigma_3 = \sigma_N$	$\sigma = \sigma_1 + \sigma_2 + \sigma_3 + \sigma_N$

For the system of N linear elastic ideal springs in series, end-to-end, with elastic modulus of individual springs $E_1, E_2, E_3 \dots E_N$ the equivalent elastic modulus E of an ensemble of springs can be calculated:

$$\frac{1}{E} = \sum_{i=1}^{N} \frac{1}{E_i} = \frac{1}{E_1} + \frac{1}{E_2} + \frac{1}{E_3} \dots \frac{1}{E_N} \tag{1}$$

For the same ensemble of springs connected in parallel, side-by-side, the equivalent elastic modulus is:

$$E = \sum_{i=1}^{N} E_i = E_1 + E_2 + E_3 + \cdots + E_N \quad (2)$$

Based on Hooke's law $E = \sigma/\varepsilon$ and using relation (1), the elastic modulus of each layer of blanket can be calculated if the modulus of the blanket and strains of layers under indentation are known (Figure 7).

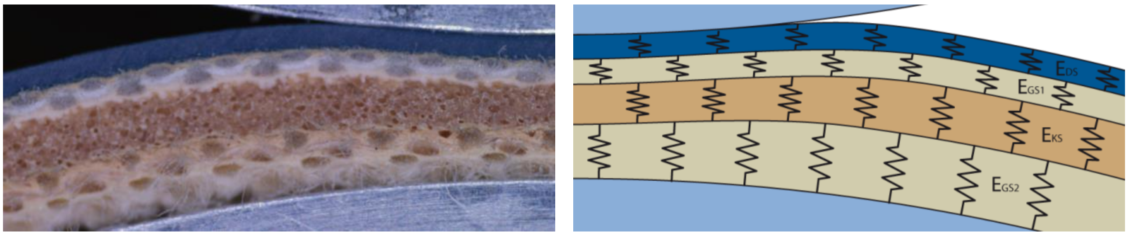


Figure 7: Printing blanket in nip: a) real blanket under indentation b) elastic foundation model of blanket (as a result of tangential resistance, the layers in the inlet and outlet zone are deformed without a kink)

The indentation and radial deformation of blanket consequently result in displacement of tangential direction, especially of incompressible layers (Figure 8), however, they are not analyzed in this study.

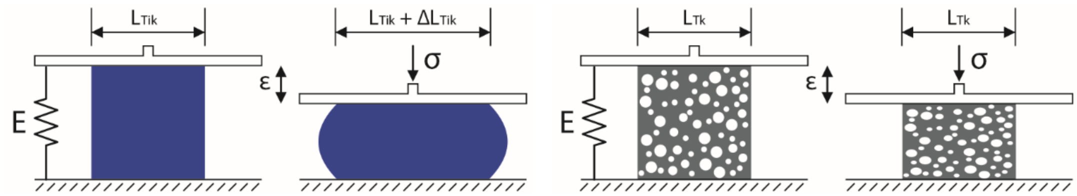


Figure 8: Horizontal displacements of two different materials under vertical pressure with consideration of friction a) ideal incompressible material with horizontal flow b) ideal compressible material without horizontal flow

2. METHODS

This study is focused on the use of special equipment and analysis techniques for the accurate and contactless measurement of displacement and the resulting micro strain and compression, specifically developed for this study. Even though they are in use in other technical sectors, these techniques were not used for printing blankets. Four main segments of this investigation are sample clipping and preparation, plane-plane and round-round indentation, acquisition of microscopic images of sample cross-sections and analysis of resulting strain and displacements.

2.1 Preparation of samples

For microscopic observation, multiple samples in size of 20 mm x 5 mm were cut. In microscopy, the depth of field is generally shallow, especially in devices without variable aperture and with large magnification. Therefore, a plane cross-section of observed sample is essential. In order to get the plane section of samples as smooth as possible, and to minimize squeeze, a sharp cutter was used. If not used, the sections would be always jagged and wavy, because of the horizontal material flow especially of very elastic and incompressible layers caused by vertical pressure of blade (Figure 8). Due to blankets inhomogeneous structures, there is unequal local stiffness and thus displacement and deformation of individual layers are not uniformly distributed over the surface. They strongly depend on the place of measurement or, if visually examined, on cross-section position and direction. Fabric layers are grid structures and their local resilience substantially affects displacement of other layers. Strength and thickness of warp threads are greater than of weft threads, and if cut along them and hit upon middle of one of these threads (Figure 9a), it appears fabric layer to be stiffer and other layers more resilient, however, it is contrariwise if cut between them (Figure 9c). The same happens if dissected across the blanket and hit upon middle of one of weft threads or between them.

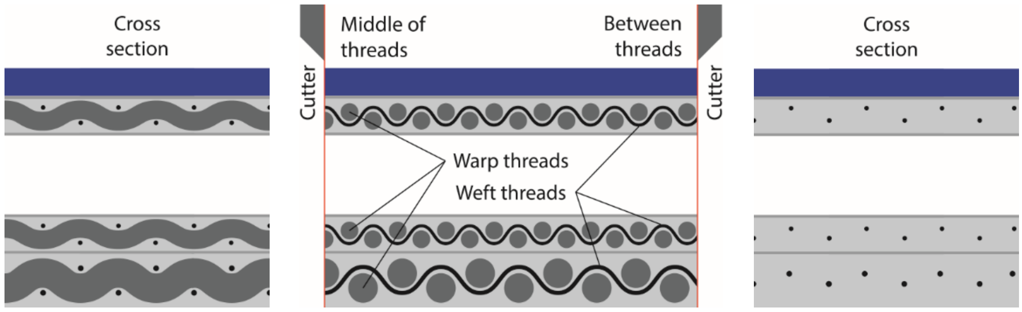


Figure 9: Model of blanket cross-section: a) cut upon middle of threads b) threads in blanket c) cut between threads (Because of the grid structure and inhomogeneity of layers, the best results were gained if blanket was cut diagonally)

It has become evident that most reliable results are gained by clipping the samples diagonally. Thus, elastic moduli of the warp and weft threads, as well as of their binding material, averaged over measured length. Thereby, the influence of distinctive inhomogeneity on the gained results is minimized.

2.2 Image acquisition

For the observation of deformations and image acquisition an optical stand microscope with a digital reflex camera and a precision cross table was additionally equipped. The device was automated with Arduino and driven by three stepper motors, one for each cross-table axis and one for a microscope focus adjustment. The resolution of cross-table was calculated to 0,625µm in both directions, so the sample could be very precisely led and positioned. The microscope was calibrated and with the maximal camera resolution of 6.000 x 4.000 pixels, whereas 1 pixel had a size of 0,459 µm so that with a single acquired image, an area of 2.754 µm x 1.836 µm could be taken. Magnification of the objective was 5x and multiplied with the 10x magnification of the ocular, it resulted in the total magnification up to 50x. In order to get high-resolution microscopic photos of the whole region of interest for every step of indentation, multiple images with defined overlap were acquired, and stitched with ImageJ plugin (Figure 10a). With every step of indentation, the cross-section of the sample becomes more uneven so the focus was readjusted in several distances in accordance with the relief of cross-section and the new series of photographs were taken. These multiple stitched photos were then stacked with ImageJ (Figure 10b). The result was the increase of depth of field and consequently supersized well-focused images (Figure 10c).

Figure 10: Acquisition and preparation of multiple microscopic images in order to get one supersized image a) stitching of ten images b) stacking of five stitched images c) one well-focused result image in high-resolution

The number of acquired single photos I_S could be calculated as a product of number of images along I_{Nx} and across I_{Ny} of the field of interest, indentation steps N_S and focus adjustment levels N_M:

$$I_S = I_{Nx}\, I_{Ny}\, N_S\, N_M \tag{2}$$

Total size in pixels of resulting image I_R along I_{Rx} and across I_{Ry} of the photographed sample can be calculated if the number of acquired images in both directions I_{Nx} and I_{Ny} as well as width I_{Sx} and height I_{Sy} of a single image is known and if overlap in both directions O_x and O_y are exactly defined:

$$I_R = I_{Rx}\, I_{Ry} = (I_{Nx}\, I_{Sx} - O_x\, I_{Nx} + O_x)(I_{Ny}\, I_{Sy} - O_y\, I_{Ny} + O_y) \tag{3}$$

The image acquisition process was fully automated and with this technique it was possible hundreds of images to make as well as to stitch and stack them in short time in order to prepare them for analysis.

2.3 Sample indentation

For this study, an indenter, based on a single-axis precision table, was constructed. The table was automated with Arduino, with one stepper motor driven and mounted on the cross table of microscope. Stepper motors usually have resolution of 200 steps per revolution but with an appropriate driver these full steps were split to 16 micro steps and overall resolution increased to 3200 micro steps per revolution. The smallest indentation increment was defined as a quotient of thread pitch T_P of the precision table and the total number of steps S_R per revolution. For this device, the indenter resolution I_R was calculated to 0,625 µm, however, while unloaded, it was measured to 0,619 µm. This relative small difference could be probably ascribed to the imprecision of the thread pitch or less likely to the play of thread.

$$I_R = \frac{T_P}{S_R} = \frac{2000\ \mu m}{3200} = 0{,}625\ \mu m \tag{4}$$

Furthermore, a flexible fastening device was built and different indenters made. To ensure straight and to both indenters parallel displacements of individual joints of layers, which could be defined and tracked by the software in the further investigation step, plane indenters were required (Figure 11a). For a visual representation of displacements in static simulated nip, round indenters were used (Figure 11b).

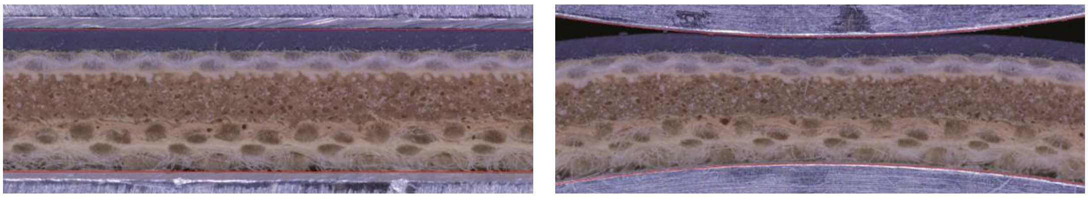


Figure 11: Sample indentations: a) plane indentation (plane-plane) and b) simulated nip (round-round)
(Plane indentation provides reliable analysis of strains while all displacements are straight and parallel)

The top rubber layer, as the only incompressible layer, starts from some point of increasing indentation to well out and appears to be thicker but in this range of deformation measurement could it be neglected.

2.4 Analysis of deformations

To define the displacements of individual layers and to calculate their strain for every step of indentation the series of resulting photos were analyzed. They were loaded in ImageJ stack, and the profiles as average of 8-bit Y-values of every image with a customized macro were exported. The only manual step in the analysis was to determine approximately positions of layer joints of interest in the first image and so to define borders that should be tracked by the software. The exported values were loaded with custom Scilab macro and the maximal gradients in the manual defined areas of interest were found in the first image and then tracked successively in entire image series. For the starting points of the joints in every current image were the positions of the joints from the previous image used and so large displacements in relatively small indentation steps were traceable (Figure 13). The found joints (in Figure 12 as A, B and C marked) were as straight lines on the corresponding image displayed and so the analysis was visually proved. This study was focused in particularly on the strain of the top rubber layer S_{AB} and the rest of layers S_{BC} of investigated blanket S_{AC} so that the positions of these joints were of major interest. When the positions are exactly defined as P_A, P_B and P_C (Figure 12) their thickness T_{AB}, T_{BC} and T_{AC} as well as their strain in every indentation step i starting from the first image s could be calculated as follows:

$$S_{AB_i} = \frac{T_{AB_i}}{T_{AB_s}} - 1 = \frac{\left(P_{B_i} - P_{A_i}\right) - \left(P_{B_s} - P_{A_s}\right)}{P_{B_s} - P_{A_s}} \tag{5}$$

$$S_{BC_i} = \frac{T_{BC_i}}{T_{BC_s}} - 1 = \frac{\left(P_{C_i} - P_{B_i}\right) - \left(P_{C_s} - P_{B_s}\right)}{P_{C_s} - P_{B_s}} \tag{6}$$

$$S_{AC_i} = \frac{T_{AC_i}}{T_{AC_s}} - 1 = \frac{\left(P_{C_i} - P_{A_i}\right) - \left(P_{C_s} - P_{A_s}\right)}{P_{C_s} - P_{A_s}} \tag{7}$$

Gained values are calculated with (5,6,7) and shown in Table 2 as well as visually represented in Figure 13. Negative strain values mean that the layers were compressed and not stretched due to indentation.

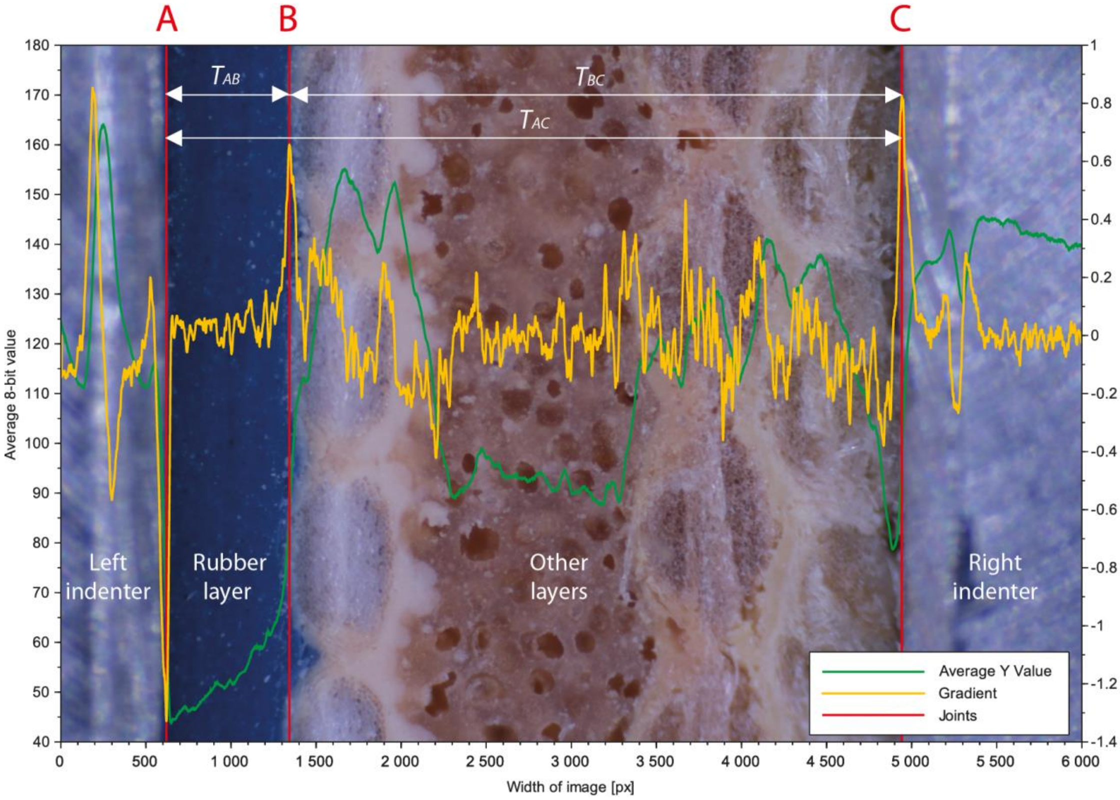


Figure 12: Defined layer joints of interest of analyzed printing blanket with average Y-values gradients and layer joints (Line A is the top side of the blanket and line C is the bottom side. Line B defines the distribution of total deformation)

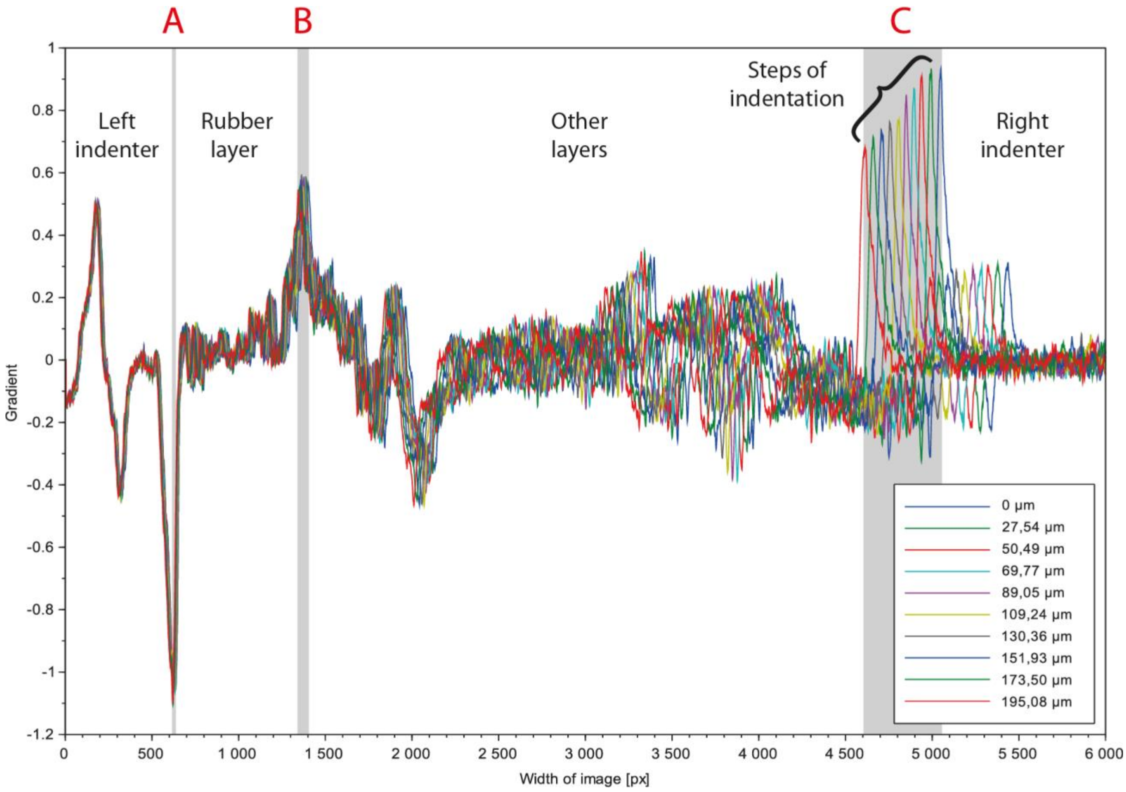


Figure 13: Gradient of average Y-values of image series of printing blanket under increasing plane indentation

As in Figure 13 shown, the right indenter (area C) had the largest displacement because all experiments were performed with them (right to left) and the left one was fixed. Left indenter (area A), though, had some displacement and that could be ascribed to the elasticity of testing device. Both of these displacements were tracked and strains considering measured positions calculated. Joint B defines how the overall deformation of blanket (AC) on the top rubber layer and the other layers is distributed (area B).

Table 2: Measured displacements and calculated strain for one sample

	Indentation [µm]	Position [px]			Thickness [µm]			Strain [%]		
		P_A	P_B	P_C	T_{AC}	T_{AB}	T_{BC}	S_{AC}	S_{AB}	S_{BC}
Image 1	0,00	627	1.400	5.048	2.029,24	354,81	1.674,43	0,00	0,00	0,00
Image 2	27,54	630	1.388	4.991	2.001,70	347,92	1.653,78	-1,36	-1,94	-1,23
Image 3	50,49	628	1.385	4.939	1.978,75	347,46	1.631,29	-2,49	-2,07	-2,58
Image 4	69,77	627	1.380	4.896	1.959,47	345,63	1.613,84	-3,44	-2,59	-3,62
Image 5	89,05	625	1.374	4.852	1.940,19	343,79	1.596,40	-4,39	-3,10	-4,66
Image 6	109,24	623	1.369	4.806	1.920,00	342,41	1.577,58	-5,38	-3,49	-5,78
Image 7	130,36	621	1.364	4.758	1.898,88	341,04	1.557,85	-6,42	-3,88	-6,96
Image 8	151,93	619	1.358	4.709	1.877,31	339,20	1.538,11	-7,49	-4,40	-8,14
Image 9	173,50	617	1.352	4.660	1.855,74	337,37	1.518,37	-8,55	-4,92	-9,32
Image 10	195,08	614	1.347	4.610	1.834,16	336,45	1.497,72	-9,61	-5,17	-10,55

The layers were characterized with a slope of regression line of measured curves in deformation area important for technical application and afterwards the gained values were used for layer comparison.

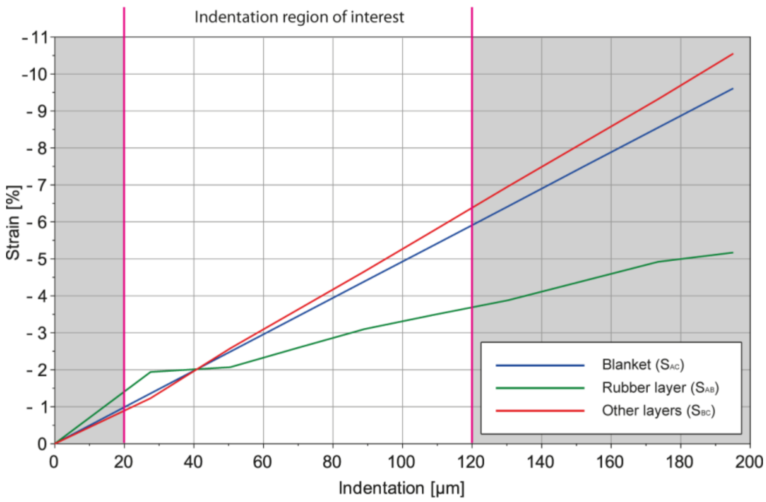


Figure 14: Deformation of individual layers of printing blanket
(Indentation region of 20 to 120 µm corresponds to the indentation in printing machine)

The analysis was very reliable when layers were straight, visually clearly separated and in different colors. Otherwise the process fails because the gradients of gained curves were not enough distinct. That was the main disadvantage of this automatic analysis technique. In some cases, there was significant improvement of layer distinction achieved by enhancing contrast of images or by splitting color channels.

3. RESULTS

In this research there were samples of five printing blankets with different structure as well as mechanical and geometrical characteristics investigated (Figure 15). The samples are adequately prepared according to the capital 2.1 and then the plain indentations performed as in capital 2.3 depicted. Microscopic images were acquired as in capital 2.2 described, and image series were analyzed as in 2.4 explained.

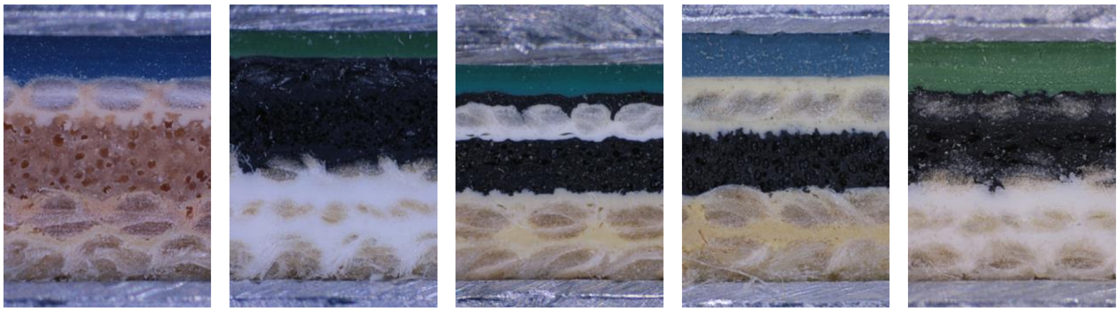


Figure 15: Five investigated compressible printing blankets
a) Blanket 1 b) Blanket 2 c) Blanket 3 d) Blanket 4 e) Blanket 5

The thickness of the entire non-deformed and unstrained blankets and of their separate layers of interest are precisely defined and used in the further strain calculation. All investigated blankets and their individual layers had significantly different thicknesses (Table 3). Since all samples were measured and investigated tangentially unstrained, they appeared up to 5 percents thicker as manufacturer specified.

Table 3: Thickness of non-deformed and unstrained blankets and separate layers of interest

Thickness [µm]	Blanket 1	Blanket 2	Blanket 3	Blanket 4	Blanket 5
Blanket (AC)	2.001,62	2.028,24	1.759,27	1.993,36	1.927,91
Top layer (AB)	334,84	215,42	233,019	352,36	410,8
Other layers (BC)	1.666,78	1.812,82	1.526,25	1.641,00	1.517,11

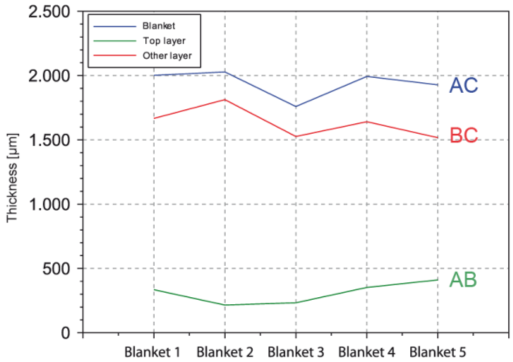
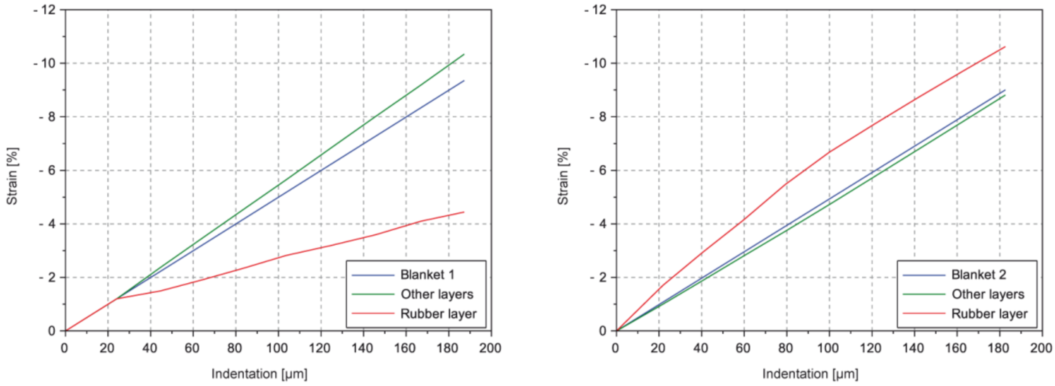


Figure 16: Thickness of investigated printing blankets and their individual layers of interest

The second investigated blanket was the thickest one but had the thinnest top layer. The third blanket was overall the thinnest and the fifth one had the thickest top rubber layer (Figure 16). In order to get the reliable results and to minimize the effect of blanket inhomogeneity, five separate samples of every blanket were investigated and the gained results were averaged and visually presented (Figure 17).



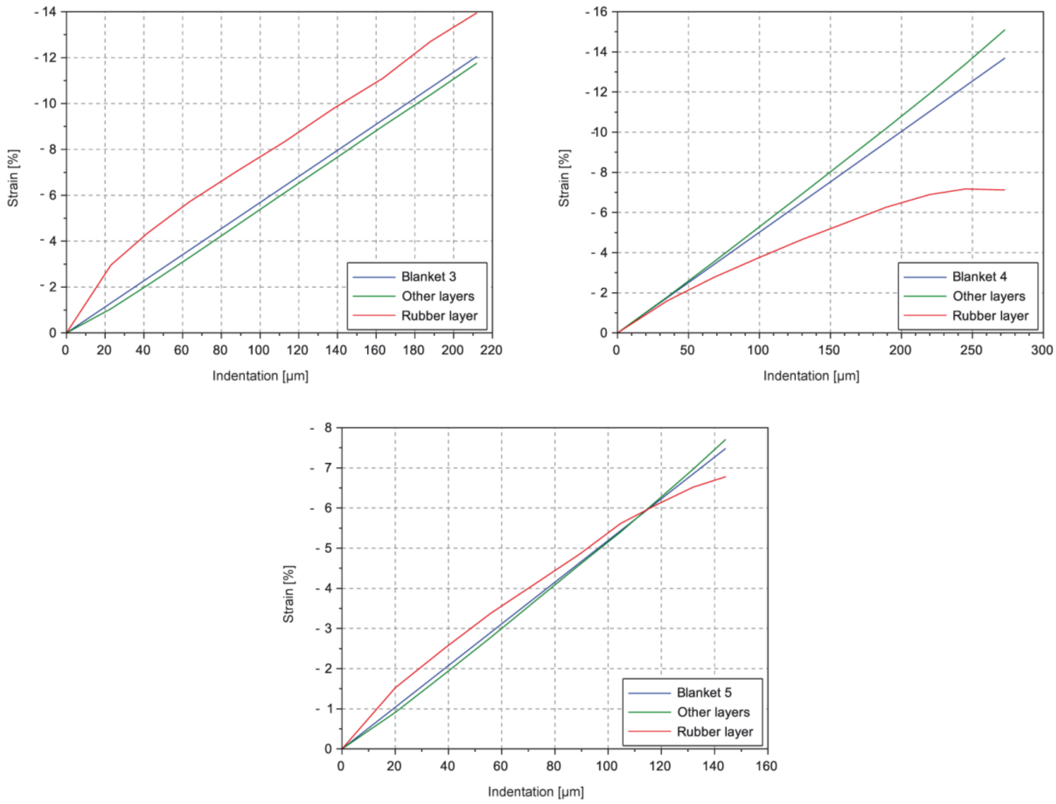


Figure 17: Results of displacement measurement and strain calculation of five studied blankets

As it can be seen in Figure 17, the top layer of the first investigated blanket was the least compressed under same indentation and the top layer of the third blanket the most. The rest of layers were deformed similarly to the whole blanket because they comprise the largest part of them. In order to compare the strain values and to make them relevant to the real condition in offset printing, the linear regressions of stress-strain curves were calculated in area from 20 to 120 µm (Engelmann et al., 1962) of indentation and their slopes were defined (Table 4). The slope of stress-strain curve correlates with the deformation and with the E modulus of the corresponding layer and provides information of its behavior in the nip.

Table 4: Slopes of regression lines of measured stress-strain curves of blankets and of separate layers of interest

	Blanket 1	**Blanket 2**	**Blanket 3**	**Blanket 4**	**Blanket 5**
Blanket (AC)	-0,0500	-0,0493	-0,0568	-0,0502	-0,0519
Top layer (AB)	-0,0205	-0,0613	-0,0582	-0,0321	-0,0465
Other layers (BC)	-0,0559	-0,0479	-0,0566	-0,0540	-0,0536

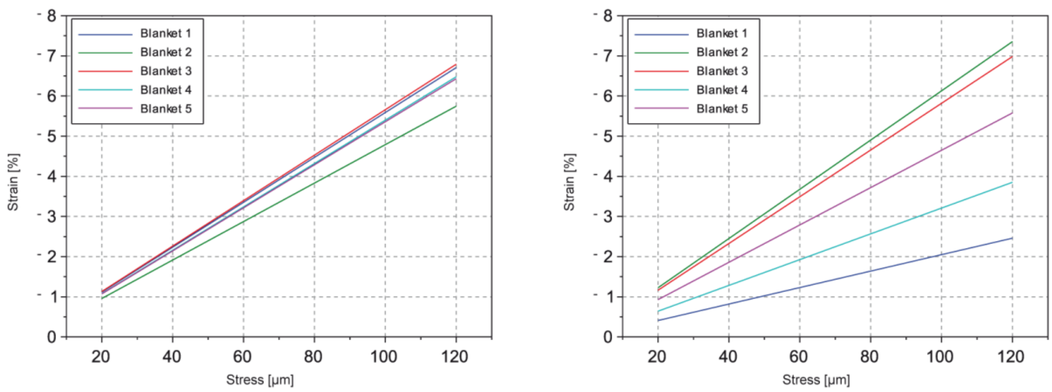


Figure 18: Calculated stress-strain curves a) other layers b) top rubber layers

In the area of deformation of interest, the top layer of the first blanket has the smallest slope of regression line, and the first layer of the second blanket, the largest one (Table 4). This indicates that the first layer of the first blanket gets less compressed and has larger elastic modulus than the rest of the blanket. On the other hand, at the second blanket, the difference between the modulus of the first layer and the rest of them is not as big as at the first blanket and the modulus of the first layer is smaller since it gets more deformed than of the rest layers of the blanket. The results show that the total deformation of different blankets is differently distributed in separate layers, depending on their elastic modulus. The largest strain difference was measured in top layers (Figure 18b) and the other layers have relatively similar strain response to applied stress (Figure 18a).

4. CONCLUSIONS

This study was performed by assumption that separate layers of printing blankets might be differently deformed due to the same indentation by the plate or the impression cylinder in the nip depending on their mechanical and viscoelastic characteristics. For this purpose, the special equipment was constructed and automated, that allows very precise indentation of specimens and microscopic image acquisition. Furthermore, the analysis technique for accurate measurement of micro displacements and calculation of resulting strain was developed. The research has shown that the micro displacements of under 0,5 µm could be searched contactless and successfully tracked in series of microscopic images acquired during increasing indentation. Unequal thickness and radial compression of layers could consequently cause different tangential displacements, especially of incompressible layers and could have a great importance on the print quality and feeding characteristics of the blanket. The calculated slopes of regression lines of calculated strains and the measured thicknesses of top rubber layers could be used by estimation of tangential displacement of this layer in and around the nip. In further work, the tangential displacements will be investigated and visually presented, especially of the top rubber.

5. ACKNOWLEDGMENTS

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TRANSFER-PRINT (SUBLIMATION) THE DETERMINATION OF THE CHROMATIC ABERRATION ON DIFFERENT FABRIC SURFACES

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Abstract: *With the rapid progress of the printing area in the digital age is such a rapid change. In particular, digital printing, technological development provides a lot of pressure to have a say in the field. One of these areas is the pressure exerted on the textile structure. Screen-printing on textile structures printing, gravure printing, flocking, printing is carried out in many different ways, such as digital printing. Transfer Printing (Sublimation) is, the technology is digital, color quality, tone transitions, easy to use, system setup costs and textiles in recent years because of their many advantages, such as product diversification printing techniques have become the preferred printing system terms. In this study; the same visual design is printed with different fabrics transfer printing technique using different transfer papers. At the end, it was observed variations between fabric structure with transfer papers.*
Key words: Sublimation, Transfer papers, Transfer-Print

1. INTRODUCTION

Textile and apparel products to create added value is critical in order to be ahead of international competition. Because the consumer demands of the rapidly changing collection of in today's world is renewed in a two-month period to be preferred for the textile and apparel products, different functionality, view features and/or environment-friendly production must come to the forefront of the process. In the development of the textile industry, by weaving, which costs less and also may be produced as an imitation of expensive fabrics, multi-color, eye-catching, the effect of printed fabric is very large. Starting from the 15th century, especially in this period until the industrial revolution, printed fabrics, has been an important commercial product. Especially fabric; fiber, weaving, knitting of the yarn, the fashion, the pressure, the batik is the main element of wooden block printing and other textile products. When creating the fabric fibers and yarns is woven or knitted surface using. This surface treatment is the next chapter print has been created. Shape, font, graphic, and the fact that most of the pictures closely, the process of transferring replicated on a surface and fast printing. Fabric and prints and designs of the visuals of self-improvement, with people constantly under pressure to develop new design acclaimed industry. The pressure applied to the fabric from the past to the present, fashion design effect, with the development of technologies in the field of pressure has increased.

Nowadays, fashion apparel textile printing with very expensive equipment, which produce for the domestic market related to the venue's arts and is a major industry and or the shape of the pattern. Textile printing technique that allows the transfer of the pattern onto the fabric and non-woven, silk screen called on the object (mesh) used in the molding tool, which stretched on a metal frame. Doctor blade called and the end of a large vehicle which rubber, paint hole by pushing back and forth according to the pattern set in the mold is transferred onto fabric. Clothing and other textile printing methods suitable plate the fabric used in the products and designs made export operations. Today, with the help of machines in series production printing is done faster (Ozkaya, 2008).

Textile substrates used in accordance with the structure; cylinder printing, screen printing, direct to garment (DTG - direct printing machine on the product - Custom), flat frame printing, rotation printing, transfer printing, spray printing, foam printing, digital printing, inkjet printing and xerography as many printing methods are used. Rapidly advancing technology are the point reached in digital technology. Advances in digital printing technology, which facilitates the work of institutions with printing needs, the price advantage and provide creative solutions for many applications, enabling brought along. If we examine the production time scale of a textile print from design conception to bulk print we can see the considerable advantages to be gained from design selection and sampling using ink jet print technology (Provost, 1994).

Providing more opportunities for experimental work, large and extremely detailed designs digital presses with the capacity to print at one time and enables the unlimited use of color. Ecologically, leaving behind paint waste, chemical industry, printing technology, this feature after having being able to process and hold the fabric has gained an important innovation (Colchester, 2007). They bring the heat transfer made of the evolving technology in the textile industry. With the help of heat and pressure can carry synthetic fabric pattern transfer printing as the pattern to the fabric wish to transfer. This technique allows to experimental research. Produced by hand using photographic or digital image allows complex pressures. It is a popular technique because it requires a template. Developed computer hardware and the imagination of the designer is to use the software to realize the wealth right. Original drawings, collages, photographs and even three-dimensional objects can be scanned, can be manipulated and can be prepared as repetitive patterns (Clarke, 2005). Film printing techniques used in textile printing business is a traditional technique in terms of production. Textile designers as contemporary textile artists in bringing together the textile art form hybrid technique. Some designers to produce batik as digital design, the work they have created with their sutures and painting process brings a unique style square. This process allows for extraordinary and original surface. There is another group of silk directly applies dyes and pigments (Yurt, 2013). One of the fastest developed in the fields of printing technology in the textile printing is sublimation printing.

1.1 Sublimation Printing

The heat is applied to the item dictionary meaning of sublimation time before proceeding to make gas from liquid into solid form. On paper can be printed with offset or digital printing. The pattern on paper, transfer printing presses with 190-210 degrees within the range of the press located on paper in sublimation dye spots are gas passes into. If fabric is 100 % polyester paint polyester fibers passing gas form.

Figure 1: Sublimation print samples

If it does not contain polyester fabric (cotton or viscose) 30 % of the paint or the gas phase 40 % portion of fabric paints but that are not permanent. The rest of the paint is released into the air in a gaseous state. Sublimation the dye does not remain on the surface of the polyester fabric into processes. This also brings its durability. Print a scratch-resistant and protects color vibrancy for a long time or wear off the predicament. Gives unlimited colors using CMYK color. This is the new printing method, used in printing fabric in roll or movie motifs known pieces of paper instead of the transfer is performed with the dyestuff on. With the help of this particular paper calender in the process (considering a large calendar such as iron) are treated under heat and pressure so that the paper and fabric occurs in the printing process. In this process the paper temporarily transferred to the motif permanently transferred or ironed the fabric is expressed. Here the surface of the carrier coating process of dyes on paper may be cited as the transition to dry textile materials. Parts of digital printing and transfer method and a feature-length is the method of printing on fabric. Unlimited color options and finely detailed photo-quality prints are obtained with this method and model. The most important feature of digital printing die – due to the absence of costs such as the cost of the movie suitable for the production of low quantities and units. The most important feature of digital printing provided by the manufacturer of production outside of the market with its own unique patterns is to provide the chance to do (Kumasbaski, 2016; Tyler, 2005).
Considering the richness of pattern and color, in recent years, technology has become a very artistic process. Transfer printing textile world to pass the 1950 quality in industrial applications with rapid progress

in technology in recent years, although the end of the year and the transfer speed printing applications increased at the same rate it has become common in the textile world. Evaporation and sublimation of disperse dyes by heat transfer printing process featuring a pattern or design is transferred to the paper using a first print. The dye which is printed on print paper, is transferred to the fabric by using heat and pressure. It saves time as compared with known age printing techniques provides a great advantage. Unlike the age of transfer printing also print, achieving the desired result, finishing etc is fully. As such, time-consuming processes. Because of this, production in half approve of his decision last time. The quality is high. Augments the appearance of a desired printed pattern in a very short time the fabric expands the range of use. Provides compatibility for fast fashion. Rapid change in fashion and new trends by reducing costs and risks in the pursuit of allows adaptation to the fast changes in the fashion world. The breadth of use provides: The technique which has been developed mainly for use in transfer printing polyester, but also mixtures of synthetic and natural fibers, such as fabrics can also be used with different content. Transfer printing also recently use a micro-fiber fabrics style name to be applied to the diversity of application areas increased with the ability. Failure to use water in the process, the lack of air pollution, thanks to features such as reducing waste and pollution, does not harm the environment and nature. All kinds of men's and women's clothing, available in numerous textile products to the underwear and beachwear. Transfer disperse dyes used in the printing of polyester, acetate, triacetate, acrylic, polyamide (nylon) can be colored fibers like. These fibers are suitable for polyester and polyester blends. Natural fiber, sublimation colouring showing the property does not matter. In terms of efficiency in transfer printing, polyester cotton blends, cotton rate of 30 % should be below (Tekstildershanesi, 2016).

1.2 Sublimation Printing Considerations

Sublimation printing images from the beginning of primarily providing color management in digital printing machinery for the formation and allowing you to correct the most accurate color prints with RIP - Color Management Program should be used. In addition to these; the process is fully finishing to the fabric (either wet or dry) must be made good. Good finishing is not made; causing shrinkage of the fabric. This causes shadow printing. During the application, the paper should be placed in such a way that on the printed side of the fabric and the fabric is made in the right direction should be sure to print. Sublimation printing for 100% polyester fabric should be printed on. Polyester cotton blend fabric for a good printing result in at least 70% polyester 30% cotton. Dye sublimation polyester fabric printing for dying fibers in dark colors will be invisible. Press must make sure that the correct temperature; Low temperatures will cause the sunken sublimation printing. High temperature will damage the structure of the fabric. The appropriate temperature range must be determined, the pressure should be adjusted so that errors in the surface of sublimation printing fabric spite of my behavior. Time should be set according to the vitality of both the fabric sublimation printing. Do not pull the fabric during sublimation printing applications, yellowing, color change, should be subject to follow the shade (Dijitalteknolojiler, 2016). The print quality of the products is transferred onto fabric products should be examined should be introduced later on. In Offset sublimation printing, press temperature, pressure, second, and 10% color differences due to paper production by 5% you're gonna be taken into consideration. Sublimation paper; should be stored at room temperature under 25 ^{0}C. Inventory definitely should not be made in a humid environment. Sunlight (UV rays) and should not be exposed to. In sublimation printing, shelf life and storage conditions are followed to the correct paper is unlimited. Sublimation printing in order to reduce to a minimum the problems arising should be considered in these circumstances. During the printing phase, printing paper and textile endless haircloth material suppresses a drum warmed up for approximately 20-30 seconds. Haircloth, the paint itself is protected by a paper strip against the pass. During the merger, dye carrier into the textile material passes from the paper. The temperature of the drum is between approximately 180-220 ^{O}C. Transfer printing, direct printing, washing is necessary because there recent, excipients, fibers have been transposed. Can buy only the dye were transferred to as fibers. This was implemented in only a single printing of synthetic fibers because it is capable of using a pressure type disperse dyes. However, today, cotton and polyester/cotton blends are applied. The yield obtained is low based on 100% polyester (Yegin, 2014).

2. METHODS

In this study; the same visual design is printed on three different fabrics using three different transfer paper. Our goal is different from the paper grammage of the fabric when you transfer on the surface to identify the parameters that affect the image quality. In the test printing, the image is transferred to transfer paper of the 60, 75, and 100 g/m2 Cham Paper - sublimation paper was used. Fabric materials: 100% polyester Chiffon, satin and Scuba fabric was used. (Table 1)

Table 1: Fabric Types

Fabric Type	Grammage (g/m2)	Content
Chiffon	68	%100 Polyester
Satin	80	%100 Polyester
Scuba Fabric	250	%100 Polyester

Transfer printing paper on the ground density values, dot gain measurement and CIE L*a*b* values are measured by TECHKON Spectro Densitometer. The fabric on the ground of the site and CIE L*a*b* values were measured with Datacolor SF600 PLUS Spectrophotometers. 6.6 mm USAV on the measuring apparatus was used. 10 points for measuring from each color through the fabric. The measurement was made using a D65 light source with shooting 10-degree angle. The scale used in the test printing, consisting of a total of 1504 EC 2002 CMYKI1_IO_1PPM5.0.5 color box. Color scale, three ISO 300 standard photography, images quality control used by one CMYK Fuji photo, the hairline until (0.25pt) starting lines of varying thickness up to 8 pt were used. In addition, the scale is written as 12 pt starting from 2 pt, points up to 100% from 1% to CMYK, trapping measurement areas have been created to control the color balance in printing gray balance scale and UGRA / FOGRA PostScript control strip scale, They are also available. In the test scale from 1% up to 100% of the halftone was used to measure the dot gain values. *(*Figure 2)

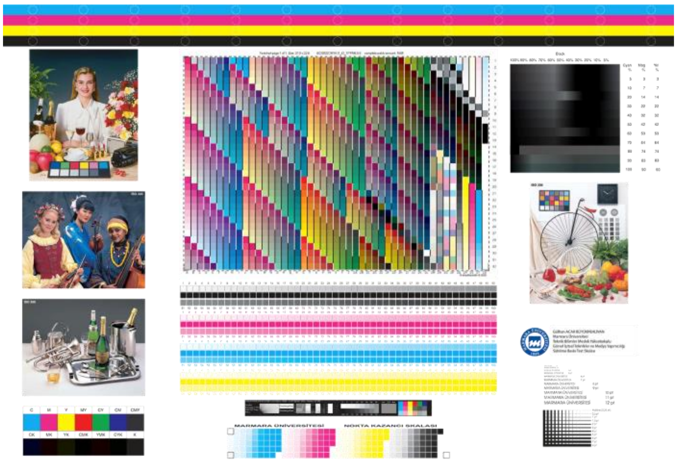

Figure 2: Sublime Text Printing Scale

On paper it was printed with Roland SOLJET PRO4 XF-640 digital machine. (Tablo 2) When creating print image, superior image quality and eco-solvent ink / solvent ink does not contain nickel component and feature has to be out long-term and relatively odorless, environmentally friendly property with ECO-SOL MAX2 was used to.

Table 2: Digital Printing Machine

Machine Model	ROLAND XF 640
Printing Area	162 cm
Number of Colors	4 color
The Main Colors Used in Printing	CMYK
The Principle of Printing Machines	PİEZO Technology
Print Width	1615 mm max.
Dye Cartridges	ECO-SOL MAX2 Cartridge 440 cc
Color	Cyan, Magenta, Yellow ve Black

Monti Antonio - Calander Press machine, was used to transfer the image to the surface of the fabric.
Table 3: Transfer Printing Machine

Machine Model	Monti Antonio - Calander PRESS
Printing Area	180 CM
Print Temperature	Cº 190º - 210º
Pressure	ATÜ 4-6 Bar
Transition Time	20-30 snS

3. RESULTS

There was no difference in terms of grammage too much L*a*b* values on the transfer printing papers in digital printing're different. (Table 3)

*Table 3: L*a*b* Value On Transfer Papers (100,75,60 g/m2)*

	100 g/m2 Paper			75 g/m2 Paper			60 g/m2 Kağıt		
	L	a	b	L	a	b	L	a	b
C	70,64	-3,23	-25,32	69,82	-3,22	-26,18	68,54	-3,36	-28,35
M	54,29	47,66	0,24	55,35	45,68	-0,15	55,48	44,62	-1,63
Y	93,81	-3,81	63,26	93,48	-3,86	61,69	95,35	-4,77	59,74
K	34,76	3,33	-0,14	39,66	2,37	-0,72	38,11	2,97	-0,83

Paint color to the fabric paper and the transfer paper in the transfer of quality standards to comply with there has been a loss of tons.

*Table 4: 75 g/m^2 paper and transfer the weight of the Magenta color in printed fabrics and ΔE and L*a*b* Values*

Fabric Type	DE*	DL*	Da*	Db*	Batch is
Ciffon	0,495	-0,176	-0,23	0,401	darker less red less blue
Scuba Fabric	0,799	0,427	-0,654	0,166	lighter less red less blue
Satin	1,435	-1,200	0,720	0,318	darker redder less blue

*Table 5: 100 g/m2 paper and transfer the weight of the Yellow color in printed fabrics and ΔE and L*a*b* Values*

Fabric Type	DE*	DL*	Da*	Db*	Batch is
Ciffon	0,289	-0,096	-0,262	-0,073	greener
Scuba Fabric	2,199	-0,169	-1,017	-1,942	darker greener less yellow
Satin	2,652	-0,847	-0,735	-2,404	darker greener less yellow

*Table 6: 75 g/m2 paper and transfer the weight of the Yellow color in printed fabrics and ΔE and L*a*b* Values*

Fabric Type	DE*	DL*	Da*	Db*	Batch is
Ciffon	3,422	0,189	0,496	3,381	lighter less green yellow
Scuba Fabric	0,903	-0,163	0,474	0,751	darker less green yellow
Satin	0,747	-0,721	0,173	-0,089	darker less green

4. CONCLUSIONS

As a result; Chiffon and satin acceptable limit *ΔE* values was observed to be much closer. Color reflections to that structure as satin shiny fabric makes it more effective and more visible. Scuba fabric was found to be a decrease in color strength than the other two fabrics in the color measurement since it is less heavy than other fabrics. Weight of lower paper (75 g/m^2) has experienced losses compared to other fabrics in chiffon with a fine transfer color onto the surface. ΔE is acceptable to have increased over the limit.
Fabric thickness is decreased with increasing color intensity, it was found to increase the color intensity thinner. Consequently customer pressure in a dense color intensity is recommended to select a thinner

fabric type. This is done in groups of different fibers study is recommended. As a result, the manufacturer will produce new products through digital printing, manufacturers will increase the variety of products they offer to consumers. Under pressure of natural fiber materials for groups of R & D work recommended to be done.

5. ACKNOWLEDGMENTS

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THE SYSTEM FOR PROCESSING PARAMETER IDENTIFICATION IN PRINTING BASED ON PRINCIPLES OF CONSTRUCTION OF EXPERT SYSTEMS

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Abstract: *This paper presents a model of the system for identification of printing process parameters on the basis of modern software systems and tools which enable a significant increase in speed of the process of getting to a solution for improvement graphic production processes as well as the process of acquiring and expanding knowledge. The model is based on the integrative modules which consist of, system for identification of printing process parameters based on algorithmic program structure, system for identification of printing process parameters based on principles of construction of expert systems as well as system for identification of printing process parameters based on distance learning. The paper gives a detailed view of the module based on the principles of construction of expert systems.*

Key words: process parameters, printing, software systems, expert systems

1. INTRODUCTION

Graphic production processes are very demanding because of the volume of the printing runs and time required for the realization of printing as a stage upon which the final processing depends on. Because of that, performers of the process must act quickly to every production problem, and find the right solution in the shortest time span. For demands like those modern computer and software systems provide special benefits.
Process parameters of the printing techniques represent a very wide set of parameters which can be used to identify the process of a specific printing technique. There are numerous printing techniques categorizations which are most commonly tightly connected to specific process parameters. One of the wider categorizations is on:

- conventional printing techniques
- digital printing techniques.

Essentially all of the conventional printing techniques can be distinguished based upon four groups of the most important process parameters:

- printing substrate
- printing plate
- printing ink
- printing press.

There is a variety of **printing substrates** and each of them has certain characteristics which are related to printing process parameters. From the printing properties of the substrate following ones stand out as the most important:

- Physical properties (thickness, paper weight, fiber direction etc.),
- Surface and insulating properties (smoothness, dimensional stability, permeability, resistance to pulling and dusting),
- Mechanical properties (resistance to breaking apart, tearing, folding, snapping, softness and compressibility),
- Optical properties (glow, whiteness, transparency and opacity)

Printing plates have an important array of parameters which have an effect on the printing process. If the fact that they are made from a large number of different materials is taken into consideration, there is a conclusion that these materials provide specific parameters relevant to the process of printing. The materials from which the printing plates can be made are: various metals, photopolymer, rubber and some other materials.

Printing inks differ in their physical and chemical properties based on the printing technique and substrate onto which they are transferred. The purpose of ink is to transfer image and text from the printing plate onto the printing substrate. Basic and the most important parameters for printing inks include consistency, surface tension,viscosity, adhesion, cohesion, tackiness, fluidity etc.

The printing press provides an important array of printing process parameters. In the offset printing technique, those parameters are also in relation to the ink transfer trajectory from the ink chamber to the printing substrate, through the indirect process of printing technique. The printing ink from the printing plate is firstly transferred onto the elastic blanket, offset rubber, from which it is later transferred onto the substrate.

In different literary sources, there are given various approaches for differentiating and grouping the printing techniques, including printing presses with their specific printing parameters [1].

The most commonly and widely used printing technique is offset printing holding more than 80% of the market share. Because of that, it is considered to be the most important printing technique. From the aspect of printing process parameters, it is the most complex technique with a large variety of parameters which are of importance to assure good quality of the impression. Usually, there are four groups of the most important parameters which are related to:

- printing substrate,
- printing plate,
- printing ink and
- printing press.

2. APPLIED DEVELOPMENT AREAS OF THE PRINTING PROCESS PARAMETERS

In the interpretation of identification of processing parameters various software's can be used to identify parameters, or interpret problems. The convenience of such interpretation belongs to, Artificial Intelligence, expert systems, neural networks, fuzzy logic, genetic algorithms, hybrid systems, distance learning, multimedia, software systems for general purpose and other applicative systems. Each of these approaches has its own logic of development with the possibility of linking the knowledge base in one general applicative model.

Methodologies for problem-solving on the basis of artificial intelligence are especially popular in scientific research as a way of reaching decisions by the logic of thinking experts in a particular field. Methodological analysis showed that there is not a large number of developed systems for graphics processes in the world and in our area they are almost non-existent. For this reason, systems applied in different processes were analyzed in order to meet the logic of solving.

There are no expert systems in graphic processes in our region. Because of this, experiences in the development of expert systems in other areas and the experience of the author [2] were analyzed in order to extract the parameters in graphic-systems which could be considered based upon approach and existing experiences in the development of expert systems.

The graphical systems from the same class have different setting parameters, meaning that every machine reacts differently to adjustments during the course of printing so that it is needed to quickly input appropriate control actions to maintain the stability of the process and print quality. Process variations occur as a result of various external influential parameters such as temperature, humidity, vibration etc. In addition, perturbation factors that the constructor of the machine did not foresee and also the impacts that come from the environment, such as. transport routes, construction that produce vibrations that can largely negatively affect the operation of printing machines and the quality of reproduction can be isolated.

All this points to the need of solving problems that occur in the printing process. Solving the above-mentioned problems by fulfilling the set goal for the setting and development of a system for the identification of the printing process parameters based on modern computing and software systems that are based on algorithmic principles, principles of construction of expert systems and distance learning should lead to a satisfactory solution.

Usually found in the analyzed literature are the systems for print control based on stochastic models which take a small number of parameters in decision making, which initiated the idea of setting up a broader concept system that would take into account the knowledge base that would include a bigger number of parameters.

3. MODEL OF SYSTEM

For the development of application programs, methodological approach of investigation is needed to establish which grounds are the best for development, and the most important place there is given to artificial intelligence through analysis of methods which gave solutions in certain areas.
Through methodological settings the conclusion was made that the developed applications can be connected so that a more complex system with significant capabilities can be made.
Methodologically it was first of all necessary to characterize the process parameters of various printing techniques on the basis of which the separation of the most widespread printing technique, offset technique could be made. Within it, there are two techniques to be considered: the so-called conventional offset (with wetting) and dry offset (without wetting). Within these offset techniques, more significant place belongs to the offset printing technique with wetting so that it is structured in more detail with the basic settings for the concretization of models.
Through development methodology, knowledge base concepts of the development of the wider area of the graphic processes are set. For modern presentation, it is especially important to develop the realistic visual representations of the process through the functional view of the process which is especially important for learning about the processes and the identification through the available knowledge.
For the development of application programs, methodological approach of investigation is needed to establish which grounds are the best for development, and the most important place there is given to artificial intelligence through analysis of methods which gave solutions in certain areas.
For the purpose of creating a software model that would further develop, the analysis was made of applicative areas for the development of identification of printing process parameters with representation concepts, descriptions of illustration and options which are available to users, performers and process operators. Through analysis, the conclusion was made that a special significance in the field of graphic processes should be given to methodological approaches through development of application based upon:

- expert approaches
- programmatic approaches on algorithmic structure and
- distance learning approaches.

Through methodological settings the conclusion was made that the applications can be connected so that a more complex system with significant capabilities can be made.
All of the development segments are set in a complex way as the fundament of a creative model based on the principle of interactive work where a wide set of capabilities for constant updating of knowledge bases is opened, especially for the process parameters which can give certain solutions which satisfy the required answers. The concept was developed on creative knowledge bases.
Based upon the previously defined basis, the model of GRID SIPPS system with special reference to offset printing was set, based on which a modern software system for the identification of process parameters of printing was made with the aim to improve the process of printing process parameters identification. This ensures maintaining of the quality of printing and quality of the knowledge bases within the system for distance learning.
Model of SIPPS GRID system (Figure 1) consists of three parts which represent conceptual approaches to printing process parameters both individually and as an integrated whole, and they are:

- Module GRID SIPPS ALG,
- Module GRID E-learning
- Module GRID ES.

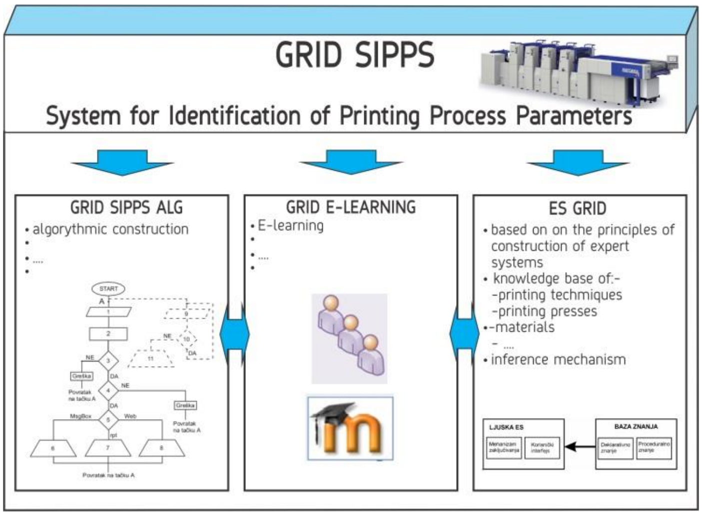

Figure 1: Model GRID SIPPS system

Module GRID SIPPS ALG

Module GRID SIPPS ALG is algorithmically based with the aim to enable the entry of data on:

- printing techniques,
- printing presses,
- printing substrates,
- graphic products,
- diagnostics,
- maintenance,
- link to the learning module,
- process parameters and
- operative system components of operating

Module GRID E-learning

Module GRID E - distance learning is based on Web-based systems and it includes the processes of information gathering, researching, creating a knowledge base with the structuring of knowledge and interacting with users. The system of education is user-oriented, where the knowledge bases are formed in relation to separate areas of interest for graphic production, such as those which include graphic processes, printing techniques, printing plates, packaging, printing materials, printing systems, color management in the reproduction process, production phases workflow automation etc.

GRID ES module

GRID ES module was developed on the principles of construction of expert systems and is based on a unique shell of an expert system that can even be applied to solve other similar tasks. It consists of a shell of expert system and knowledge base of the expert system.

4. GRID ES system

In order to develop modules of GRID ES system the aspiration was turned to its universality in order to:

- develop universal concepts applicable to other modules of the GRID system
- form a shared knowledge base,
- implement developed solution in solving of similar tasks
- enable development and maintenance of a knowledge base

Module of GRID ES system pursued:

- development of universal shell of an expert system with universal procedures, rules, knowledge representations, evaluations, display of output for loading and crosscheck of input data from other GRID system modules
- Development of a hierarchical knowledge base with structured data, declarative knowledge in the form of the facts and procedural - IF THEN rules, evaluations, input and output data, memory data and their ways of the inscription.

In creating of the GRID ES modules concept following requirements were set:

- placing of universal concept that would be applicable for similar GRID system modules
- clearly allocating shared knowledge base
- applicability of proposed solution for solving similar tasks with minimal changes in the shell, and
- dedicating special attention to further development and maintenance of knowledge base.

From this, the main tasks for development of GRID ES system can be extracted:

- development of universal ES shell
- development of knowledge base

In addition, in the case that there is no solution in the existing database it is needed to:

- Provide a list of possible solutions at this level of problem solving,
- allow some of these solutions to be modified by the user,
- check that this solution is not already in the knowledge base, and if it is not, save it as new knowledge and
- knowledge engineer can permanently store new knowledge such as those in the knowledge base and in that case check the requirements for decision-making on the choice of knowledge or erase them from the knowledge base

GRID ES shell

From this, the main tasks for development of GRID ES system can be extracted:

- the development of universal ES shell
  - the universal procedure for loading and checking of input data from other GRID system modules
  - the universal procedure for working with rules (mechanism of inference),
  - the universal methodology of new knowledge representation in form of facts and rules
  - the universal methodology of evaluation of individual solutions based on expert judgment,
  - the universal methodology for displaying of output results.

- development of knowledge base
  - the organization of knowledge base is hierarchical,
  - the structure of data that make up the knowledge base: declarative knowledge in the form of facts and procedural - IF THEN rules,
  - the possibility of solutions evaluation,
  - the structure of input data
  - the structure of output data - solutions,
  - the subscores - format, and whether to record them.

The universal shell represents the fundament of GRID ES system, with whose launching meta-knowledge will be loaded (file META.KSL), through which the tasks that the shell should solve are described, as well as procedures which are called upon depending on the chosen task. After running the shell, the tasks which are recorded in the knowledge base and which the shell can solve are displayed on the main menu. In the knowledge base "zadatak i", the procedural knowledge that defines the way of solving particular task is stored. With the selection of one of listed task the procedure "radi zadatak i" is run. After the completion

of the chosen task, the main menu is offered again to the user so that he could call upon any another task, it could be the next task or the one that has already been executed earlier.
Schematic representation of the operation of EC shell is shown in Figure 2, where the most detailed presentation of procedure "radi zadatak i" is given. After running the shell the next sequence of task is given as options:

- knowledge base
- influential parameters
- diagnostics

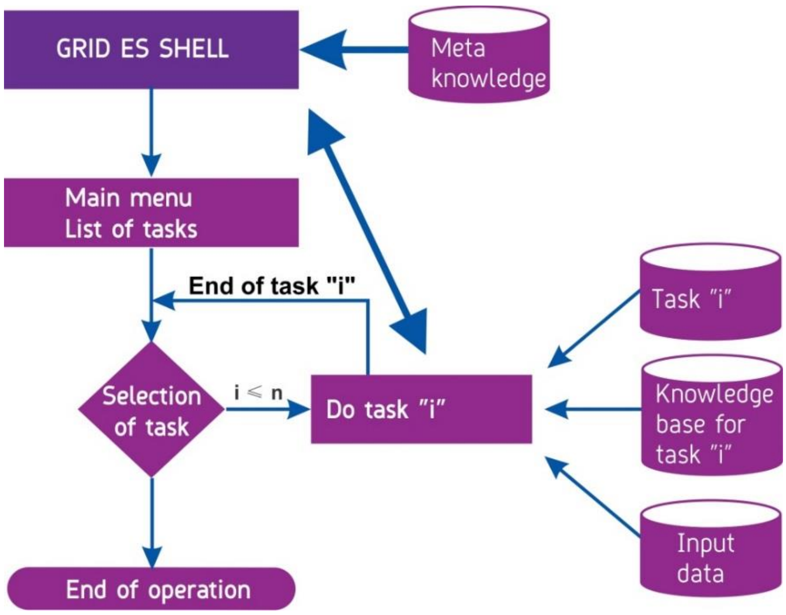

Figure 2: Schematic representation of GRID ES system shell operation

By calling one of the tasks, the first to load is the needed knowledge base for the chosen task and necessary input data - output (results) from previous modules.
The shell of GRID ES system is designed as universal and in this sense, it is needed to develop key shell procedures that will be used in all modules.
Key procedures can be divided into several groups, Figure 3:

- procedures for the selection of the order, actualization, evaluation, etc.
- procedure for input data loading,
- procedures for working with the knowledge base,
- procedures for communication, dialogues, menus, and other common procedures.

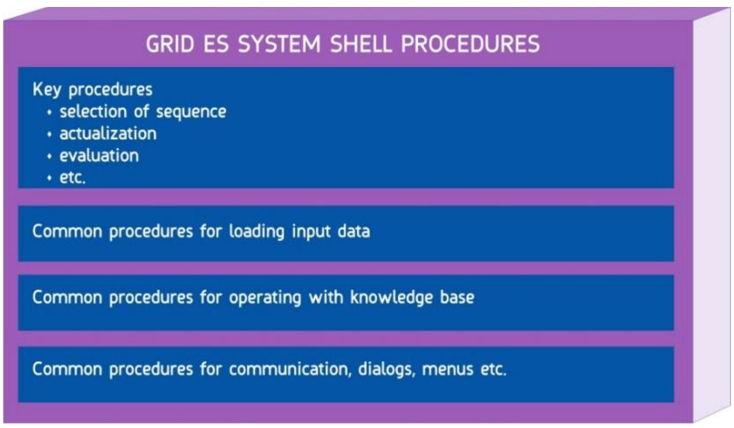

Figure 3: Structure of GRID ES system shell

Figure 4 provides an overview of the key procedures used for choosing of the sequence of graphic operations within the GRID ES system shell.

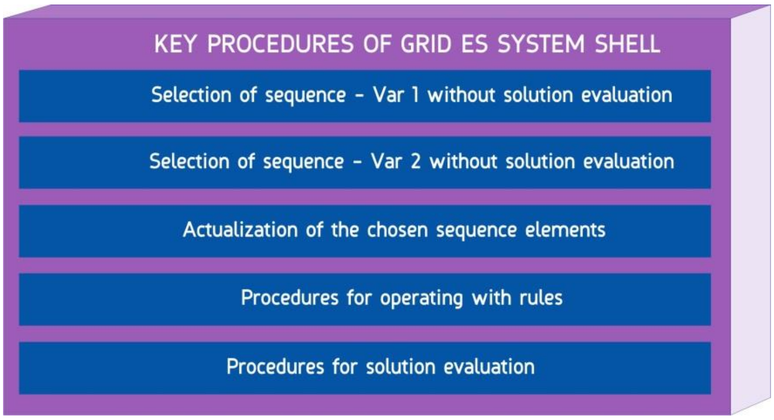

Figure 4: Key procedures of GRID ES system shell

Figure 5 represents the view of common procedures for loading and checking of input data, loading the knowledge base of GRID ES system shell.

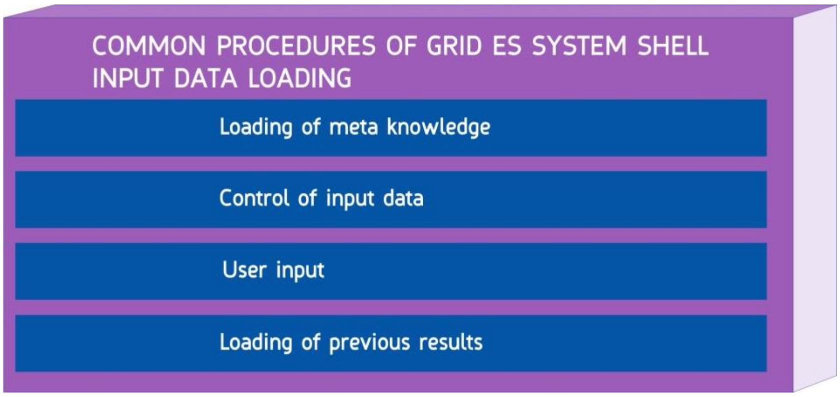

Figure 5: The common procedures for loading the input data

Figure 6 presents the overview of procedures for working with the knowledge base.

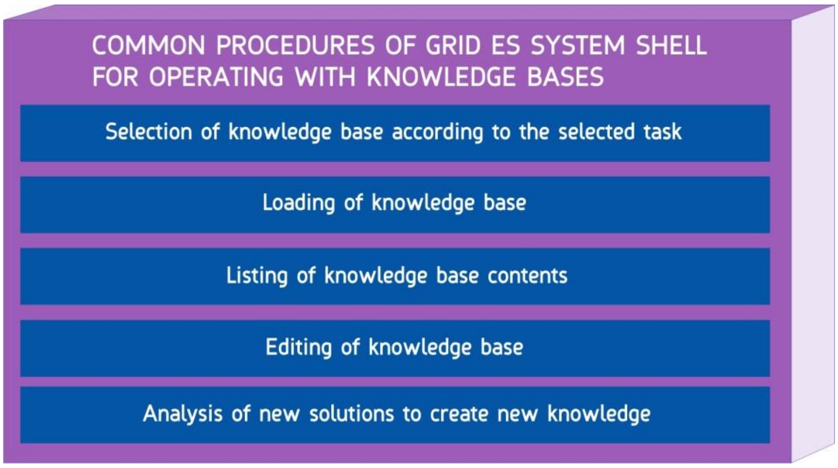

Figure 6: The common procedures for working with the knowledge base

The GRID ES system shell is built modularly. Each of the modules is stored in a separate file with the KSL - Knowledge Specification Language extension. It consists of the following modules:

- basic shell procedures for running the GRID ES system - GRID-ES.KSL
- common procedures (operations with windows, the interpretation of user input, working mode selection, ...) - ZAJEDN.KSL
- Common procedures for dealing with the rules (the formation of the list of rules for the current assignment, print the rules, check the rules, print messages on the fulfillment or non-fulfillment of conditions, and therefore the rules, ...) .- AKTUL.KSL
- common procedures to display and record output - IZLAZ.KSL

Knowledge base of GRID ES system

The fundament of the new solution is a knowledge base that contains hierarchically organized knowledge, presented in the form of IF-THEN rules and facts. At the highest level is so called meta-knowledge which is used to manage the operation of GRID ES system in terms of choice of modules which are to operate. After the selection of module to be executed, necessary knowledge bases, containing both declarative knowledge (facts and rules) and procedural knowledge needed to solve a specific task are loaded. Knowledge base, as shown in figure 7, is made of:

- meta knowledge (file META.KSL), which describes the tasks that the shell should be solving as well as procedures that are called upon depending on the selected task
- declarative knowledge - facts,
- procedural knowledge - rules.

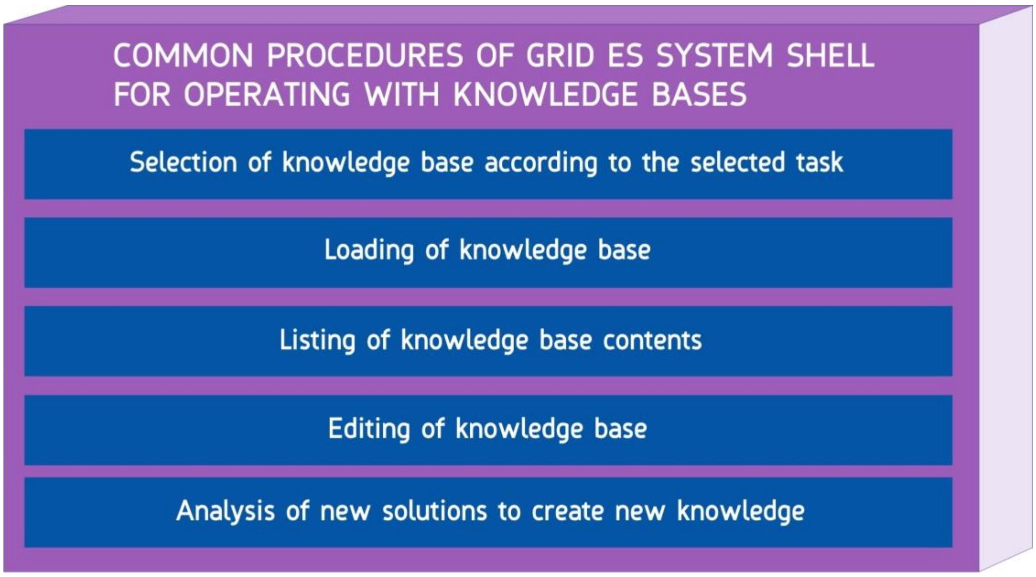

Figure 7: Knowledge base structure meta knowledge

Meta knowledge

The fundament of the new solution is a knowledge base that contains hierarchically organized knowledge, presented in the form of IF-THEN rules and facts. At the highest level is so called meta knowledge which is used to manage the operation of GRID ES system in terms of choice of modules which are to operate. Figure 8 shows the procedures that represent meta knowledge.

Name	Opis
action koji_zadatak;	Procedure for selection of task to be executed
relation radi_zadatak(baza_znanja)	Procedure for running module for operation with knowledge base – BAZA
relation radi_zadatak(proc_param)	Procedure for running module for process parameters PR_PAR
relation radi_zadatak(dijagnostika)	Procedure for running module for diagnostic of problem in printing press operation DIJAGN

Figure 8: Procedure that represent meta knowledge

Display of the GRID ES system operation

Below is an overview segment of GRID ES system operation through the display of several characteristic views that occur during the operation of the system.
Basic options - modules are:

- Knowledge Base GRID ES - enables the display of the contents of the knowledge base in the form of facts and rules
- Process parameters - enables the correction of values of influential printing parameters on the basis of established rules on the values that the individual printing parameters should have
- Diagnostic of printing presses - enables the creation of a diagnostic procedure for identifying and solving problems in printing press operation.

Knowledge base options

Given the fact that the knowledge base is the key component in working of a system, GRID ES Knowledge base option allows display of knowledge base contents through users choice of the desired content to be shown.
Figure 9 gives an overview of the segment of knowledge base content of substrate materials to be printed on, given in the form of facts.

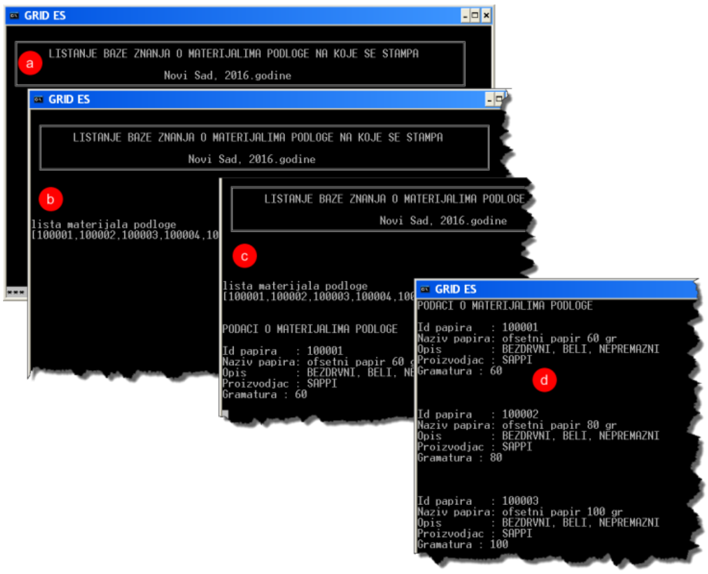

Figure 9: Display of the contents of the knowledge base of substrate materials for printing

Diagnostic and process parameters

The significant increase in capabilities of the system is the introduction of a list of rules that apply to the actualization of each diagnostic activities from the diagnostic procedure that is chosen as the best for solving a particular problem. The advantage of this concept is that for the actualization of some diagnostic a set of rules is provided in which it is possible to provide different conditions in a simple form under which an activity should be chosen.

The first step is the choice of the best diagnostic procedure that contains a list of specific diagnostic activities to be conducted in solving a particular problem. In this step, firstly all of the diagnostic procedures have to be chosen in the form of facts dijagnosticki_postupak. After that, based on the evaluation of experts for selected diagnostic procedures that are given as facts ocena_eksperata and weight coefficients of influence of each parameter on the overall summary assessment of the diagnostic process in form of the fact tezinski_koef, estimates for each of the selected diagnostic procedures are determined in order to get the best possible diagnostic procedure as a result, as shown in Figure 10.

Figure 10: Display of selection of diagnostic procedures

5. CONCLUSIONS

For the purposes of system development, the systematization was made for the most important process parameters of printing techniques which represent an extremely wide range of parameters through which the process of certain printing technique can be identified. Approaches to the development, application tools and features of existing solutions were discussed. Most of the analyzed systems are based on artificial intelligence techniques, expert systems, neural networks and fuzzy logic. From the analysis, certain typical approaches can be extracted.

GRID ES module was developed on the principles of construction of expert systems and is based on a unique expert system shell, which can be even be applied to solve other similar tasks. In the development of GRID ES system module aspiration was turned to its universality. In order to develop a universal concept that is applicable to other modules of the system, a common knowledge base was formed. Developed solution could be applied to solving similar tasks, and that would allow the development and maintenance of a knowledge base. Module GRID ES system is designed to identify the most influential process parameters of sheet-fed offset printing, creating of offset printing process models through modeling of the most influential parameters.

6. ACKNOWLEDGMENTS

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Original scientific paper

INFLUENCE OF SHORTWAVE RADIATION ON INK-JET COLOUR PRINTS

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Abstract: *The aim of our study was to determine to what extent the spectral composition of light influences the lightfastness of colour prints. Samples of cyan, magenta, yellow and black ink were printed on permanent paper using an ink-jet printer. Print and paper samples were exposed to the xenon light. The exposure to light was conducted under well-controlled conditions of temperature and humidity. Using two different filter systems, the spectral composition of light as daylight in open space and light behind the window glass was simulated. Exactly defined time of exposure enabled the study of the fading dynamics as well as to examine the influence of different spectral composition of light on paper samples and prints. Based on the spectrophotometric measurements, the colour changes on papers and prints were evaluated using the CIEDE2000 equation. The research showed that light which included radiation with shorter wavelength proved to be more destructive, in particular for the cyan and magenta prints. With the time of illumination, the values of the colour differences on magenta prints increased exponentially. Colour differences on other printed samples were increasing linearly with the time. According to the results, dye-based coloured inks are not suitable for sustainable documents. Black inks, however, can provide long lasting documents.*

Key words: spectral composition of light, colour differences, ink-jet print, permanent paper, dye-based inks

1. INTRODUCTION

Along with computers, almost hand in hand the digital printing technology was developed. Due to its affordability the most prevalent among digital printing technologies is ink-jet technology (Yung, 2003; Hudd, 2010). Ink-jet is one of the non-contact printing technologies (Yung, 2003), where the image is formed by spraying ink from a small nozzle on the substrate. Drying is mainly effected with the absorption of ink into material and not by heat, which can further affect the characteristics of the printing substrate and the appearance of the colour (Hudd, 2010). For ink-jet as well as for electrographic printing technology it has been found that the best durability of prints is achieved with black ink on permanent paper (Černič, 2008). According to several studies, the colour prints persist less than ten years of age. To improve the durability of ink-jet prints manufacturers are constantly improving the composition of inks. The development in the field of ink-jet technology and the use of pigment-based rather than dye-based inks leads to better stability of prints (Černič, 2008; Rasmusson et al, 2005; Norberg et al, 2002; Wu et al, 2007; Pugh et al, 2002; Medley, 2003). With the use of dyes as colorants, more saturated colours and low light scattering can be achieved. However, dyes do not have good fastness to humidity and light. (Svanholm, 2007, Bamfield, 2001).

Physical and chemical factors, e.g. light, temperature and humidity influence the stability of the colour prints. The sensitivity of material to physical and chemical factors depends on the chemical properties of the material used (Černič, 2008; Blaznik et al, 2013). It has been proven that stability of prints is not simply determined only by using dye-based or pigment-based inks. Colour fastness of ink-jet prints is also influenced by other factors, such as treatment time, temperature, humidity during exposure to light as well as intensity of light (Možina et al, 2008; Rasmusson et al. 2005).

Along with the printing technology also the manufacture of paper is developing. Therefore, the quality of the print is not only influenced by the characteristics of the ink droplets, which are controlled by surface tension and viscosity of the ink, the print quality also depends on surface tension, porosity and surface roughness of the paper (Svanholm, 2007). From the perspective of sensitivity to light, cellulose is a pure polymeric substance, which is relatively well light resistant. Less light resistant papers sometimes include artificially produced additives to change certain paper properties. However, under the influence of light, the additives react in a different way that causes the change in chemical composition of material which consequently impacts the color of the substrate and print (Černič, 2008; Feller, 1994; Vikman, 2003; Norberg et al, 2002).

Changes that occur due to external factors can be estimated through various measurements. Colorimetric measurements represent a non-destructive way to determine the changes of optical properties (Feller,

1994; Zwitter, 2006). Such methods allow monitoring the process in dependence on various factors. For the evaluation of perceived differences, the equations for the quantitative numerical evaluation are used (Kuheni, 2008).
Therefore, the aim of our study was to minimize the influence of paper on print resistance and to determine to what extent different spectral composition of light influences the lightfastness of colour prints.

2. METHODS

2.1 Paper

The Pulp and Paper Institute from Ljubljana, Slovenia manufactured permanent paper (PP) with grammage of 80 g/m^2. The paper was made in accordance with the permanence and durability requirements from the standards EN ISO 9706 and ISO 11108.

2.2 Preparation of prints

Four colour (cyan, magenta, yellow and black) fields of 100% intensity were printed. All prints were printed on the top side (A) of permanent paper. Officejet 6000 by Hewlett Packard was chosen for printing. The printer technology is based on the thermal ink-jet technology, with the maximum print resolution 4800 × 1200 dpi, with the minimum droplet size 1.3 pl and with dye-based ink for cyan, magenta, yellow and a pigment-based ink for black prints.

2.3 Light fastness of colour prints and paper

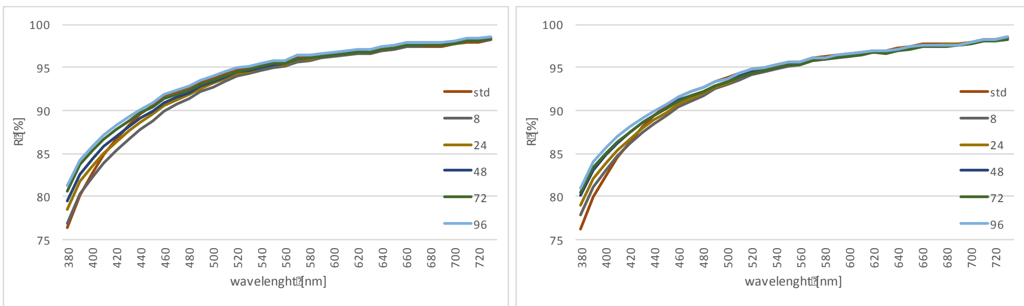
To determine light fastness of colour prints and paper, Xenotest Alpha (Atlas, USA) was used, with a xenon arc lamp which simulates intensive daylight at the constant temperature 35°C and relative humidity 35%. With the first filter, Xenochrome 300, radiation of shorter wavelengths was included (λ>300 nm) and the spectrum simulated daylight at open space. With the second filter, Xenochrome 320, light behind the window glass was simulated (λ>320 nm). The samples of colour prints and paper were exposed to xenon light for 8, 24, 48, 72 and 96 hours.

2.4 Spectrophotometric measurements in VIS spectral range and numerical evaluation of colour differences

The influence of light on the fastness of colour prints on permanent paper was evaluated. The measurements were performed with a spectrophotometer iOne (X-Rite, USA) according to the ISO 13655 standard, with (45°a:0°) measurement geometry and white backing, using D65 illuminant and 2° standard observer for the computation of the colorimetric values from the spectral reflectance measurements. The colour differences (ΔE) between the exposed and non-exposed samples were calculated according to the CIEDE2000 equation for colour differences (Kuehni, 2008).

3. RESULTS

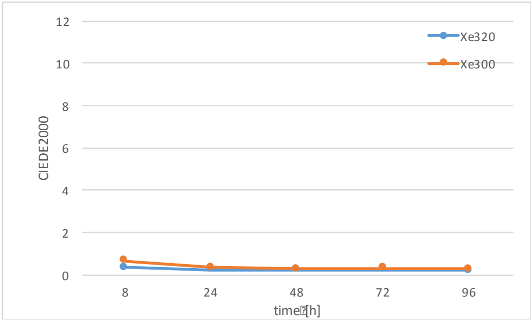
Figure 1 shows the reflectance curves in VIS spectral range for permanent paper after certain time of illumination, i.e. exposure to light with different spectral composition.



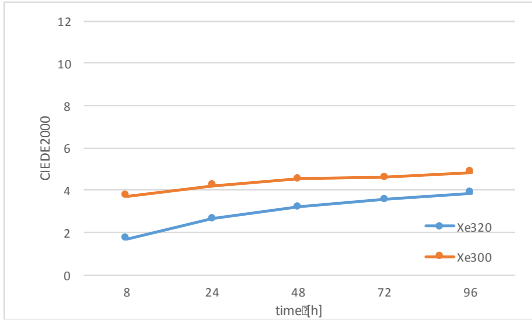
a) *b)*

Figure 1: Reflectance (R) of permanent paper before (std) and after 8, 24, 48, 72, 96 hours of exposure to light: a) λ>300 nm, b) λ>320 nm

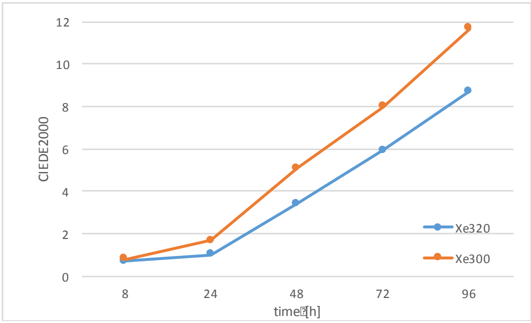
Figure 2 shows the influence of spectral composition of light on change in colour of paper, as well as on cyan, magenta, yellow and black prints after certain time of illumination.



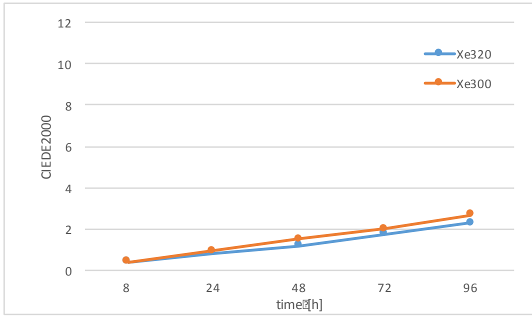
a)



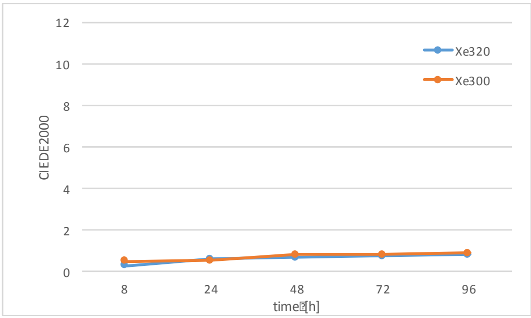
b)



c)



d)



e)

Figure 2: Colour difference (CIEDE2000) after exposure to light, λ>300 nm (Xe300) or λ>320 nm (Xe320) for (a) paper and (b) cyan, (c) magenta, (d) yellow, (e) black prints

4. DISCUSSION

4.1 Light fastness of paper

Paper remains an important carrier of printed information and it can influence the stability of prints (Blaznik et al, 2013; Černič et al, 2000; Feller, 1994; Vikman, 2003). However, since the purpose of the present research was to study the stability of colour prints, a permanent paper was selected as a substrate. Based on the preliminary research, we assumed that permanent paper exhibits excellent lightfastness properties. As shown in Figure 1 very small differences in the reflectance curves were observed before and after the illumination. Also, different range of UV radiation had no significant influence on reflectance of permanent paper.

Figure 2a clearly shows that the spectral composition of light had barely some influence on the colour change of permanent paper. With increasing time of illumination colour differences became even lower in comparison to the values established after eight hours of exposure. Therefore, it can be concluded, that permanent paper has very good lightfastness and that changes which occurred during illumination were not visible.

4.2 Light fastness of prints

Figures 2b, d, e show that colour changes on cyan, yellow and black prints were almost linearly increasing with time during the exposure to light.
Due to the fact that after eight hours of illumination colour difference on cyan prints (Figure 2b) represented more than 70% of the final value, i.e. after 96 hours, it can be concluded that during the initial period cyan prints rapidly responded to the influence of light. After eight hours of illumination with light which included radiation above 320 nm the value of colour difference for cyan print was more than 1. However, the influence of radiation which included shorter wavelengths (λ>300) was even more evident and the colour difference reached almost four units, the value which represents approximately 220% of the difference which appeared under the influence of radiation with smaller amount of UV radiation (λ>320) at the same time. Nevertheless, no sharp swings were observed on the cyan prints as the changes occurred gradually with time. After 96 hours of exposure including radiation above 300 nm, colour difference reached 4.83 units and this represented approximately 130 % of the change observed under the influence of radiation containing only wavelengths above 320 nm.
Yellow prints (Figure 2d) showed more gradual response to light. The colour differences were lower at the beginning but they continued to increase with time. The spectral composition of light had only minor effect on the changes which appeared on yellow prints, but colour differences after 96 hours were slightly higher after exposure to light which included radiation above 300 nm.
According to the manufacturer, black ink consisted of pigments. Therefore, comparing to the chromatic prints, better stability of black prints was anticipated as pigment-based inks are usually more persistent (Svanholm, 2007; Zollinger, 2003). As expected, black prints were more resistant to the influence of light in comparison to the colour prints. After 96 hours of illumination, colour difference was not higher than 1 (Figure 2e), indicating that changes were not noticeable. The spectral composition of light had practically no influence on the results (Figure 2e).
Magenta prints (Figure 2c) exhibited an exponential increase of colour differences, therefore significant changes occurred in a very short period of time. According to the results it can be assumed that magenta inks still represent the weakest link in ink-jet printing (Bamfield, 2001). After eight hours of illumination, colour difference was not as big as on cyan prints at the same time, but the colour changes on magenta prints increased rapidly and after 96 hours of exposure to light which included radiation above 300 nm the colour difference reached approximately 1500% of the value reached after eight hours. Exposure to light which included smaller amount of UV radiation (λ>320) caused slightly smaller but still very intensive changes (ΔE^{*}_{00}=8.5) and this value represents approximately 1200% of the change after eight hours of illumination.

5. CONCLUSIONS

It can be established that only negligible colour changes occurred on permanent paper during the time of illumination. Furthermore, even shortwave radiation had a minimal influence on its colour. According to the results, permanent paper has excellent light fastness properties.
Results have shown that colour differences on cyan, yellow and black prints increased almost linearly with time, although with different speed. The changes on magenta prints occurred exponentially, leading to immense colour changes. Spectrophotometric measurements of the cyan prints have shown that greater changes occurred in the initial stage of illumination.
The comparison of the results shows that the presence of UV radiation with shorter wavelength influenced colour prints to a great extent. The destructive influence was observed particularly on the cyan and magenta prints.
Increased amount of UV radiation had a negative influence on the resistance of black prints also. However, colour changes on black prints were significantly lower in comparison with cyan, magenta and yellow prints which were made with dye-based inks.
When preparing documents of lasting value, attention should be payed to the structure of ink, substrate and also to printing technology. According to the results, dye-based inks are not suitable for documents with longer durability. The use of pigment-based ink and permanent paper can guarantee a longer lifetime of documents.

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THE CHARACTERIZATION OF WASTE OFFSET DEVELOPER SLUDGE TREATED BY SOLIDIFICATION/STABILIZATION

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Abstract: *The solidification/stabilization (S/S) treatment of electrocoagulation sludge was conducted with four immobilization agents: Portland cement, calx, bentonite, and local clay. The sludge developed after the electrocoagulation treatment of the waste offset developer in laboratory conditions by applying a batch reactor with four iron electrodes set at a distance of 0.5 cm, current density of 8 mA cm^{-2} and operational time of 60 minutes. The efficiency of the S/S treatment was monitored by applying toxicity characteristic leaching procedure (TCLP) test with one extraction fluid during a certain time. By comparing the copper concentration levels in the leaching solutions of S/S mixtures with maximally allowed concentrations according to current regulations, the characterization of sludge as waste in terms of its toxicity was executed.*

Key words: solidification/stabilization, leaching test, electrocoagulation, waste offset developer, sludge, copper

1. INTRODUCTION

Solidification and stabilization techniques are considered to be suitable for the treatment of different types of waste. The development of specific formulations for the treatment of different types of waste began at the end of the 1960s and the beginning of the 1970s of the 20th century (Malviya and Chaudhary, 2006). The term solidification/stabilization (S/S) is used for describing a wide specter of techniques that are used for the transformation of waste into forms that are less harmful to the environment (Chen et al., 2009). The goals of the S/S treatment are achieving or maintaining the desired physical properties and the chemical stabilization or permanent pollutant binding. The S/S treatment is one of the most popular technologies owing to several criteria: its efficiency in the preservation of human health and the environment, its accordance with legal regulations and demands, the possibility of implementation, and cost-effectiveness (Spence and Shi, 2005).

The amount and the composition of the printing waste depends on the the raw materials used, the process techniques applied and the properties to be achieved (Prica et al., 2011). In general, the waste materials are most often not geochemically stable and safe to the environment. That is why an assessment of the potential risk of waste pollutants released during the different phases of their exposure to environmental conditions is necessary. It is generally thought that the highest potential risk comes exactly from the leaching of soluble waste pollutants when they come into contact with water (Prica, 2008).

Leaching is a process by which inorganic and organic pollutants are released from the solid into the liquid phase via dissolution, desorption or complexing that are controlled by pH value, redox conditions, dissolved organic matter, and microbiological activity. The process itself is universal because every material, when it comes into contact with water, leaches components from its surface or from the inside, depending on the porosity.

The leaching of contaminants from waste into the water phase is influenced by: chemical processes (dissolution, adsorption and availability) and the processes of physical transport (advection and diffusion). The leaching of pollutants into the water phase is most frequently a combination of these two processes, but normally only several factors have a dominant influence (Van der Sloot and Dijkstra, 2004). Chemical factors that influence the leaching of many waste contaminants into the water phase are: pH value, oxidized or reduced forms of pollutants, oxidation/reduction state of waste and the environment, buffer capacity of immobilization agents, the presence of organic matter, the composition of water phase, and ion strength.

The objectives of this study was to evaluate the effectiveness of S/S treatments (with the addition of Portland cement, calx, bentonite, and local clay as immobilization agents) of waste offset developer sludge obtained after electrocoagulation process. Also, the characterization of sludge as waste in terms of its toxicity was executed.

2. METHODS

2.1 The electrocoagulation treatment of the waste offset developer

For the batch electrocogulation reactor, a borosilicate glass was used (250 ml in volume) with 220 ml of the waste offset developer. The electrocoagulation treatment was conducted with four Fe electrodes placed at a distance of 0.5 cm. The external electrodes were connected to the DC power supply (DF 1730LCD) with constant current density of 8 mA cm^{-2} during the operational time of 60 minutes. A balanced stirring of the electrocoagulation treated waste offset developer was achieved by using a magnetic stirrer (IKA color squid) (Adamovic et al., 2016). The waste offset developer sludge obtained was separated from the liquid phase by membrane filtration and dried to constant mass at 105^{o}C.

2.2 The characterization of the waste offset developer sludge

The characterization of sludge of the electrocoagulation treated waste offset developer was conducted according to the pseudo-total content of heavy metals. The pseudo-total content of heavy metals in the sludge was determined by acidic digestion in according to the ISO 11466:1995 method (ISO, 1995). The samples obtained were analyzed by applying the AAS flame technique (Perkin Elmer AAnalyst™ 700) to a pseudo-total content of metals in accordance with the standard EPA 7000B procedure (EPA, 2007). Also, the sludge characterization included the initial performance of TCLP (Toxicity Characteristic Leaching Procedure) on a raw sample of the electrocoagulation treated waste offset developer in order to determine its character.

2.3 The characterization of immobilization agents

The chemical composition of immobilization agents (Portland cement (PC), calx (C), bentonite (B), and local clay (LC)) for the S/S treatment of electrocoagulation sludge is shown in Table 1.

Table 1: The chemical composition of immobilization agents

Compounds	Composition (%wt)			
	PC	C	B	LC
SiO_2	23.40	-	58.90	55.70
Al_2O_3	6.12	-	22.70	14.91
Fe_2O_3	3.21	-	4.83	5.78
MgO	1.01	-	1.40	2.86
CaO	63.20	99.00	1.85	5.90
K_2O	0.54	-	0.24	-
Na_2O	0.12	-	0.12	0.83
SO_3	1.18	-	-	0.22
TiO_2	-	-	-	0.80
Ignition loss	1.40	-	10.60	10.58

Specific surface, volume and size of the pores were determined by nitrogen adsorption on 77 K obtained by using the analyzer for the characterization of porous and powder materials (Autosorb iQ_2, Quantachrome Instruments, USA). The specific surfaces of immobilization agents were determined by applying the Brauner-Emmett-Teller (BET) method and the porosity by applying the Barret-Joyner-Halenda (BJH) and t-t methods. Clays were characterized from the aspect of cation exchange capacity (CEC). The physical and structural characteristics of immobilization agents are presented in Table 2.

Table 2: Physical and structural characteristics of immobilization agents

Parameter	PC	C	B	LC
BET (m^2g^{-1})	3.15	4.85	39.6	12.4
t-test (cm^3g^{-1})	0	0	0.007	0
BJH (cm^3g^{-1})	0.007	0.005	0.032	0.051
CEC (meq/100g)	-	-	70.4	44.7

2.4 The S/S mixture preparation

The S/S mixtures were created by mixing the dried electrocoagulation treated waste offset developer sludge with immobilization agents in the ratio of 50 to 50. To the homogenized S/S mixtures an optimal content of deionized water was added according to the ASTM D1557-00 procedure (ASTM, 2000). Then, the S/S mixtures were placed into inert plastic bags to be stored in for 28 days at room temperature (23±2^{o}C). TCLP test was then applied to the S/S mixtures, and content of copper was determined in leaching solution.

2.5 TLCP test

For the TLCP test, we used the electrocoagulation waste offset sludge containing particles smaller than 1 cm in diameter. In order to execute the TLCP test, the adequate extraction fluid first had to be determined according to the TLCP procedure (USEPA, 1996). A dried sample of the S/S mixture, 2g in mass, and the extraction fluid in the ratio of 1 to 20 were measured into a glass dish and were subjected to continuous stirring on a stirrer (KS 501 Digital IKA-WERKE, Germany) for 18 hours at room temperature. Then, the extract was analyzed for the content of copper via the AAS method (EPA, 2007). Copper contents were assessed on sample triplicate and mean values were used. The relative standard deviations (% RSD) obtained (n=3) were below 10%.

3. RESULTS AND DISCUSSION

The content of copper in the sludge of the electrocoagulation treated waste offset developer was determined by the method of acidic digestion. The results show the presence of iron and copper in mass concentrations of 455570 and 351 mg kg^{-1}, respectively.
For the classification and characterization of the electrocoagulation treated waste offset developer sludge as waste, the iron and copper values were compared to the limiting values prescribed by the EPA 658/09 (EPA, 2009). The iron value was not defined, whereas the value of copper exceeds the limiting value of 60 mg kg^{-1} prescribed by the EPA 658/09, which determines the tested sludge of electrocoagulation treated waste offset developer as hazardous waste that has to be treated before being disposed.
The concentrations of copper leached from the electrocoagulation sludge and the stabilized S/S mixtures (S50PC50, S50C50, S50B50, S50LC50) by applying the TCLP test are shown in Table 3.

Table 3: The concentrations of copper leached from the electrocoagulation sludge and the S/S mixtures with immobilization agents according to the TLCP test

Sample	Concentration 10^{-2} (mg L^{-1})
EC sludge	157,5
S50PC50	51,6
S50C50	47,9
S50LC50	41,7
S50B50	31,6
MAC*	2500
* Maximum allowed concentration of copper by the TCLP procedure (“Sl. glasnik RS“, br. 56/2010)	

The concentrations of copper leached from the electrocoagulation sludge and S/S mixtures of the waste offset developer with immobilization agents according to the TLCP test are significantly lower than the maximum allowed concentration prescribed by the Regulation on categories, evaluation and classification of waste (“Sl. glasnik RS“, br. 56/2010). The electrocoagulation waste offset developer sludge does not contain toxic characteristics and hence can be described as non-hazardous waste that can safely be disposed of into the environment. The efficacy of immobilization agents decreases in the order of the immobilization agent specific surface decrease: bentonite > local clay > calx > Portland cement. Immobilization agents of bentonite, local clay, calx, and Portland cement have contributed to the lowering of the mobility of copper, compared to its mobility in the electrocoagulation sludge, by 5.0, 3.8, 3.3 and 3.0 times, respectively (Table 3). The results of the efficacy of specific immobilization agents are in accordance with their structural characteristics (BET specific surface, porosity and cation exchange capacity). Specific surfaces decrease in the same order as the efficacy of immobilization agents. Also, the capacity of cation exchange of bentonite is 1.6 times higher than the one of local clay. The local clay porosity is higher than the one of Portland cement and calx from 4.6 to 7.3 times and from 6.4 to 10.2 times, respectively.

4. CONCLUSIONS

According to the TLCP test, it may be concluded that the S/S mixtures of the electrocoagulation waste offset developer sludge and immobilization agents do not contain toxic characteristics and are non-hazardous and safe for the disposal into the environment. The most efficient immobilization agent is bentonite, which when compared with the other immobilization agents has a bigger BET specific surface, higher cation exchange capacity and porosity and it is the only agent that contains micropores. If the S/S treatment is observed from the economic aspect, the fact is that it can be efficiently executed even with non-commercial local clay.

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Paper as a printing substrate

THE INFLUENCE OF THERMOCHROMIC INK ON RECOVERED CARDBOARD BIODEGRADATION

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Abstract: *As the packaging industry is growing lately and the amount of packaging waste increases, it becomes one of the major environmental problems. Packaging waste comprising about one-third of all municipal solid waste, mainly plastic and paper based. Anaerobic degradation is one of the most environmentally friendly methods for solid organic waste treatment and widely applied for bio-energy production. In this study, the influence of screen print thermochromic ink on biodegradability aspect of three different cardboard materials (Umca Color - UC, Propack - PP, Lux Pack - LP) were studied using the soil burial test under anaerobic conditions. Neat and printed cardboard samples were evaluated for changes over 3 months by visual examination, weight loss measurements, volatile solids reduction and surface properties. The surface free energy (SFE) and adhesion parameters were determined for all samples, and showed a very high binding of ink to all cardboard samples. Thermochromic ink reduces the biodegradation of cardboard due to strong ink adhesion on cardboard. If a large SFE interphase is, separation of ink from the substrate occurs. The highest reduction of biodegradation for printed samples was noticed for UC sample. After 120 days the total weight loss for all three neat cardboard samples was similar (about UC 38.4%, PP 34.8%, LP 31.5%). Printed samples showed lower values of biodegradation, up to 36 % reduction compared to neat samples after 120 days.*

Key words: surface free energy, adhesion, biodegradation, cardboard, thermochromic ink

1. INTRODUCTION

Municipal solid waste continues to be a major environmental problem. Biodegradable municipal waste consists mostly of organic fraction, paper, wood and textiles. Existing methods of waste management include processing and recycling, incineration, composting or aerobic digestion, anaerobic digestion and landfilling. Anaerobic digestion occurs in landfilling sites as natural process but produced methane can be collected or flamed. Paper is mostly recycled by conventional methods like deinking. 40% of paper is wet and is not suitable for recycling but is suitable for composting or digestion (Murphy and Power 2006). Even though paper based materials are often recycled by means of deinking flotation, not all products are suitable for it. Paper based packaging contaminated with food is not desirable in paper recycling facilities due to cleaning difficulties, which leads to contamination issues (Twede, Diana; . Selke, Susan; l Kamdem and Shires, David ; Pira 2015). Besides food contaminants, in the classic flotation deinking process a certain types of prints can cause problems as well. It is known that classic offset prints are easy deinkable by conventional process, but flexographic and UV curing inks can hardly be removed from recycled pulp (Faul 2010). The quality of the waste paper may ultimately decrease as more and more ‘‘marginal’’ paper fractions are collected for recycling and the contents of harmful substances in paper thereby increase (Pivnenko et al. 2015). Study conducted on deinkability aspect of thermochromic inks showed they are very difficult to deink by conventional deinking process (Vukoje et al. 2016). Thus it is crucial to find an alternative method to classic recycling process, such as composting or anaerobic digestion.

Anaerobic digestion (AD) is a promising technology which is widely used in the treatment of various organic wastes, mostly for the treatment of the rapidly biodegradable municipal solid waste, agro-wastes, sewage sludge, etc. It is a natural process where anaerobic bacteria existing in an oxygen free environment degrade organic matter releasing biogas that primarily contains methane (CH_4) and carbon dioxide (CO_2). Anaerobic process, if properly applied, can have more advantages than other processes like high degree of waste stabilization, low production of waste biological sludge, low nutrient requirements, no oxygen requirements and useful energy end product – methane (Ismail and Abderrezaq 2007).

Even there are numbers of different methods for biodegradation examination; the soil burial test is one of the simplest methods. The soil beds containing the samples are incubated at a constant temperature for between 28 days and 12 months. The moisture content is normally set at 20–30%, although it is better calculated as a percentage (40–50%) of the soil's maximum water holding capacity (Chandra 1998).

Variety types of paper and board can be used in packaging applications. Cardboard can either be a single or a multi-layer material. It can be made of more than one type of pulp and it often incorporates a recycled

fibres. In multi layered cardboards, the inner layers are usually made of from lower quality pulp than the outer layers. In order to improve printability, the cardboard can contain clay or other coating on one or both surfaces. Cardboard is often classified by its thickness, ranging from 410 to 610 µm (Twede, Diana; . Selke, Susan; l Kamdem and Shires, David ; Pira 2015). Cardboards can be classified using a brief description consisting of two letters and a number, for example GC1; where G represents coated, C- chromo and 1- low quality.
Thermochromic inks are temperature sensitive materials which change colour with heat. In their cool state, they exhibit colour, and when heated, they become clear or translucent. The temperature range at which transition of coloured to colourless state occurs is commonly called the activation temperature (TA). The change of colour may be irreversible or reversible (Homola 2008). The reversible inks microcapsule consists of leuco dye, solvent and colour developer. The main disadvantage of organic microcapsules is their insufficient light stability and high sensitivity to environmental changes (Rožić et al. 2015) .Thermochromic inks are available for use on a variety of substrates and they have been developed for many types of printing processes, such as screen printing, gravure and flexography, and more recently for applications in offset lithography (Bamfield, P, Hutchings 2010).
Many studies have reported the degradation of paper based materials in various environments such as aerobic and anaerobic (Yen and Brune 2007; Wang et al. 2015; Fonoll et al. 2016), but there is lack of studies about influence of printing inks on biodegradation, especially for thermochromic inks.

2. METHODS

2.1 Materials

Three different cardboard materials were used in biodegradability test. The used cardboards are representing different classes of cardboards (Table 1) according to their properties and quality.

Table 1: Cardboard classification

Cardboard samples	Abbreviation	Grammage, g/m^2	Classification
Lux Pack	LP	350	GC1
Propack	PP	350	GT2
Umca Color	UC	350	GD2

All cardboard samples were analysed in the terms of thickness, moisture, ash and $CaCO_3$ content. Thickness of all samples was determined according to T411 standard. Moisture content was determined according to T412 om-94, while ash content was determined according to T413 (combustion at 900°C). Alkalinity of paper as calcium carbonate was determined according to T533.
All three cardboard samples were printed with thermochromic ink in order to examine how it affects the process of biodegradation. One leuco dye based, screen-printing UV curable thermochromic ink produced by CTI® was used for printing. The thermochromic ink was coloured in purple below its activation temperature (TA=31 °C) and changed to pink above the activation point. The biodegradation of neat (UC, LP, PP) and printed cardboard (UC-UV, LP-UV, PP-UV) samples was studied using the soil burial test under anaerobic conditions as it will be described in the text.

2.2 Printing

The printing trials were carried out using the Siebdruckgeräte von Holzschuher K.G., Wuppertal. The cardboards were printed in full tone, under the same conditions. The printed samples were dried under the UV irradiance (30 W/cm) using Technigraf Aktiprint L 10-1 device.

2.3 Determination of surface properties

The evaluation of surface free energy (SFE) of neat and cardboard printed with thermochromic ink was carried out by measuring contact angle of standard liquids. Measurements were conducted on DataPhysics OCA 30 Goniometer, using the Sessile Drop method. Standard test liquids whose surface tensions are known (Table 2) were demineralized water, diiodomethane and glycerol. Measurements were performed at room temperature of 23.0 ± 0.2ºC. The volume of droplet was 1 µL. Contact angle was captured by CCD camera and measured 1 s after the droplet was formed. Average values of ten drops on different places of the same sample were taken and presented as mean±SD in Table 4.

Table 2: Surface tensions (γ) of test liquids and their dispersive (γ^d) and polar (γ^p) components

Liquid	Surface tension (mJ m^{-2})		
	γ	γ^d	γ^p
Water	72.80	21.80	51.00
Diiodomethane	50.80	50.80	0.00
Glycerol	63.40	37.00	26.40

Using the Owens Wendt calculation method the surface free energy (γ) of the samples was determined as well as their dispersive (γ^d) and polar (γ^p) components. This calculation method is integrated in the software (SCA20, Version 2.01) and carried out automatically. The obtained surface free energy and its components are presented in the results section (Table 5). From the obtained SFE, adhesion parameters were calculated. Thermodynamic work of adhesion W_a between two phases was calculated according to (Eq. 1) (Żenkienwicz 2007) :

$$W_a = \gamma_1 + \gamma_2 + \gamma_{12} \tag{1}$$

Where the subscript refers to surface free energy of the each solid, in our case cardboard and ink print, and the γ_{12} denotes their surface free energy of the interphase. Using the Owens-Wendt model the surface free energy of the interphase was determined according to Eq. 2 (Żenkienwicz 2007) :

$$\gamma_{12} = \gamma_1 + \gamma_2 - 2\sqrt{\gamma_1^d \gamma_2^d} - 2\sqrt{\gamma_1^p \gamma_2^p} \tag{2}$$

2.4 Soil burial experiments

Soil was sieved to less than 2 mm particle size. Large plant materials, stones, and other inert materials were removed. Laboratory soil burial experiments were conducted at room temperature 25±3°C by placing the neat and printed cardboard samples horizontally in laboratory glass containers filled with soil. Samples were cut in 4 x 5 cm. All the samples were buried for 14, 32, 50, 80 and 120 days in glass containers filled with the soil. The water content of the soil was adjusted to 60% of its maximum water retention capacity. The commercial available reagent was used in order to allow the development of anaerobic conditions. The existence of anaerobic conditions was proved with *Anaerotest* (Merck) strips.

2.5 Visual observation of surface appearance change

Changes in the appearance of sample surfaces were observed before and after biodegradation. Photos of all samples were taken in order to visually evaluate the substrate degradation over time. A method of visual evaluation can be used in order to describe biodegradation as a first indication of any microbial activity in the terms of visible surface changes (formation of holes or cracks, de-fragmentation, changes in colour)(Shah et al. 2008).

2.6 Weight loss measurement and Volatile solids (VS) determination

After the soil burial test, biodegradability was measured through weight loss and volatile solids (VS) reduction. After the incubation in the soil containers, the samples were taken out and rinsed with distilled water to remove soil particles from the surface. Then were dried to constant weight and weighed. The weight loss percentage was calculated according to Eq.3:

$$\% W = \frac{m_0 - m_1}{m_0} \cdot 100 \tag{3}$$

where, m_0 is the initial weight of the sample, m_1 is the final weight of the sample after degradation.
The volatile solids (VS) were determined by ignition of material in muffle furnace at 550 °C during 2 h. All the samples were tested for VS.

2.7 Colour measurement

The colour measurement was carried out using X-Rite i1Pro spectrophotometer at temperature of 23±2°C. The colour of original printed cardboards and printed samples after biodegradation was determined according to the *CIE L*a*b** system. The average of ten values of those measurements was presented in Result section (Table 8). The total colour difference ΔE*Lab was determined according to the Equation 4 and presented in Figure 11.

$$\Delta E = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2} \quad (4)$$

3. RESULTS AND DISCUSSION

Due to the different constitution materials and quality properties the cardboard samples were examined for some basic properties such as thickness, moisture, ash and $CaCO_3$ content and results are presented in Table 3. All the samples have similar moisture content. The lowest amount of ash content was found in LP sample, followed by UC and PP. The amount of $CaCO_3$ increases in a series of: PP < LP < UC. This value can originate from fillers as well as from coatings. All samples differ in thickness, which grows in a row: UC < PP <LP. Due to different degrees of wetting, the thickness of TC UV print is different for all samples, and increases in a row: PP < UC < LP.

Table 3: Properties of used cardboards

	moisture, %	ash, %	$CaCO_3$, %	Thickness, mm	Thickness of TC UV print, mm
LP	4,63	9,67	13,09	0,563	0,010
PP	4,28	18,51	12,56	0,494	0,003
UC	4,51	16,25	15,28	0,453	0,005

In order to obtain surface free energy (SFE) of all samples and adhesion parameters, the samples were examined for contact angle measurements with different liquids. Results of contact angle determination are presented in Table 4, while results of SFE determination and adhesion parameters are presented in Tables 5 and 6.

Table 4: Contact angle measurements

Sample	Contact angle Θ		
	Water	Diiodomethane	Glycerol
LP	68.4±3.48	56.9±3.59	105.9±2.90
PP	98.5±7.39	73.0±2.98	58.2±5.17
UC	58.2±4.40	48.1±3.01	97.8±2.29
LP-UV	103.0±4.48	46.8±1.70	99.1±1.95
PP-UV	96.6±4.51	44.7±1.73	101.1±1.93
UC-UV	114.8±4.48	32.7±1.67	119.3±2.23

Obtained contact angles presented in Table 4 show mostly hydrophilic surface properties of cardboard except for PP which shows hydrophobic surface. The highest hydrophilic surface is noticed for UC sample. All samples of prints show hydrophobic surface (UC-UV > LP-UV > PP-UV).

Table 5: Surface properties

Sample	Surface free energy (mJ m^{-2}) γ - OW			x^d(%) (γ^d/γ)
	γ^d	γ^p	γ	
LP	17.22	10.01	27.23	63,24
PP	13.9	1.44	15.34	90,61
UC	20.58	13.56	34.14	60,28
LP-UV	30.43	0.00	30.43	100,00
PP-UV	29.19	0.18	29.37	99,39
UC-UV	32.91	2.12	35.03	93,95

Table 6: Adhesion parameters

Sample	Adhesion parameters (mJ m^{-2})	
	γ_{12}	W_a
LP - UV	11.88	45.78
PP - UV	3.41	41.30
UC - UV	6.40	62.77

In the Table 5 the obtained results for surface free energy of neat and printed cardboard samples are given. Neat cardboard samples have a large proportion of polar component in its SFE, as indicated by the γ^p and the dispersion index x^d. The highest polar character of surface is observed for UC sample (13.56 mJ m^{-2}), followed by LP (10.01 mJ m^{-2}), which is characteristic for the hydrophilic surface. Compared to UC and LP sample, PP sample has hydrophobic surface with the smallest polar component (1.44 mJ m^{-2}). SFE of neat cardboard samples increases in a row: PP < LP < UC. By observing the SFE of prints, they are similar in all samples. SFE of prints on all samples mostly originate from its dispersive component, which is characteristic for hydrophobic surface. It is evident that LP-UV sample does not have hydrophilic molecules on the surface (γ^p = 0.00 mJ m^{-2}), and its total SFE is equal to its dispersive component. The other two printed cardboards (PP-UV and UC-UV) show the existence of polar components on their surface according to obtained SFE. From this it can be concluded that an adhesive bond between cardboard and ink is mostly provided by nonpolar interactions.
Table 6 shows the adhesion parameters for cardboards and prints. Optimum adhesion can be achieved when the following conditions are fulfilled: W_a = maximum, γ_{12} = minimal, and $\gamma_1 = \gamma_2$. As these conditions are satisfied, adhesion will be optimal. Considering these conditions, it can be concluded that the greatest adhesion is achieved on a UC-UV sample (W_a = largest, SFE of both phases are almost equal) regardless to larger SFE of interphase (γ_{12}). In other two samples (PP-UV and LP-UV) the work of adhesion is similar but noticeably lower than in the UC-UV sample. This can be attributed to the large SFE of interphase (in the case of the LP-UV) and with different SFE of individual phases (in the case of PP-UV). The obtained results show that the interaction between all tested cardboards and TC ink are strong. The work of adhesion is the highest for UC-UV sample (62.77 mJ m^{-2}) (Table 6). The smallest work of adhesion is observed for the PP-UV sample (41.30 mJ m^{-2}) due to largest differences in SFE of individual phases.
The adhesion of ink onto the cardboard substrate depends on the intermolecular interactions between them. Cardboards with hydrophilic (polar) surface (LP and UC) show higher values of SFE of interphase. The highest SFE of interphase is observed for the LP-UV sample (11.88 mJ m^{-2}). In this case the adhesion is provided only by the dispersive bond due to absence of polar components in the print. The high SFE of interphase can be explained by the existence of polar molecules on the surface of LP cardboard which creates resistance to print and thus preventing the binding and absorption of ink on the surface of cardboard. This resistance will result as a higher γ_{12} value. Cardboard with hydrophobic surface (PP) shows the minimum value of SFE of interphase (3.41 mJ m^{-2}). Furthermore, SFE of interphase also affects the thickness of print on the cardboard surface. The greater the SFE of interphase, the thickness of the print on the cardboard higher is (Table 3 and 6). Thus, LP-UV results in the thickest print, followed by UC-UV, and PP-UV with a minimum thickness of the print. Due to maximum absorbency of ink on PP cardboard, the smallest is the difference in the contact angles of neat and printed PP cardboard (Table 4). In order to make a conclusion about biodegradability, changes in the appearance of sample surfaces were observed before and after biodegradation during the whole sampling time. Samples were taken out from the soil containers in different sampling periods (14, 32, 50, 80 and 120 days). Formation of holes, cracks and changes in colour were noticed.

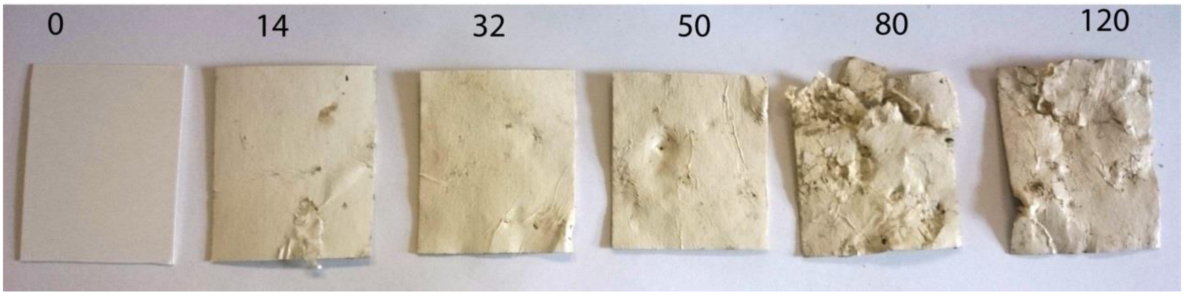

Figure 1: Biodegradation over 120 days for neat LP cardboard

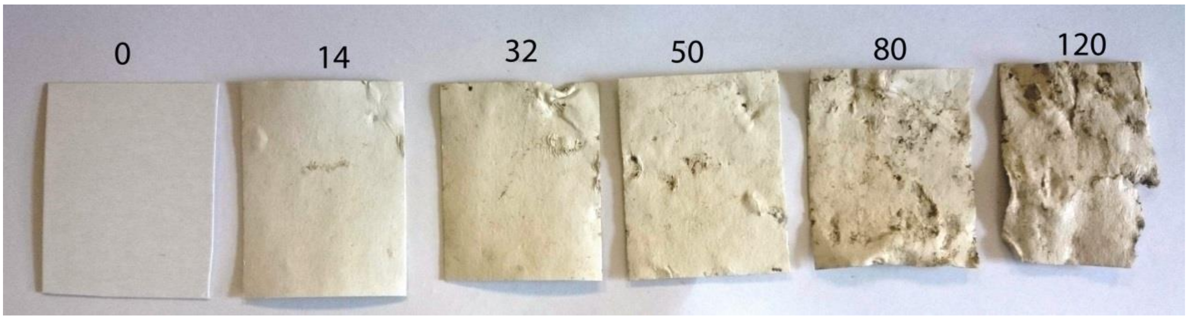

Figure 2: Biodegradation over 120 days for PP neat cardboard

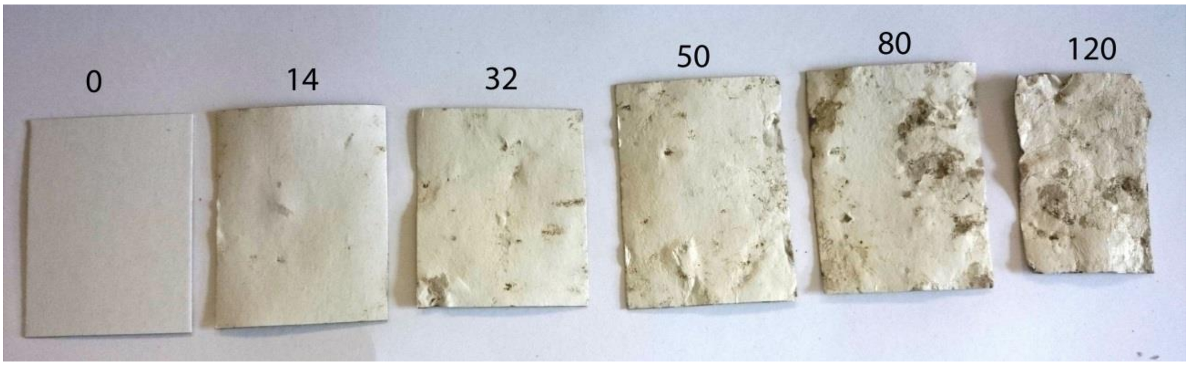

Figure 3: Biodegradation over 120 days for neat UC cardboard

From Figure 1, 2 and 3 it can be noticed that the biggest changes on the surface of neat cardboard samples occur after 80 days. During the 14, 32 and 50 days, the biggest changes are reflected in the change of color, ie. they tend to yellow. The biggest changes occur after 120 days of biodegradation for all samples. Also, changes in the coating can be noticed, due to formation of wrinkles and cracks.

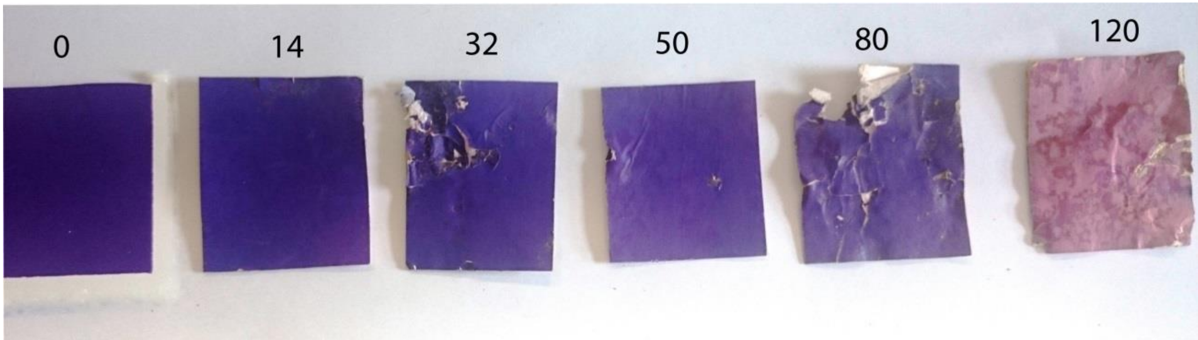

Figure 4: Biodegradation over 120 days for printed LP- UV cardboard

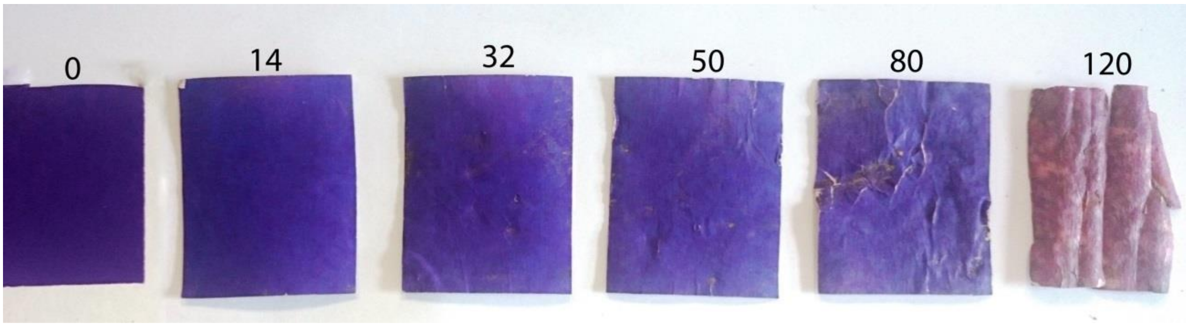

Figure 5: Biodegradation over 120 days for printed PP- UV cardboard

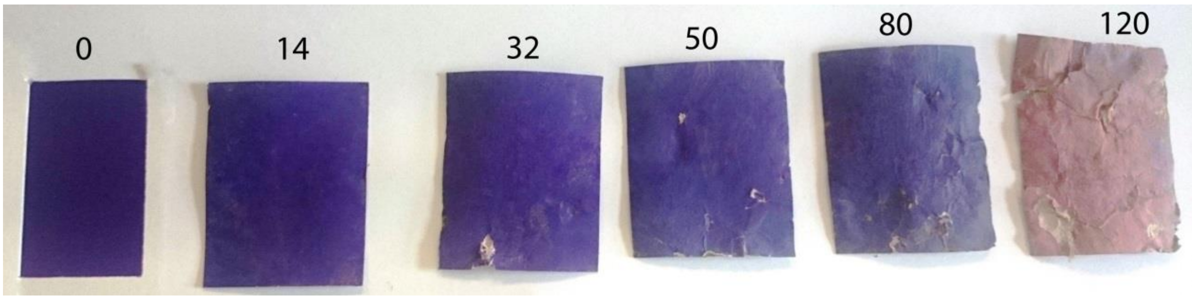

Figure 6: Biodegradation over 120 days for printed UC- UV cardboard

Observing the printed cardboard samples (Figures 4, 5 and 6), the most significant changes are in the colour of the print after 120 days. The print is much lighter on all printed samples. During the first 14 days of biodegradation test, no significant change in colour or on the surface of samples occurred. After 32 days in the LP-UV and UC – UV samples can be noticed the formation of cracks in the print, while in PP-UV sample it is visible after 80 days. In the LP-UV sample cracks in the print are the most significant but also detachment of ink layer from substrate can be observed. This can be attributed to the maximum value of SFE of interphase γ_{12} between the cardboard and ink (Table 6). As SFE of interphase increases in a row: PP-UV < UC-UV < LP-UV, the cracking and lamination of ink layer from the cardboard surface can be noticed.

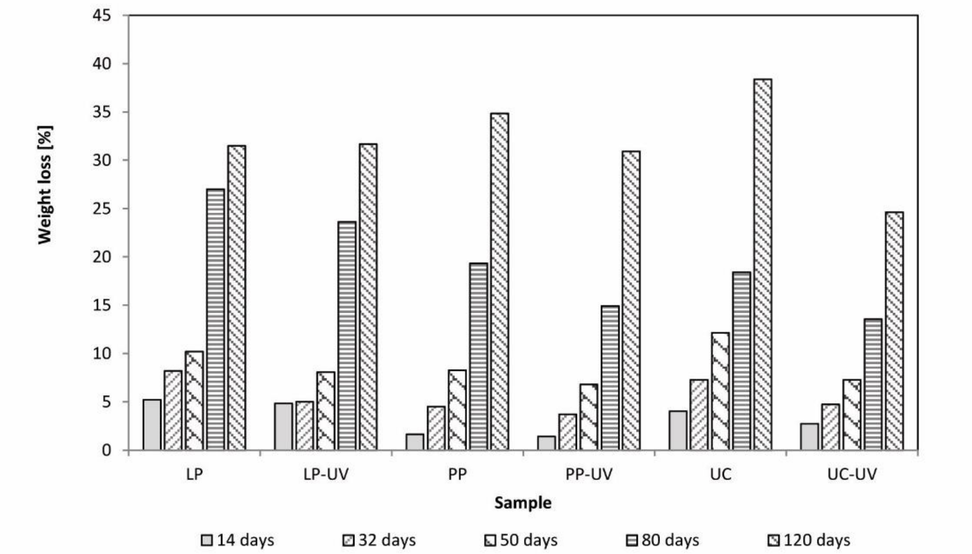

Figure 7: Biodegradation of samples through weight loss over 120 days

By observing the neat cardboard samples, the highest level of weight loss shows UC. After 120 days the total weight loss was about 38.4%, followed by the PP with 34.8%. The smallest weight loss has LP, with 31.5% after 120 days of biodegradation. This sequence can be attributed to the thickness of cardboard – the thinner the cardboard, better degradation is. Considering only the printed samples, it is obvious that the largest weight loss shows the sample LP – UV (31.7%), followed by the PP-UV (30.94%). The lowest weight loss was observed at the UC – UV sample (24.6%). The smallest changes in weight loss of all samples are in the first 50 days. After 80 days, there is a significant change in the weight loss of samples, particularly evident for the LP and LP-UV pattern. As with other samples, the biggest changes were observed after 120 days.

Table 7: The influence of thermochromic ink on the reduction of biodegradation over time, compared to neat cardboard

	Time (days)				
	14	32	50	80	120
PP/PP-UV	14.38 %	17.50 %	14.65 %	14.65 %	11.21 %
LP/LP-UV	7.00 %	38.78 %	20.72 %	12.45 %	0.00 %
UC/UC-UV	31.85 %	35.07 %	40.23 %	26.29 %	35.80 %

Thermochromic ink significantly influence the degree of cardboard biodegradation. Although sometimes ink can serve as a food source for the microorganisms and thus improve the degree of biodegradation (Lucas et al. 2008), here the different trend was observed. Degree of biodegradation was observed through weight loss, in all printed samples compared to neat cardboard. The total weight loss of PP – UV after 120 days was reduced by about 11% compared to the neat cardboard. The greatest impact of thermochromic ink on biodegradation was observed in UC-UV sample. The total degradation after 120 days compared to neat sample was reduced by 35%. This can be attributed to the high adhesion of ink to the substrate. The sample UC-UV has the greatest adhesion of TC ink to the substrate (62.77 mJ m^{-2}). During all the time interval of biodegradation, printed samples were reduced by about 26 - 40% (Table 7). As in the PP-UV and UV-LP samples the obtained work of adhesion is quite the same (Table 6), reduction of weight loss in the samples was lower than in UC-UV sample. In addition, it can also be attributed to SFE of interphase between the ink and the substrate. LP-UV pattern has the highest SFE of interphase, and during the 120 days the reduction of weight loss differed and cannot be observed by a specific rule. The SFE of interphase in the UC-UV sample was double less than in LP- UV sample and it can be seen that there is less variation in the weight loss reduction during the sampling time, and varies from 26 to 40%. Due to lowest SFE of interphase in PP-UV, the regular reduction of weight loss vs. sampling time (14 ± 3%), or with very small deviations, can be observed.

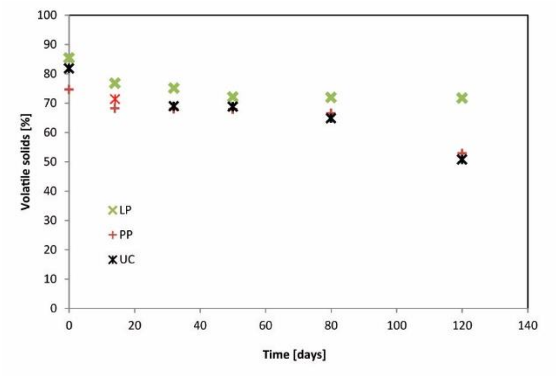

Figure 8: Reduction of volatile solids over time for neat cardboard

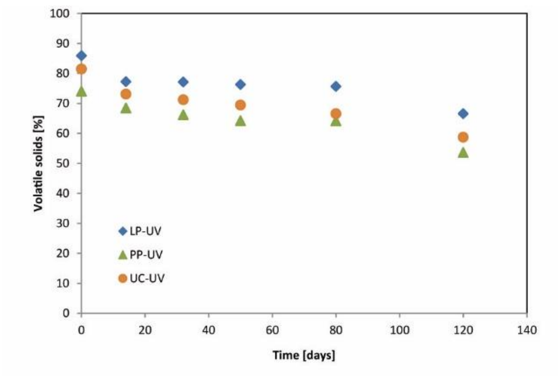

Figure 9: Reduction of volatile solids over time for printed cardboard

Concerning the percentage of ash in neat samples (Table 3), it is expected that the LP sample will have the largest share of VS. Observing neat samples (Figure 8), after 120 days the highest percentage reduction in VS was observed at UC (37.9%), followed by PP (27.6%) and LP-UV (16.1%) compared to the initial share of VS in all samples. These results confirm the results of the weight loss determination. For all printed cardboard samples (Figure 9), percentages of VS decrease are very similar. After 120 days, for UC-UV a reduction of VS was around 27.9%, for PP-UV 27.6% and for LP-UV 22.48%. In the printed samples decrease of VS originate from cardboard and from ink degradation. From this it can be concluded that weight losses during 120 days originates not only from decomposition of organic matter but also from defragmentation and washout of coatings and fillers.

Table 8: Colorimetric properties of thermochromic ink at 23±2°C

DAYS	LP-UV			PP-UV			UC-UV		
	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**
0	34,70	40,47	-35,34	34,70	37,67	-33,95	35,66	45,12	-25,51
14	37,29	30,65	-31,81	37,14	30,13	-32,35	36,37	31,37	-27,76
32	36,39	26,11	-29,98	38,43	28,59	-28,99	42,15	24,44	-22,26
50	39,74	24,81	-27,15	38,31	23,03	-26,33	42,46	21,57	-20,05
80	41,75	23,19	-19,93	43,92	26,35	-21,15	46,62	20,21	-12,63
120	57,79	33,25	8,50	50,34	24,63	4,43	59,40	25,41	8,16

Table 8 shows that all samples over time bright, ie their colour start to fade. *a** value is reduced to almost half of its value but still remains in the red area of *L*a*b** colour space, while the value of *b** changes from negative to positive values. This means that the blue thermochromic microcapsules are biodegradable during conducted degradation process. Blue thermocromic microcapsules in the formulation of the print are responsible for the purple coloration of the print (Figure 10). By mixing blue leuco dye to a conventional pink ink will result in a purple ink formulation.

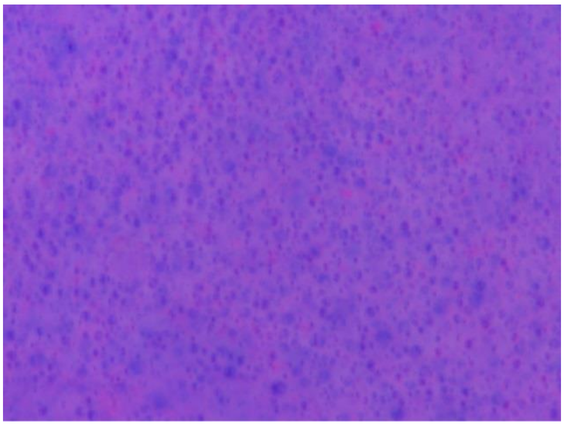

Figure 10: Blue microcapsules in ink formulation (original sample) at magnification of 2000x

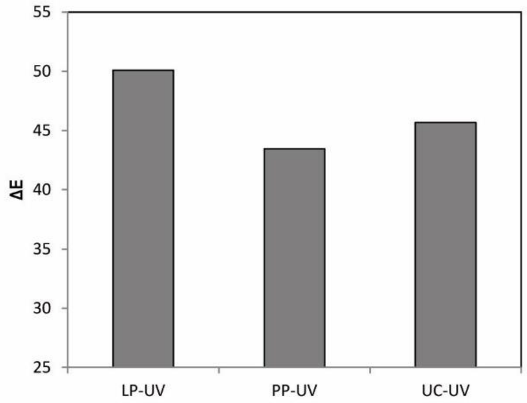

Figure 11: Total colour differenc after 120 days of biodegradation

Figures 4, 5, 6, 11 and Table 8 shows that the print was mostly discoloured after 120 days. In the period to 80 days, changes in colour were not so significant. The highest change in colour (ΔE) was observed in the case of LP-UV cardboard while the lowest in the case of PP-UV cardboard (Figure 11). This could be associated with an SFE of interphase. The higher the SFE of interphase is, the greater the change in colour after 120 days can be noticed. As the γ_{12} increases in a row: PP-UV < UC-UV < LP-UV; the difference in colour (ΔE) increases in a series of PP-UV < UC-UV< LP-UV. Stronger bond between the ink and cardboard will result in better colour stability. The higher the value of SFE of the interface is, the forces of binding to the substrate are less.

4. CONCLUSIONS

Thermochromic ink reduces the biodegradation of cardboard. The greatest role plays the ink adhesion on cardboard, but also its SFE of interphase. The greater the adhesion of ink on the surface will result in lower weight loss, i.e. lower degree of biodegradation. If a large SFE of interphase is, separation of ink from the substrate occurs. This can improve the biodegradation of the sample.

5. ACKNOWLEDGMENTS

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SPECIFIC FIBRE MASS OF SINGLE CELLULOSE FIBRES OF DIFFERENT ORIGIN

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Abstract: *Paper production is mainly based on fibrous raw material which may consist of primary or secondary fibres. Primary fibres are obtained directly from plant raw materials, mainly from wood and annual non-wood plants. Industrially, mostly thinnings and sawmill wastes are used.*
Secondary fibres are produced from recovered paper. Rags are used only in very small amounts. Synthetic and mineral fibres do not play an important role.Chemical pulp is produced by chemical pulping of vegetable raw materials such as not only hardwood and softwood, but also from straw from different kinds of cereals, bagasse, reed, or esparto grass, and from other annual non-wood plants. During chemical pulping, the most of the lignin is removed from the raw material. The technological processes of the pulp and paper producing cause the change of the length and surface of the cellulose fibres with a different order of magnitude. Fibre length is a fundamental property of pulp. The determination of the fibre length and surface character of pulp fibres is important in papermaking technology and environmental protection as well. The mass and the strengths of the produced paper are characterized by those of the included single fibres. New method has been elaborated for measuring the mass of cellulosic single fibres of different origin and of different pre-treatments. The number of single fibres in a known amount of pulp fibres has been measured in an aqueous suspension for this purpose. The measurement has been fulfilled in a Kajaani FS 100 fibre length analyser. This analyser is consisting of a capillary tube (0.2 mm) through which an aqueous suspension (density of suspension: 1 per thousand) of the fibres is passed.

Key words: pulp fibres, fiber length, fibre weight, specific fibre weight, Kajaani FS 100 fibre length analyser

1. INTRODUCTION

The properties of papers are highly depended on the quality of the included cellulosic fibres. Interfibrillar and intermolecular actions occur during the papermaking process. The first interaction among the fibres is the felting occurring in the sieve section whereas the second one is the forming of hydrogen bonds among the cellulose molecules during drying. Such fibres are needed for the procedure in which the ratio between the length and the width of the fibre is 70:1. The mass and the strengths of the produced paper are characterized by those of the included single fibres. Consequently new method has been elaborated by us for the measurement of the mass of the mentioned single fibres. The measurement has been fulfilled in a Kajaani FS 100 fibre length analyser. This analyser is consisting of a capillary tube (0.2 mm) through which an aqueous suspension (density of suspension: 1 per thousand) of the fibres is passed.
The pulp and paper industry started to use the Kajaani FS-100 in the 1980, this was the the first automated fiber analyser (Bichard and Scudamore, 1988) "and is an optical device accepted as method for laboratory fibre length measurements (Tappi T271) to measure fibre length and coarseness" (Copur and Makkonen, 2007). This tool is ready for quick and one simple measurement procedure (Piirainen, 1985). The main part of the device a capillary tube (0,2 mm) through which the thin suspension of the fibres is conducted. On the one side of the capillary is positioned a lamp and on the other, opposite side is a detector. When a fibre go through the capillary, the polarized picture of the single fibre is transmitted into the detector and from this we can calculate the length of the fibre. "A low-pressure vacuum pump and chamber collect the analyzed fibres. The measurement range is between 0-6.79 mm, divided into 24 classes, of which the first 12 classes are resolved to 0.2 mm lengths and the last 12 have a resolution of 0.4 mm (for the 0-0.7 mm range)" (Jackson, 1988). The fibre counting is manually with a keyboard. The fibre suspension is diluted (0.0004% consistency).

2. METHODS

In our method for the establishing of the mass of cellulosic single fibres the following 4 steps should be fulfilled:

1. Determination of the dry matter content of the sample
2. Cellulose sample with 0.1-0.2 g absolute dry fibre content should be pulped in 1000 ml distilled water
3. 100 ml of the above mentioned suspension should be diluted to 1000 ml by distilled water.
4. 100 ml of the suspension should be filled into the Kajaani 100 fibre analyser to determine the average fibre length (l_{af}) and the total number of the included fibres (tn).

Average single fibre mass (m_{asf}) can be calculated by dividing the included mass of the (m_f) by their above gained number (tn):

$$m_{asf}(g) = \frac{m_{af}(g)}{tn} \tag{1}$$

The above discussed data enable the calculation of the specific mass (m_{spec}) in g/mm of the single fibre:

$$m_{spec}(g/mm) = \frac{m_{asf}(g)}{l_{af}(mm)} \tag{2}$$

3. EXPERIMENTS

Our above discussed experimental method has been applied for the following studied fibres:

- Different ECF bleached pine fibres
- Different pine sulphate celluloses
- Semi-chemical-pulp – cellulose fibres (mixed hardwood)
- Chemical Thermo Mechanical Pulp (CTMP, pine)

1. Initially the impact of the grinding of different ECF bleached pine fibres in Jokro mill has been determined on the mass of the single fibre. 5 samples of different freeness (12, 18, 24, 32, 60 °SR) have been produced by grinding in Jokro mill. 5 Bauer McNett fractions have been separated (mesh: 14, 30, 50, 100, 200) from each mentioned samples of different freeness respectively. The average mass and length of single fibre of mentioned samples have been determined and compared with each other.

2. The average mass and length of single fibres of dried and never dried pine sulphate celluloses respectively after grinding in PFI mill have been determined and compared with each other thereafter.

3. Further experiments have been performed with Chemical Thermo Mechanical Pulp (CTMP) single fibres.

4. Finally the average mass and length of single fibre of 9 different cellulosic fibres of the same freeness have also been studied.

4. RESULTS AND DISCUSSION

Obtained data in the 1. set of experiments are summarised in Table 1. and in Figure 1.

Table 1: Average fibre length and mass of ECF bleached pine fibres of 5 different freeness (after grinding in Jokro mill) and 5 Bauer McNett fractions of each freeness.

Finnish bleached pine fibres of different freeness ground in a Jokro mill			
Bauer McNett fractions	Freeness	Fibre length	Fibre weiht
	°SR	mm	µg
14	12	2,7	1,8
30		1,92	0,95
50		1,1	0,797
100		0,65	0,742
200		0,52	0,741
14	18	2,7	0,8
30		1,94	0,6
50		1,16	0,5
100		0,67	0,4
200		0,43	0,259
14	24	2,59	0,2
30		1,86	0,1
50		1,09	0,052
100		0,61	0,034
200		0,33	0,032
14	32	2,54	0,795
30		1,87	0,325
50		1,05	0,132
100		0,58	0,145
200		0,31	0,1
14	60	2,59	0,889
30		1,89	0,592
50		1,01	0,291
100		0,56	0,266
200		0,34	0,26

The first observation from the obtained data is that the grinding practically does not decrease the average length of single fibres but it is significantly decreases their mass.

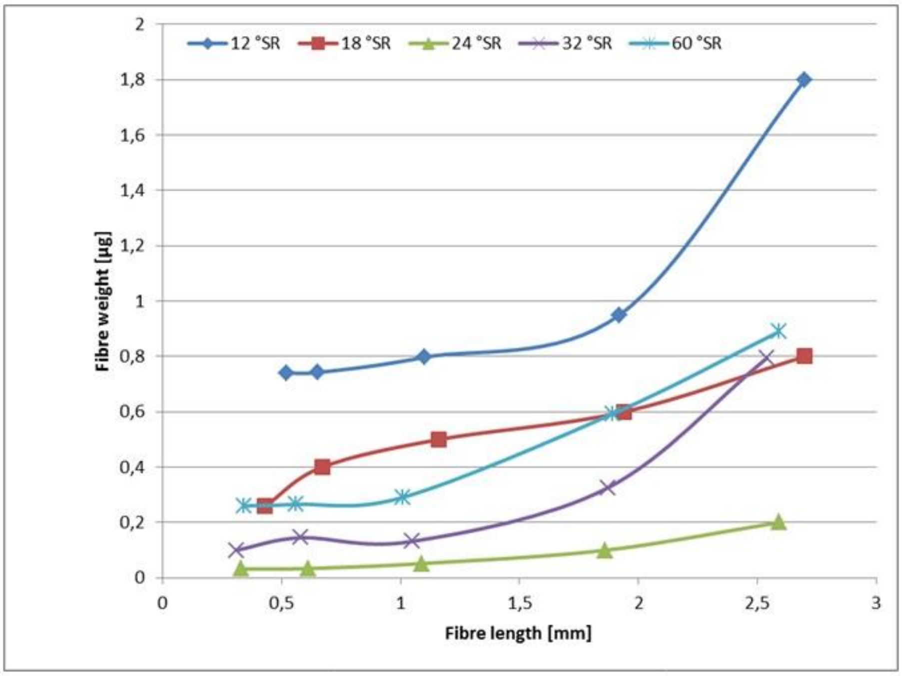

Figure 1: Average fibre length and mass of ECF bleached pine fibres of 5 different freeness and 5 Bauer McNett fractions of each freeness.

From this might be concluded that the grinding keeps the lengths of the fibre practically unchanged but it is sensitively decreasing its cross section. Final conclusion is that in the length acting binding forces are strong primary ones whereas in the cross sections acting ones are much weaker secondary forces.
Obtained data in the 2. set of experiments are summarised in Tables 2 an 3.

Table 2: Changes in average fibre mass, average fibre length and specific fibre mass of never dried pine sulphate cellulose single fibre in the function of freeness after grinding in PFI mill.

Bleached never dried sulphate pine ground in a PFI mill			
Freeness	Fibre length	Fibre weight	Specific fibre weight
SR°	mm	µg	µg/mm
13	2,27	0,303	0,133
22	2,26	0,298	0,131
33	2,23	0,295	0,132
47	2,21	0,295	0,133
57	2,19	0,289	0,131

Table 3: Changes in the average fibre mass, average fibre length and in then specific fibre mass of dried pine sulphate cellulose single fibre in the function of freeness after grinding in PFI mill.

Bleached dried sulphate pine ground in a PFI mill			
Freeness	Fibre length	Fibre mass	Specific fibre mass
SR°	mm	µg	µg/mm
13	2,3	0,381	0,165
20	2,27	0,314	0,138
32	2,25	0,283	0,125
45	2,08	0,273	0,131
54	2,04	0,268	0,131

Concerning changes in fibre length and fibre mass after grinding leading to freeness form 13 °SR to 57 °SR enabled the conclusion that small loss occurred in them as well of dried (Table 2.) as of never dried samples (table 3.) The changes in specific fibre mass are nearly neglectable in both samples because the loss in fibre length and fibre mass are proportional.

Table 4: Changes in average fibre mass, average fibre length and specific fibre mass of never dried Chemical Thermo Mechanical Pulp (CTMP) single fibre in the function of freeness after grinding in PFI mill.

Never dried Chemical Thermo Mechanical Pulp (CTMP) ground in a PFI mill			
Freeness	Fibre length	Fibre weight	Specific fibre weight
SR°	mm	µg	µg/mm
26	2,2	0,628	0,285
35	1,81	0,537	0,296
40	1,73	0,401	0,231
54	1,44	0,366	0,254

Table 5: Changes in average fibre mass, average fibre length and specific fibre mass of dried Chemical Thermo Mechanical Pulp (CTMP) single fibre in the function of freeness after grinding in PFI mill.

Dried Chemical Thermo Mechanical Pulp (CTMP) ground in a PFI mill			
Freeness	Fibre length	Fibre weight	Specific fibre weight
SR°	mm	µg	µg/mm
23	2,31	0,607	0,262
30	1,96	0,342	0,174
42	1,71	0,299	0,174
52	1,36	0,246	0,180

Both the length and the mass of CTMP single fibres decreased in the function of the increased freeness as well for dried as for never dried samples. No such tendency could be concluded in case of specific fibre mass data. Obtained data in the 4. set of experiments are summarised in Figures 2 and 3.

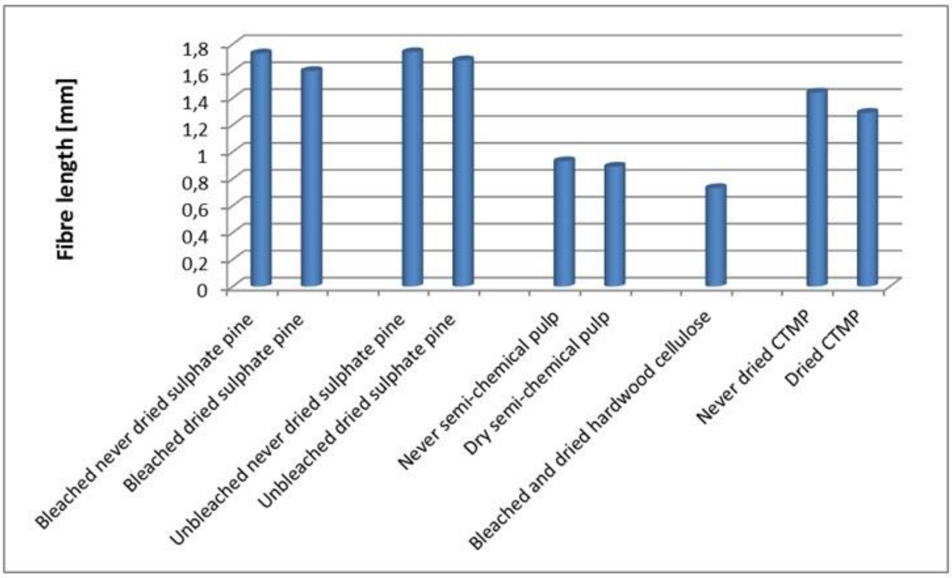

Figure 2: Changes in the average fibre length of cellulose single fibre of different prehistory at the same freeness (50 °SR).

Comparing the average fibre length could be concluded that the unbleached never dried pine sulphate cellulose has the highest value and the bleached hardwood cellulose has the lowest one.

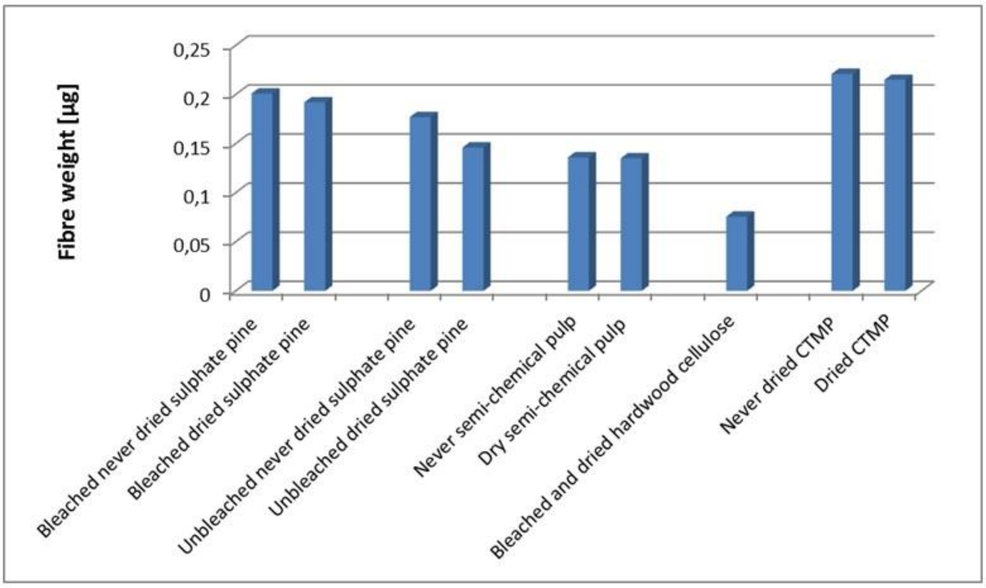

Figure 3: Changes in the average fibre mass of cellulose single fibre of different prehistory at the same freeness (50 °SR).

5. CONCLUSIONS

The elaborated by us method for the determination of the average single fibre mass for cellulosic fibre of different origin could be successfully used for a wide range of cellulosic fibres.
Comparing the results of average fibre mass could be concluded that the unbleached never dried pine sulphate cellulose has the highest value and the bleached hardwood cellulose has the lowest one.

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EXAMINATION OF THE DURABILITY OF TEXT BOOKS

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Abstract: *Although nowadays the use of the devices of electronic communication as an option is more and more frequently considered, school books have still remained the fundamental learning aids. Three years ago, the Hungarian government has decided to provide pupils and students with free school books, gradually up to the age group of maturity examiners. For this reason, the government has centralized school book publication, and made it a responsibility of a single, state-owned publishing company. To reduce costs, the competent ministry did not only decrease the diversity of school books, but also had the intention to order durable school books – serving for at least 4 school years – from printing companies. But what is a durable school book like? In this respect, the government has issued a decree that defines specific technologies as expected manufacturing procedures. On the other hand, technological parameters, control test methods have not been set out. All the stakeholders agree that pupils and students use school books in "heavy duty" mode. But how can durability in the face of such use and stress be interpreted? The studies of the authorities have been focused on examining how simple tests and evaluation methods can be used for assessing the "structural" (binding) durability of school books. What models can be used to estimate the durability period? What control measurements can be used to check the produced school books in terms of durability?*
The article describes the test methods that the authors have determined for the description of the structural durability of school books. There were seven types of school books differing from each other in format and/or binding technology tested, and applied to model the book-using "'habits" of students; the results have been systematically arranged, and options have been determined for the improvement of durability properties.
In summary of the test results, it can be claimed that with respect to durability school books are made ideal when they are designed in smaller dimensions and with the smallest possible weight. It is better to have paperback covers, because during the performed tests hardcover books reflected more serious damage.

Key words: textbooks, durability, bookbinding, universal book tester

1. INTRODUCTION

Today, during the production of books nearly all the binding operations are performed with machines. These technologies have developed a lot in the past 5–6 decades, especially the so-called perfect binding techniques. They properly satisfy the demands relating to the general use of books.
It is primarily libraries that have had demands for so-called durable books, while this need has become increasingly stressed in the production of school books, too. In recent years, Hungary has particularly seen this issue associated with the quality properties of the so-called durable school books coming to the focus of attention. The fact that the need for durable school books has become important has been largely fostered by the government's effort launched in 2014 for the provision and distribution of durable school books. Requirements relating to school books (especially durable school books) are stipulated in Ministerial Decree 17/2014 (March 12) of the Ministry of Human Capacities. In terms of structural considerations and book binding, from among the provisions set out in the Decree it is only the so-called technological requirements that bring about harder tasks and challenges than before.
Technological requirements pertaining to durable books:

a) assembling the sheets of the school book with the use of thread-stitching or backlash lining,
b) durable and at the same time light form of binding: reinforced paperback (cover: at least 260 grams/square meter, cellulose-containing cardboard four times grooved), or hard-covered, or flexible binding,
c) B/5 or A/4 sized book block,
d) use of light inner paper,
e) surface finishing of the cover (thermofoil).

Based on the Decree, from a technological (binding) perspective books are evaluated with the respect to the following criteria.
Criteria of evaluation for school books of general subjects (technological – binding - criteria)

1. Dimensions of the book block, number of pages, mass and weight with respect to the age of the student
2. Quality of the used paper and other materials, durability of the book.
3. Typography, fonts types, font sizes, system of highlights and displays
4. Page-setting, ratio and harmony of texts to images, typography of highlights and displays
5. Quality and legibility of printing, application of colours.

It is apparent that the above-quoted Decree does not set out specific criteria, requirements in relation to the structural, mechanical properties of school books (durable books), the concept of durability.
Although the printing industry and the various research institutions associated with the printing industry apply well-known test techniques, methods and devices that are useful for determining the mechanical properties of a given book (mostly constituents) with respect to a specific requirements or even set of criteria, at the same time the methods for the evaluation of these test methods and the obtained results are not covered in any standardized, broadly accepted system. It means that generally accepted, objective methods and standards that would determine the mechanical and technological durability of binded books, and in particular the so-called durable books (library books and school books), on the level of definitions and substances are not available (Manufacturing Standards and Specifications for Textbooks, 2012).
To promote the resolution of the issues listed above, our study has had the goal to elaborate quality indicators for durable school books, as well as define and model the properties of their durability.

2. METHODS OF THE RESEARCH

As it has been mentioned above, currently there is no uniform, generally accepted test method or standard that would specify the requirements in association with the examination and review of the binding quality of binded books, their durability, or the evaluation of the obtained results.
On the other hand, we are able to summarize the known test methods that are currently used for the verification of the binding quality of new, completed and binded books. Nevertheless, these test methods are not suitable for shedding light to information in relation to expected lifetime, its resistance to the mechanical and other impacts that affect the book during use. There are different devices from various manufacturers to examine the binding strength of books made with perfect binding. Examples include the Smithers' Pira Book tester or the Moffett Page Pull tester-80 (Figure 2).


Figure 1: Smithers' Pira Book tester and Moffett Page pull tester-80

During the examination conducted with the MOFFETT Flex tester-40 equipment, loading is exercised on the clamped and tested book pages cyclically, in contrast with the form of loading used by the above-described binding strength testing devices (non-recurrent stress that gradually increases up to the limit of binding strength). With the equipment, the stress that imitates page turning is exercised on the tested page of the book at a 40 cycles/minute rate. Two types of loading strengths can be applied. The number of stress cycles is recorded, and the equipment automatically stops when the examined page becomes torn, or any other damage takes place (Rebsamen, 2003).

The binding strength of the given book can be described with the number of the stress cycles (and the extent of the applied loading) (Rebsamen, 2002; 2009).

Figure 2: MOFFETT Flex tester-40

A major advantage of this type of equipment in comparison with the previous devices is that it can be used only with perfect binded books.

Figure 3: Moffett UBT-9 Universal Book tester

The Moffett UBT-9 (Figure 3) is designed to test the durability, that is, it evaluates several aspects of a hardcover binding; the abrasion resistance of covering materials, the integrity of the hinges, the stiffness and resistance to de-lamination of the boards, and to a limited degree, the durability of the sewn or adhesive bound book blocks (Rebsamen, 2003; 2013).

The device consists essentially of a rectangular test chamber constructed of steel, lined with 50 by 50 mesh of No. 304 stainless steel wire 0.009 inch in diameter. The chamber is supported and rotated by a drive shaft attached perpendicular to the center of its base. Viewed from the front, the drive is inclined at an angle of 20° from the horizontal, and rotates in a clockwise direction at a speed of 20 rpm. The dimensions of the test chamber vary with the size of the volume being tested. The spine of the book is perpendicular to the squared ends of the chamber. As the chamber rotates, the book slides in a regulated manner, receiving impact stresses on the bottom, along with the abrasion of the edges and shoulder, and some flexing of the hinges. The principle actions of the UBT are pulling of the head-cap, sliding the book off the shelf, dropping the book on a book truck or a return box, and sliding the book across the table or down a chute!

Table 1: Capable of the Moffett Universal Book Tester Model-9

Actions Produce the Following Results
1. abrasion of the shoulder of the spine
2. abrasions of the edges of the cover
3. light abrasion of the cover surface
4. distortion by impact
5. abrasion of the tail-cap and edges
6. hinge flexing action
7. breaking and tearing of the internal hinge
8. failure of sewn or adhesive bindings and splitting of the spine
9. abrasion and turning up of the edge of cover*

* We have assessed the testing of this property to be important.

The tested school books are used at primary and secondary schools. All of them have been provided by the manufacturers for testing. Their properties are specified in Table 2.

Table 2: school books subjected to testing and their properties

Book No.	Cover	Binding	Size	Tested Quantity
7-9	hard-covered	thread-stitched	A4	3 pcs
13-15	hard-covered	thread-stitched	B5	3 pcs
16-18	hard-covered	thread-sealed	B5	3 pcs
19-21, 25-27, 28-30	soft-covered	thread-stitched	A4	3 pcs
4-6	soft-covered	thread-stitched	B5	3 pcs
22-24	soft-covered	perfect bound with PUR	A4	3 pcs
1-3,10-12	soft-covered	perfect bound with PUR	B5	3 pcs

3. RESULTS

Due to the limitations of the extended abstract, only a part of the study will be presented. For paperback school books, durability tests assessing the conditions of the spine edges and corners, as well as binding conditions have been carried out. The other tests are conducted in a similar manner, and summed up in the conclusion.

3.1 Abrasion at the spine edges

From among the B/5 sized school books with perfect PUR binding, the school book with the 250 g/m^2 cardboard cover and non-gloss foil coating (Figure 4) proved to be the best concerning the abrasion of spine edges. The abrasion is hardly visible to the naked eye. The moderate damage is also due to the light, 230-gram weight of the book, as the book smashes against the sides of the machine with less power.

Figure 4: B/5 sized book showing the least abrasion on the spine edges

Similarly, from among the B/5 books the largest extent of spine abrasion has been suffered by school book (Figure 5) with perfect PUR binding.

Figure 5: The largest extent of spine edge abrasion has been experienced for B/5 sized book 10-12

With respect to the properties of the cover, it has a flexible cover of small square meter weight that does not compensate for the weight of the book.

Figure 6: A/4 sized, 28-30 thread-stitched school book with a smaller extent of spine edge abrasion

In the A/4 format, the best final result has been achieved by the 410-gram, thread-stitched school book (Figure 6). Its cover is of 260 g/m^2 weight. During the test, abrasion apparently occurred after the 50th minute, but it did not change drastically even by the end of the 60th minute.

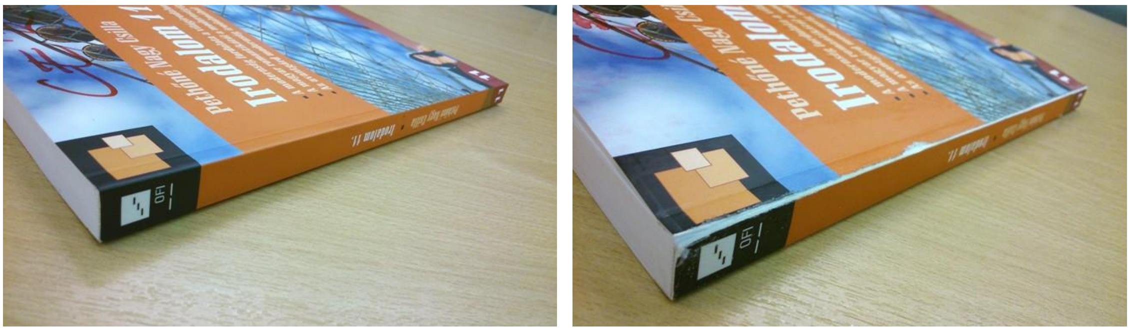

Figure 7: A/4 format, 25-27 thread-stitched school book with a considerable extent of spine edge abrasion

The thread-stitched book (Figure 7) proved to be the book with the worst spine edge. The weight of its cover is 260 g/m^2. It was thinner and more flexible than the most durable book, and therefore the book showed no rigidity in the test machine. It smashed against the walls of the chamber more easily, and due to their flexibility it more easily leant against the rounded corners, and therefore suffered abrasion over a larger area.

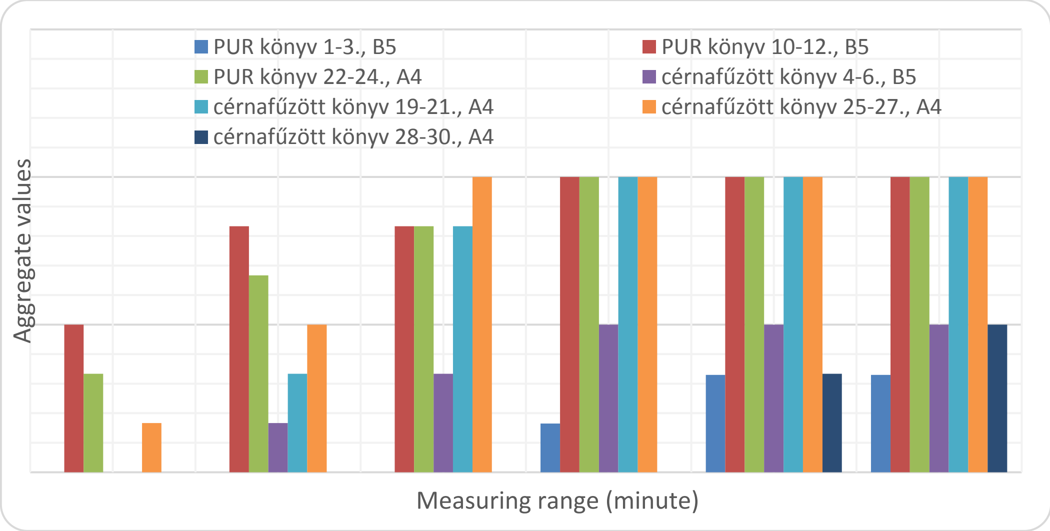

Figure 8: Spine edge abrasion for paperback books

In the light of the aggregated evaluation (Figure 8), it can be claimed that while initially the B/5 school book with perfect PUR binding showed strong abrasion, the spine edge abrasion of A/4- school books surpassed this extent of abrasion, and eventually even worse statistics could be obtained. It is also dependent on the type of the cover material and the weight of the book. In general, the worst type was the aurocard paper type in the case of large-format books. With respect to spine edge abrasion, smaller format books achieved better results.

3.2 Abrasion at the spine corners

For the study of spine corners, the smallest extent of abrasion has been experienced for the same book where the least spine edge abrasion has been seen (Figure 9*)*. No signs of impacts can be detected at the corners. The upper part of the spine edge can be regarded to belong to the corner section. This part – extending 1 cm along the spine edge towards the middle of the book block – has not become considerably worn, either. In the opening of the book, it can be observed that along this line the cover has not become worn so that any tear could be observed when pages are turned.

Figure 9: Slight spine corner abrasion on the 28-30 thread-stitched school book

By the end of the measurement, more serious corner damage has been detected in the case of three books. Two types of school books (Figure 10) that have the same type of covers and inner sheets – their corner damage has been also similar. On the other hand, in the measuring range it can be seen that over time book 19-21 and 25-27 have not suffered comparable abrasion even with similar base materials. The abrasion has been the most significant in the head section, as in both cases the covers have been worn down to the adhesive layers, and therefore they have become detached and torn down to a depth of 0.5 cm together with the end papers, along the spine edges.

Figure 10: Spine corner abrasion of the 25-27 and 19-21 school books

In B/5 size, the 570-gram 10-12 school book with perfect PUR binding (Figure 11) proved to be the least durable at the edges. Because of its weight, the flexible block and thin cover made the book rub along the rounded sides of the chambers, and smash against the spines. For this book type, the cover has become worn down to the adhesive layer along the spine edge, while in the head the extent of abrasion was even more serious. It means that the cover material has become so much worn that together with the end paper the spine has torn up to 0.5 cm along the spine.

Figure 11: Strongly worn spine corners in the 10-12 school books with perfect PUR binding

According the summary shown in the graph *(Figure 12)*, paperback school books have been given evaluation over value 2 on the aggregate. All of them have been considerably changed, damaged. This change has not caused damage to the spine binding. Better results in the abrasion of spine corners have been achieved for B/5 format books.

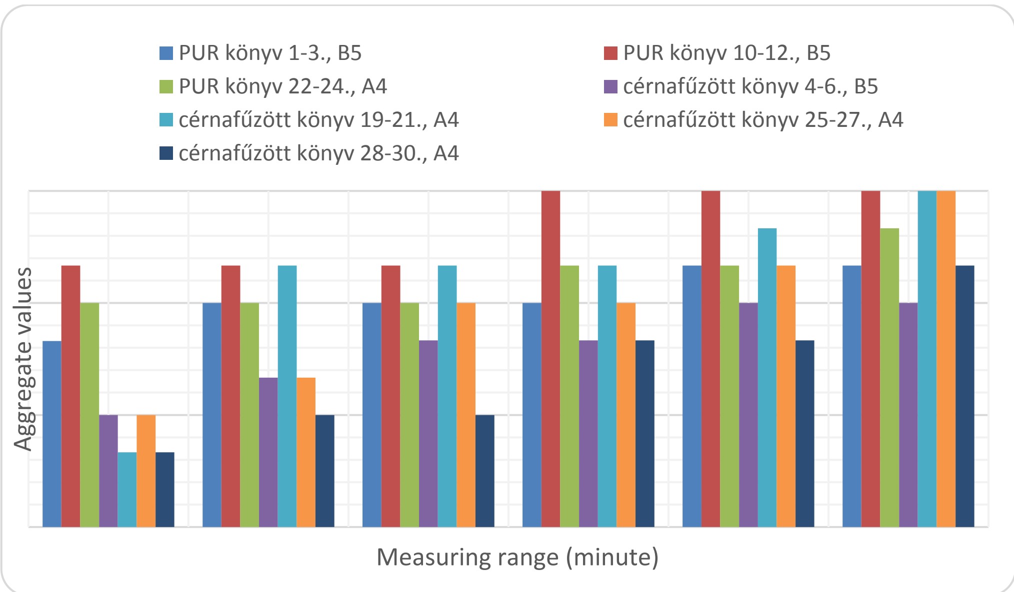

Figure 12: Spine corner abrasion for paperback books

3.3 Conditions of spine binding

The most durable binding has belonged to the B/5 sized 10-12 school book with perfect PUR binding. The graph reflects that no values have been given to it. The perfect PUR binding has proved to be strong enough in for the 496 gram weight. The sheets have remained stable.

Figure 13: Conditions of binding on the A/4 format, 25-27 thread-stitched school book

The A/4 format, 25-27 thread-stitched school book has proved to have the weakest binding (Figure 13). It has the largest weight among paperback school books. As a result of the large format and 570 gram weight, the thread-stitched spine edge has suffered larger impacts, and therefore this binding has weakened more significantly and sooner than the others. The stability of sheets has changed only to a smaller extent. Impacts have concentrated along the spine edge, and therefore this part has demonstrated stronger abrasion, as a result of which the first sheet has become torn in the head.

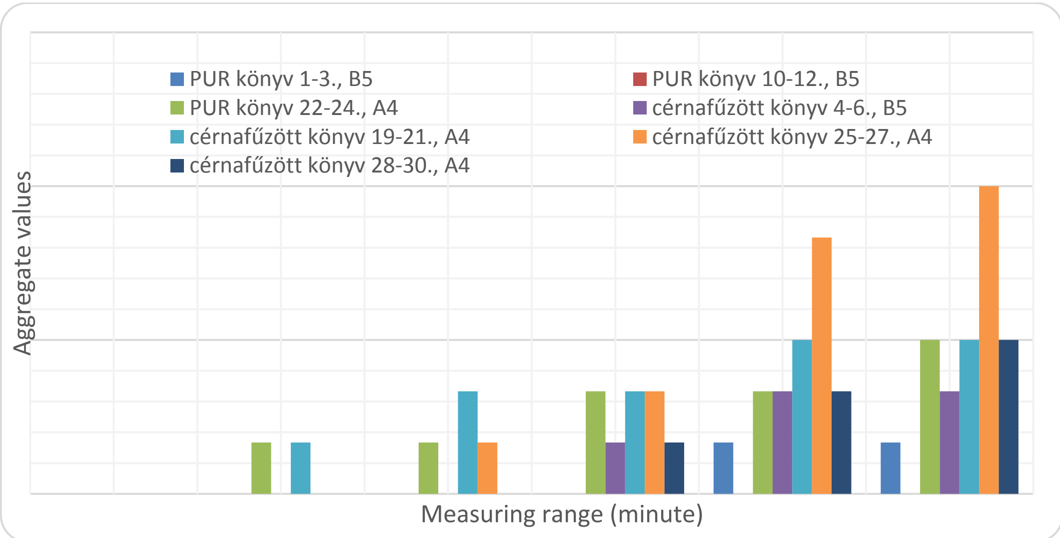

Figure 14: Conditions of spine binding for paperback books

By the end of the 60th minute, the binding has fallen into pieces in nine of the cases (Figure 14). The quality of the received school books can be regarded as appropriate. According to the summary tables, minor changes have occurred only at the end of the 50th minute.

4. CONCLUSIONS

In summary of the test results, it can be claimed that with respect to durability school books are made ideal when they are designed in smaller dimensions and with the smallest possible weight. It is better to have paperback covers, because during the performed tests hardcover books reflected more serious damage.
It has also been proved that it is reasonable to modify the test methods described in the referenced technical literature, because the recommended full testing time (60 minutes) that we have also applied is

insufficient. In our experience – and it is also reflected in the results –, it is too short. Outcomes showing serious or total damage have occurred less frequently than expected.
Obviously, another conclusion that can be potentially drawn in view of the measured results that the examined test books have had better than average quality in view of durability. Still, it can be true. Nonetheless, based on our studies this assumption cannot be scientifically confirmed.
The test method has to be refined in two respects. On the one hand, the damage time or intensity should be increased until total destruction so that clean-cut quality-related findings could be made in connection with the individual binding technologies. On the other hand, it is important to compare the accelerated destructive study with real-life use to see at what intensity the model examination can lead to the accessibility of the expected durability requirements. In this context, tests have already been conducted, and the associated results are still under processing.

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FIBRES & PAPER 2030 – SUSTAINABLE PACKAGING SOLUTIONS FOR THE WORLD OF TOMORROW

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Abstract: *The whole paper market is in transition - looking far ahead is of crucial importance if our sector wants to continue the success story of packaging materials. That's why a core project team including representatives from the whole paper industry (suppliers, manufacturers or converters) - led by Papiertechnische Stiftung PTS - looked even further ahead in the future of fibre based materials and its value chain to identify future requirements and new application areas.*
By using the method of "retropolation", the project showed that in the near future logistical concepts no longer serve the commercial interests of single groups or individuals, but society as a whole, and are geared towards ecological sustainability. Furthermore the project confirmed that in a future global bio-economy, the demand for sustainable, bio-based economic concepts will grow steadily.
That's why PTS is working intensively on the development of sustainable packaging solutions, which are essential in the sustainable world of tomorrow as well as thermo-formable and permselective packaging materials. One step in the future is the Cornet project "ACTIPOLY" with the aim to develop novel fibre-based thermo-formable packaging materials for the production of compostable trays for fresh food packaging. The second step is the project "SELECTPERM" with the objective to develop a packaging concept for regional fruit and vegetable products based on permselective packaging materials, i.e. packaging materials with selective gas permeability for oxygen and carbon dioxide. Both projects show that innovative product solutions in the logistics of tomorrow are no longer a vision, they are reality!

Key words: future project, smart packaging, sustainability, thermo-formable packaging materials, permselective packaging materials

1. A COMPLETE INDUSTRY LOOKS AHEAD

With the Roadmap 2050 and Two-Team Project of CEPI, the paper sector has confirmed its role as innovation driver in Europe by setting important technological and environmental trends. The sector has now looked even further ahead in the future of paper and its value chain: Based on the findings and results obtained by the two CEPI initiatives, future requirements and application areas for paper and other fibre-based materials were identified in a recently completed project called "Fibres & Paper 2030". Over a period of 15 months, representatives from trade associations and companies worked together to describe future markets and business opportunities for the year 2030. The main challenge was to do this in such a way that practically useful knowledge can be derived for course-setting strategic decisions and new, attractive business options.

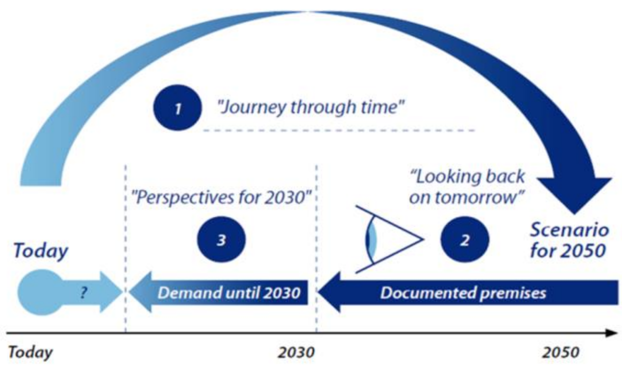

Figure 1: Method of retropolation: Travelling through time to the day after tomorrow to look back on tomorrow [Davydov, 2015]

In project meetings the team used the method of "retropolation"(Figure 1), which means they simulated a journey into the year 2050 to look back into the year 2030. They identified eight topics as being most relevant to the sector's future: nutrition, health & hygiene, mobility, information / communication / education/knowledge, logistics, future cities & architecture, living & working, and general conditions. This basic scenario was documented for the subsequent project work in the form of 106 premises (2). In six brainstorming workshops, 103 project participants from various fields and sectors looked back from 2050 on the year 2030 and even further behind towards today, developing almost 1500 ideas for new business opportunities (3). After consolidating and evaluating these ideas, a total of 640 were left. 375 of them were considered to be directly related to paper because they could be realized with the know-how currently available in the paper chain. 275 ideas were indirectly related to paper, which means they are recognizable as attractive future demands but require further research to clarify how future paper materials can contribute to meeting them (Davydov, 2016).
The project results were published in the brochure "Fibres & Paper 2030 – shaping a sustainable future". The brochure can be found on the project homepage (www.fibre-paper-2030.com) – which is meant as an invitation to act jointly for the sector's future.

2. LOGISTICS OF THE FUTURE

One of the most important thematic areas is logistics. In the near future, the system with which we are familiar today will develop into an n-dimensional logistics landscape without some of the former restrictions/disadvantages: no empty transports, minimal traffic jams, low pollution and noise despite increasing traffic and movement of freight. Over or underproduction will be virtually eliminated as well as faulty deliveries or losses due to obsolescence and spoilage.
The logistics of the future is characterized mainly by "smart packaging". Multisensory packaging materials with printed RFID technology can be used to track the supply chain, packaging materials with cooling properties, memory functions and freshness sensors contribute to increased food security and an optimized utilization of material and goods (Dobrucka et al, 2014).
The project showed that in the near future logistical concepts no longer serve the commercial interests of single groups or individuals, but society as a whole, and are geared towards ecological sustainability. Furthermore the project confirmed that in a future global bio-economy, the demand for sustainable, bio-based economic concepts will grow steadily (Davydov, 2016). That's why PTS is working intensively on the development of sustainable packaging solutions, which are essential in the sustainable world of tomorrow as well as thermo-formable and permselective packaging materials.

3. DEVELOPMENT OF THERMO-FORMABLE PACKAGING MATERIALS

One important step in the sustainable future is the ERA-NET CORNET project "ACTIPOLY". The goal of the project is the development of a novel fibre-based thermo-formable packaging material with barrier and antimicrobial functionalities intended to extend the shelf-life of fresh food. Focus will be also set on recyclability and compostability of the packaging material after usage.
The innovative core element of this project is the modification of fibre-based materials to introduce thermoplasticity. This will be essential for the production of trays. Such modifications are expected to push paper and fibre-based materials into a novel class of products exhibiting extraordinary properties where nearly no eco-friendly solutions are yet available on the market. Further development steps will include barrier functionalities for moisture and O_2 impermeability optimized for thermo-processing and also antimicrobial coatings, both intended to preserve the freshness and edibility of the packaging good and thus extending shelf-life. In the following figure 2 the development steps towards innovative trays are illustrated (Papiertechnische Stiftung, 2015; Papiertechnische Stiftung, 2016).

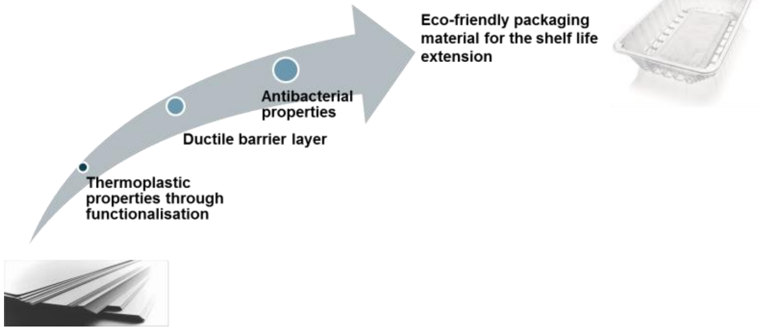

Figure 2: The development steps towards packaging trays for example for meat

4. DEVELOPMENT OF PERMSELECTIVE MATERIALS

The second step is the CORNET-project “SELECTPERM” with the objective to develop a packaging concept for regional fruit and vegetable products based on permselective packaging materials, i.e. packaging materials with selective gas permeability for oxygen and carbon dioxide. Particular emphasis is placed on ecologically beneficial packaging materials as well as their simple and easy recyclability.
The motivation behind the project was that despite the steadily growing popular demand for convenience foods like freshly cut fruit and vegetables there continues to be no efficient packaging solution for these products. Packaging solutions currently available on the market are perforated films and closed conventional packages. Both have drawbacks: in the first case, it is not possible to adjust modified atmospheric conditions inside the package. This can lower the shelf life of the packed goods. In the latter case, the barrier effect against oxygen and carbon dioxide is too big, which can promote anaerobic microbial growth inside the package (Rengstl, 2014).

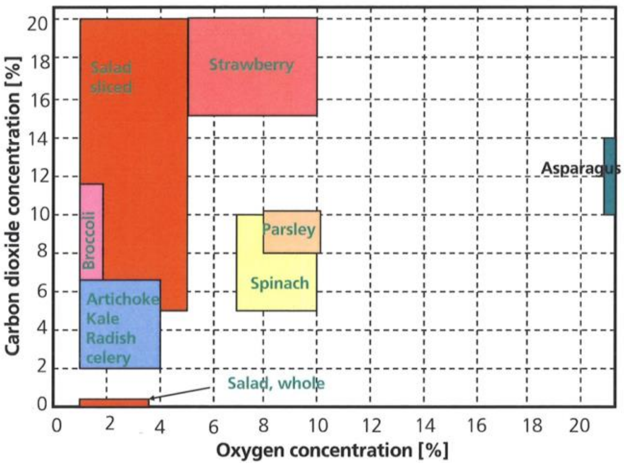

Figure 3: Required atmospheric conditions for various foods (Salveit, 2003)

Main aim of the project is therefore the systematic development of a cost-effective, environment-friendly package that is selectively permeable to oxygen and carbon dioxide. Its permeation characteristics are to be adjusted to the specific requirements of respiring goods (Figure 3). Ideally, the package will make it possible to optimally regulate the gaseous atmosphere in its interior for the packed food, thus increasing the shelf life and quality.

5. SUMMARY AND OUTLOOK

The future project “Fibres & Paper 2030” did not only provide important impulses for the paper industry. It pointed furthermore out, that paper as an innovative material will form an integral part of everyday life. Innovative product solutions in logistics are no longer a vision, they are reality!

One prerequisite for the development of further innovations is that we work together in interdisciplinary networks to gather and exchange information about requirement profiles and include developers, engineers and designers at an early stage to take full advantage of the new design opportunities offered by “papers for the future“.

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STRENGTH PROPERTIES OF NEWSPRINT FROM RECOVERED PAPER IN ADMIXURE WITH WHEAT PULP

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Abstract: *For papermakers throughout the world recovered paper that is repulped and made into new paper has become an important complement to virgin fibre. However, it should be noted that the maintenance of the fibre cycle relies on the feed of a certain amount of virgin fibres to ensure the strength and other properties of the paper to be produced. Therefore, along used papers and paperboards less expensive sources of virgin fibres such as non-wood fibres, especially agricultural waste, could be interesting alternative for pulp and paper industry. As newsprints are not high quality papers according to its optical, mechanical and chemical characteristics, in this research the possibility of using wheat semichemical pulp mixed with recycled pulp for making newsprint was studied at laboratory scale. For that purpose the tensile strength, tear resistance, bursting strength and surface strength (wax picking test) of laboratory made papers were determined according to TAPPI standards and compared to each other. Results indicated that addition of 10 to 30% wheat pulp to recycled pulp did not significantly changed the sheet strength of the laboratory newsprint compared with the control sheet (100% repulped recovered paper). Overall, the results showed that wheat straw as cheap, abundant and renewable agricultural residue of annual crops is valuable raw material which can be used as a lignocellulosic fibre for making newsprint in combination with recycled fibres.*

Key words: wheat straw, semichemical pulp, newsprint, strength properties

1. INTRODUCTION

Although the recovered paper is important complement to virgin fibre, in pulp and paper industry fibres of cellulose pulp derived still predominantly from wood (Schott et al., 2003). In Europe, recovered paper has become a major raw material representing 51 % of the total volume of the raw materials used by the paper industry (Grossmann, 2009). However, it should be noted that the maintenance of the fibre cycle relies on the feed of a certain amount of virgin fibres to ensure the strength and other properties of the paper to be produced. Therefore during papermaking process from recycled pulp, definite percentage of virgin wood (softwood) pulp is added to provide the desired strength of paper. Worldwide in the last few decades' non-wood plants and agricultural residues as virgin fibre resources attracted renewed interest for paper products. Till now only about 2% of the raw materials involved in papermaking in USA and Europe are non-wood fibres (Grossmann, 2009). Studying on utilisation of suitable non-wood species was provoked with increased trend in need and consumption of wood for different purposes and consequently the shortage of conventional wood raw material for pulping industry. Based on numerous advantages which non-wood plants offer, including short growth cycles, abundant availability and low price, such sources of fibres are used mainly for cardboards and fluting papers as low quality paper (Schall et al., 2009., Sarkhosha et al. 2009). One of the most investigated agricultural residue as non-wood raw material for pulp and paper industry is wheat straw (Potůček et al., 2014). This is understandable considering that the wheat is the most widely cultivated crop in the world (Curtis) which consequently generates substantial quantities of residues of about 529 million tons worldwide every day (Govumoni et al., 2013.). Along lots of benefits which the utilization of wheat straw for pulp and paper production have, there are also some deficiencies such as low pulp yield and problems whit the recovery of spent puling liquors by soda pulping process (Veisi & Mahdavi, 2016). On a global scale so far wheat straw pulp, carried out by soda-anthraquinone process, based on its mechanical properties has proven as a good substitute to old corrugated cardboard (OCC) pulp for making fluting paper. Namely, blending of wheat straw soda – anthraquinone pulp with OCC pulp in different ratios significantly improved all the paper properties, except tear index, compared to 100% OCC pulp (Schall et al., 2009., Sarkhosha et al. 2009).
The aim of this research was to determine the potential value of wheat straw for pulp and papermaking based on strength properties of laboratory made newsprint from recovered paper in admixture with variable content of wheat pulp. As newsprint represents a lower grade paper along accepting four-color printing (CMYK), paper strength properties are the most important one.

2. METHODS

The experimental part of this research was divided into three stages: 1. obtaining wheat pulp; 2. forming laboratory papers with variable contents of wheat pulp; 3. analysing strength properties of laboratory made newsprint sheets

2.1 Obtaining wheat pulp

For this study wheat straw as an agricultural residue of wheat crop was used. After harvesting these winter crop, the straw was collected from the fields and was cut manually into 1- to 3-cm-long pieces before it was converted into semichemical pulp according to the soda method (Plazonic et al. 2016). Operating conditions of straw pulping are presented in Table 1.

Table 1: Operating Conditions of Straw Pulping

Agricultural residues	Pulping method	Extraction conditions
Wheat straw	Soda pulping	Temperature of 120 °C, alkali level of 16% for 60 min, and a 10:1 liquid to biomass ratio

After the thermal treatment under controlled and defined extraction conditions, the pulp slurry was removed from the black process liquor by decantation and rinsed with water. In a Valley beater (Techlab Systems (TLS), Spain), pulp was diluted with tap water to maintain the pulp suspension at a 1.5% consistency and fiberized. Finally, the pulp was drained by Manual Sheet Former TAPPI (Techlab Systems (TLS), Spain) and allowed to dry to a moisture content of approximately 7% at the room temperature.

2.2 Forming laboratory newsprint with variable contents of wheat pulp

The obtained unbleached wheat pulp was mixed with recycled newsprint in different weight ratios in order to form laboratory newsprint sheets at 45 g/m^2 basis weight needed for this research. According to the general process flow of forming newsprint sheets presented in Fig. 1, three sheets containing variable content of straw pulp (Paper Sample No. 1-3) and a control sheet (Paper Sample No. 0), made only from repulped recover paper were formed (Table 2.).

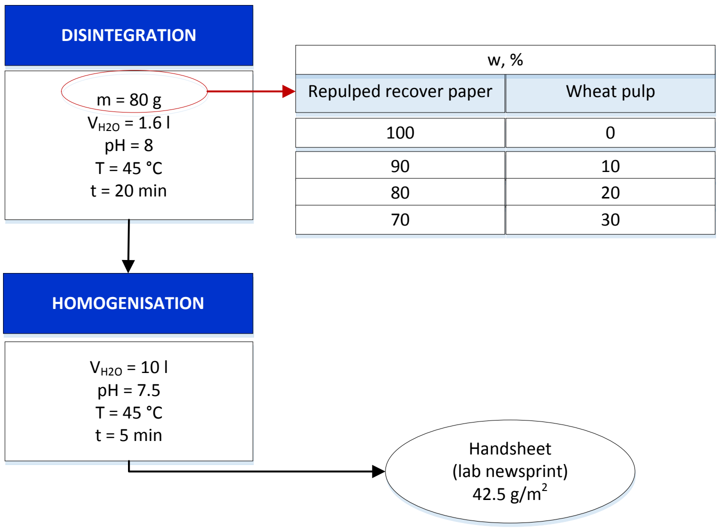
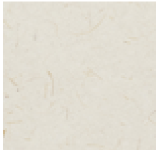


Figure 1: Workflow of forming newsprint sheets

Table 2: Combination of different ratios of wheat pulp and repulped recovered paper for laboratory newsprint sheets

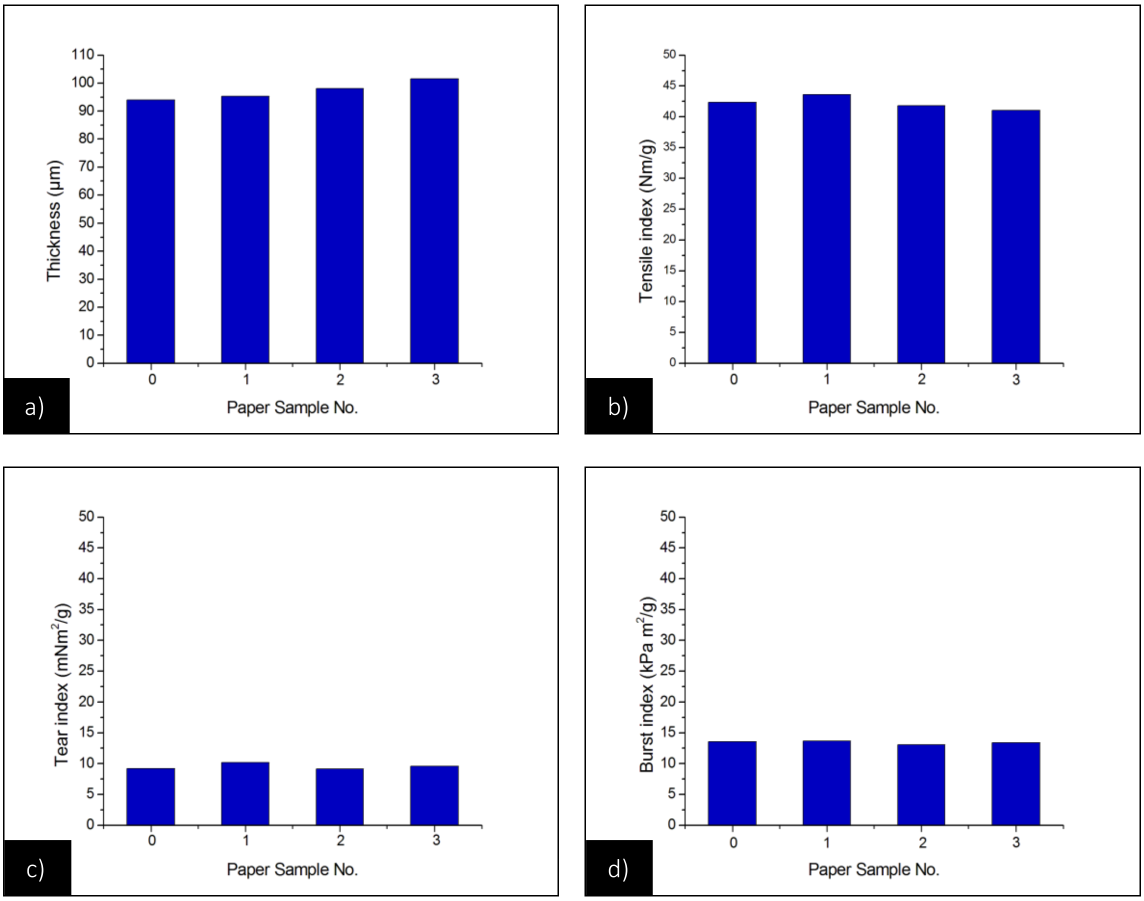
Paper Sample No.		0	1	2	3
Content	Wheat pulp	0%	10%	20%	30%
	Repulped recover paper	100%	90%	80%	70%
Explanations		Control sheet	Gradual reduction of repulped recover paper and increment of imported wheat fiber pulp		
Appearance					

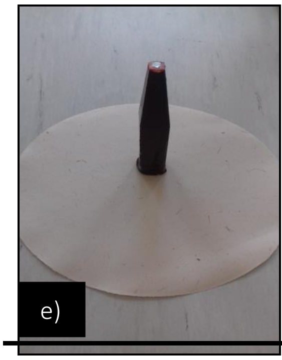
2.3 Analysing strength properties of formed newsprint sheets

The newsprint sheets properties were determined according to TAPPI standards except for thickness, which was determined by the ISO standard method.
The thickness of newsprint sheets was determined according to ISO 534 (2011), which defines a single sheet thickness as a distance between one surface of a paper and the other, measured under an applied static load. These measurements were taken with a digital electronic thickness gauge (Enrico Toniolo S.R.L., Italy), where cylindrical stainless steel weight makes pressure of 0.5 kg/cm2 (49.03 kPa).
By TAPPI standard method, TAPPI T494 (2001), the test piece of laboratory sheet was stretched to the point where the rupture occurs. The maximum tensile force the test piece can withstand before it breaks and the corresponding elongation of the strip were measured and recorded. Meanwhile, TAPPI T414 (1998) Elmendorf-type procedure, was used to measure the mean force needed to tear a single thickness of sample of newsprint that has an initial cut i.e. internal resistance of laboratory made newsprint sheets. The burst strength of each sheet was measured according to TAPPI T403 (1997) procedure.
The standard Dennison wax pick test was performed to determine the highest wax number that will not give paper failure when pulled from the surface in accordance with the TAPPI T459 (1993). This test uses a series of waxes having different adhesiveness that are numbered from 2A to 26A. The lowest wax number that does not disturb the test surface is quoted as the Critical Wax Strength Number (CWSN) and is used as a measure of the surface strength of uncoated and coated papers. A high CWSN designates a strong surface strength.
As laboratory made newsprint sheets are not homogenous materials, in all strength paper testing measurements were repeated 10 times to obtain a more precise estimate of the value for the property measured.

3. RESULTS

After the experiment data processing, the effects of varies blending levels of two pulp types (wheat pulp and repulped recover paper) on the average thickness and strength properties (tensile index, tear index, burst index and CWSN) of the newsprint handsheets was established. Figures 2a-e summarise the influence of variable soda wheat pulp content in laboratory made newsprint samples on paper strength properties. Paper Sample No.0 is Control sheet formed only from repulped recover paper, while in Paper samples No. 1-3 repulped recover paper content were gradual reduced by increment of imported wheat fiber pulp (10-30%).





Paper Sample No.	CWSN
0	7A
1	7A
2	7A
3	6A

Figure 2: Effect of wheat fibre pulp on: a) thickness of newsprint sheets; b) tensile index of newsprint sheets; c) tear index of newsprint sheets; d) burst index of newsprint sheets; e) CWSN of newsprint sheets

4. DISCUSSION

The strength properties of paper samples are substantially influenced by individual characteristics of cellulose fibres as well as by the paper network structure. It is important to say how this research was studied at laboratory scale. Namely, if we talk about commercial newsprint behaviour due to the orientation of fibres some strength properties are derminated for two directions. Namely, for measuring tensile and tear resistance from the same sheet of paper two strips were cut in two directions: machine direction (MD - the direction in which the paper moves during manufacture) and cross-machine direction (CD - the direction at right angles to the machine direction). In laboratory made newspapers, fibres are not properly oriented as in commercial papers, due to the way of functioning semi-automatic Rapid-Kothen sheet former used for making laboratory sheets. Laboratory papers as fibre-based material contain significant variations in a structure. These variations are natural due to fact that its individual fibres are differ in length, shape, chemical structure etc. The differences and variations of properties of

fibres increase during pulping and in papermaking process variations in the structure and properties of paper are created as well. The inhomogeneity of the pulp and paper material strongly effect on the strength properties results of the paper.
The effect of wheat fibre pulp on strength properties of laboratory newspaper samples were discussed by comparison with control sheet (Paper sample No.0). On the basis of these results (Figure 2a-e), it can be concluded that all variety of wheat fiber pulp, carried out by conventional soda process, resulted in laboratory newspapers having almost equal values in all of the observed properties.
In the case of thickness, results were in a range between 94.0 and 101.5µm. The Figure 2a shows the relationship between thickness and imported wheat fiber pulp in repulped recover paper of handsheet. Namely, addition of wheat fiber pulp to the main recovered paper portion produced laboratory newspapers with higher thickness.
Tensile index, tear index and burst index are probably the most used ones for the direct measurement of the paper strength potential. Figure 2b shows the relationship between tensile index and laboratory newsprint samples composition. It can be seen that the trend of tensile strength development after wheat fiber pulp addition was negligible decreased. The tensile index of Control sheet was 42.34 ± 3.45 Nm/g and of Paper sample No.3 with the highest content of wheat fiber pulp was 41.02 ± 1.61 Nm/g. Tear index and burst index values were similar for all analysed Paper samples. No significant changes were observed in tear index (Figure 2c) and burst index (Figure 2d) of laboratory made newsprint sheets with the addition of wheat straw pulp.
From Figure 2e it could be clearly seen how the surface strength (CWSN value) of the laboratory papers containing straw fibre pulp were similar to those of the control sheet (CWSN =7A), except for Paper Sample No.3 with 30% of straw fibre pulp (CWSN= 6A).
In the scope of our study, the preliminary results obtained offer a possibility to utilize soda pulp from wheat straw, at least partially, in the pulp and paper industry, e.g., in admixure with recovered paper to manufacture newsprint.

5. CONCLUSIONS

The aim of the research was to point out the influence of wheat fibre pulp on strength properties of newsprint. The admixture of 10% of soda wheat fibre pulp and 90% recovered paper produced laboratory newsprint with greater tensile, tear and burst strength than the control sample of 100% recovered paper newsprint. The maximum portion of wheat fibre pulp in newspaper handsheet was 30%, and strength properties of those papers were negligible lower in comparison to control sample. Overall, the results of this study suggest that the potential of wheat straw in supplying fibre for making newsprint should be further considered.

6. ACKNOWLEDGMENTS

The authors are grateful for the funding provided by the University of Zagreb.

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DYNAMIC COLOUR CHANGE OF THERMOCHROMIC INKS CONTAINING CUSTOM MADE THERMOCHROMIC PIGMENTS

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Abstract: *The aim of this work was to prepare series of thermochromic pigments by microencapsulating three-component leuco dye based thermochromic system in melamine-formaldehyde polymeric envelope. Thermochromic system used in scope of this work contained crystal violet lactone as a colour former, bisphenol A as a developer and 1-tetradecanol as a co-solvent. The process of in-situ polymerization varied in type of emulsifier and prepolymer used. Other parameters, such as temperature, pH, content of the continuous phase and content of the thermochromic core, were kept constant. Prepared pigments were dried in a spray dryer. Microcapsules were analysed by scanning electron microscopy before and after drying. Each obtained pigment powder was mixed into water-based and solvent-based binder. Final thermochromic ink was coated on standard IGT paper and let to dry. Paper substrate with a layer of thermochromic ink was placed on thermally regulated copper plate and reflectance spectra were continuously captured during heating and cooling of the sample. The dynamic colour change was evaluated by using cumulative colour difference in CIELAB space. The preparation of microcapsules with poly(ethylene-alt-maleic anhydride) emulsifier resulted in stable pigments that produced good thermochromic behaviour of the final ink, with large colour contrast and the temperatures characterizing the dynamic colour change lower than those of the original thermochromic system.*

Keywords: thermochromic, microcapsules, dynamic colour change

1. INTRODUCTION

Production of thermally sensitive prints is based on the application of special inks containing thermochromic (TC) pigments that can be either leuco dye based or liquid crystal based (Kulčar et al, 2010; Klanjšek, 2011; Jakovljević et al, 2013). In most of applications, reversible leuco dye based TC systems become decoloured when heated and exhibit very complex dynamic colour change (Panák, et al, 2012; Panák, et al, 2015; Hajzeri et al, 2015).

These inks can be used for print protection and quick verification (Philips, 2003; Philips, 2000; Benson, 2001). By appropriate modelling, image appearance can be changed when the image is heated above activation temperature of applied TC inks (Johansson and Kruse, 2005; Panák et al, 2011; Panák et al, 2015). The colour change is based on the interaction of a colour former with a developer in a co-solvent environment (Panák, et al, 2012; Panák, et al, 2015; Hajzeri et al, 2015; Tang et al, 2010).

When the co-solvent is in the solid state, the coloured complex of the colour former and the developer is usually formed. The complex is destroyed by melting of the co-solvent and the system becomes colourless. The dynamic colour change of leuco dye based system heavily depends on chemical structure of its components and their molar ratio (Panák, et al, 2012; Panák, et al, 2015; Hajzeri et al, 2015; Tang et al, 2010; Bourque and White, 2015). Because the leuco dye based TC systems undergo the phase change, they have to be transformed to the pigment by microencapsulation (Seeboth and Lötzsch, 2014; 2008). Melamine-formaldehyde (MF) resin is reported as the shell-forming polymer of TC pigments (Seeboth and Lötzsch, 2014; Seeboth and Lötzsch, 2008; Katsuyuki and Kuniyuki, 2002; Ono, 2012). The microencapsulation into MF resin is well described in the literature (Palanikkumaran et al, 2009; Alic et al, 2011; Boh et al, 2005; Krupa et al, 2014; Sumiga, 2011). The core material is emulsified in a water continuous phase that contains the dissolved MF prepolymer, or the MF prepolymer is added after emulsification. As the second step, the *in-situ* polymerization is performed by adjusting the pH and temperature in the reactor. In the microencapsulation of phase change materials, styrene-maleic anhydride (SMA) copolymer is often applied as an emulsifier (Boh et al, 2005; Krupa et al, 2014; Sumiga, 2011). Polyvinyl alcohol (PVA) can be found as the emulsifier of TC systems in patent literature (Katsuyuki and Kuniyuki, 2002; Ono, 2012). Seeboth et al. discusses the role of the emulsifier structure on the functionality of the final thermochromic system (Seeboth and Lötzsch, 2014).

In our previously published work (Panák et al, 2011), we have used commercially available water solution of sodium salt of SMA copolymer for emulsification. The dynamic colour change of resulting MF-microencapsulated pigments was very low. This paper focuses on colour change of TC inks, where custom made TC pigments are microencapsulated in MF resin using different emulsifiers and each pigment is dispersed in water- and solvent-based binder, respectively.

2. MATERIALS AND METHODS

2.1 Thermochromic system

The three-component TC system containing crystal violet lactone (6-(dimethylamino)-3,3-bis[p-(dimethylamino) phenyl] phthalide, > 95%) as the colour former, bisphenol A (2,2-bis(4-hydroxyphenyl)propane, > 99%) as the developer and 1-tetradecanol (> 98%) as the co-solvent with the molar ratio of 1 : 4 : 100 was chosen as the functional thermochromic core of microcapsules. The preparation and characteristics of this TC system can be found elsewhere (Panák et al, 2015; Panák et al, 2017). The above-mentioned chemicals were purchased from Tokyo Chemical Industry (JP) and were used without further purification.

2.2 Microencapsulation

Prepared TC pigments are listed in Table 1. They differ in type and content of the emulsifier, and the stirring method applied during the polymerization. Also, two melamine-formaldehyde prepolymers were used: Melapret NF 70 and Melapret PTS 70, both supplied by Melamine (SI). The rest of the process, described in the following text, was kept the same.

Table 1: Overview of prepared samples.

Sample	Emulsifier	Supplier	Dry content [g]	Prepolymer	Stirring
X0	Poly(ethylene-alt-maleic anhydride) M_w = 100 000–500 000	Sigma Aldrich	2	NF 70	magnetic
X1	Poly(ethylene-alt-maleic anhydride) M_w = 100 000–500 000	Sigma Aldrich	2	NF 70	shaft
X2	Poly(methyl vinyl ether-alt-maleic anhydride) M_w = 216 000	Sigma Aldrich	2	NF 70	magnetic
X3	Poly(styrene-co-maleic anhydride), cumene terminated , M_n = 1 600	Sigma Aldrich	2	NF 70	shaft
X4	Poly(styrene-alt-maleic acid) sodium salt Mw = 350 000, 13 mass % in H_2O	Sigma Aldrich	1.5	NF 70	shaft
X5	Xiran SL26080 S25 Poly(styrene-alt-maleic acid) sodium salt M_w = 80 000, 24.3 mass % in H_2O	Polyscope	1.5	NF 70	shaft
X6	Xiran SL26080 S25 Amic acid solution of poly(styrene-alt-maleic acid) ammonia salt M_w = 5 000, 30.08 mass % in H_2O	Polyscope	1.5	NF 70	shaft
P1	Moviol 18-88, Polyvinyl alcohol M_w = 130 000	Sigma Aldrich	1.1	NF 70	magnetic
P2	Moviol 18-88, Polyvinyl alcohol M_w = 130 000	Sigma Aldrich	1.1	PTS 70	magnetic
C1	Hexadecyltrimethylammonium chloride	Tokyo Chemical Industry	0.2	PTS 70	magnetic
C2	Trimethylstearylammonium chloride	Tokyo Chemical Industry	0.2	NF 70	magnetic

For pH adjustments, 5 % solution of NaOH and 5 % solution of acetic acid were used. First, the emulsifier was dissolved in 170 ml of demineralized water at 60–90 °C and the pH was adjusted to 4.8. Then, 20 g of TC system was added and emulsified for 20 minutes at 7 000 rpm by Ultra Turax T18 homogenizer (IKA) at the temperature of 70 °C. Before the end of the emulsification, 9.5 grams of the prepolymer were dissolved in 20 ml of demineralized water at room temperature. The solution of prepolymer was also adjusted to the value of 4.8 pH. The emulsion was poured into a glass reactor, followed by a slow addition of prepolymer solution at constant mixing at 1 000 rpm. If needed, pH in the reactor was adjusted to the value of 4.8. The temperature reached the desired value of 69–72 °C within 5 minutes and was kept in this interval for the rest of the microencapsulation process that took 180 minutes. Finally, the pH in the reactor was adjusted to 7 and while mixed, the suspension was cooled down to 20–23 °C. Dry particles were obtained by Mini Spray Dryer B-290 (Büchi) with the temperature of the jet set to 120 °C.

2.3 Inks

Selected pigment powders were mixed into water-based and solvent-based binder. The water-based binder was a 3 % solution of carboxymethyl cellulose (Mw 250 000) purchased from Sigma Aldrich (USA), and the solvent-based binder was a commercially available screen-printing varnish Polyplast PY383 (Fujifilm Sericol, UK). Formulated thermochromic inks were coated on the standard IGT paper (IGT Testing Systems, NL) by the four-sided film applicator (Sheen Instruments) with the nominal thickness of wet layer of 60 µmand let to dry.

2.4 Analyses

Paper substrate with the dry layer of thermochromic ink was placed on a copper plate heated or cooled by the Peltier element connected to a programmable controlling unit. The temperature program had cooling–heating–cooling sequence. The higher temperature limit was set to 50 °C and the lower temperature limit to 5 °C. The continuous temperature change was about 5 °C/minute. At the beginning of the program and after reaching each cooling or heating temperature limit, the sample was tempered for 5 minutes. Reflectance spectra were measured by i1Pro spectrophotometer (X-Rite) with 45c/0 geometry in shortest possible intervals (approx. 3 s); measured values were recorded using KeyWizard software together with the time stamp. The time of the reflectance measurement was synchronized with the time recorded along with the temperature from the controlling unit of the Peltier element. This way all spectra were assigned with corresponding temperature. In evaluation, only the last heating–cooling cycle was considered in order to minimize the influence of sample temperature history. Reflectance spectra were transformed to CIELAB space using D65 standard illuminant and 2° observer. The dynamic colour change was evaluated by using cumulative colour difference ΔE_C; the concept is in detail explained elsewhere [5, 24]. Then, the gradient $G(T)$ of $\Delta E_C(T)$ at i-th measurement was calculated separately for heating and cooling according to the Equation 1.

$$G\left(T_{(i)}\right) = \left| 0.5 \times \left(\frac{\Delta E_{C(i)} - \Delta E_{C(i-1)}}{T_{(i)} - T_{(i-1)}} + \frac{\Delta E_{C(i+1)} - \Delta E_{C(i)}}{T_{(i+1)} - T_{(i)}} \right) \right| \tag{1}$$

Based on the $G(T)$, the characteristic temperatures were determined: the temperature at which the decolouration starts (T_{DS}) and the decolouration ends (T_{DE}) at heating, and the colouration starts (T_{CS}) and colouration ends (T_{CE}) at cooling. These temperatures corresponded to the temperatures at which the $G(T)$ = 1; the threshold was derived from the most commonly used value of just noticeable colour difference. The ΔE_C value at 50 °C on heating was taken as the value of colour contrast (*CC*).
Microcapsules were analysed by SEM microscopy (VEGA II LSU, TESCAN) before and after spray drying. All samples were coated by thin gold layer prior to scanning.

3. RESULTS AND DISCUSSION

3.1 SEM analysis

The SEM micrographs of prepared pigments are presented in Figures 1–9. The best results were obtained by the application of poly(ethylene-alt-maleic anhydride) copolymer as the emulsifier (see Figures 1 and 2). The thermochromic core seems to be completely encapsulated in polymeric envelope and most of the particles are regularly shaped, without excess wallforming material. During drying, almost all material was captured in the collecting cyclone of the dryer and obtained microcapsules retained their shape. This indicates that microcapsules are stable under the conditions applied in spray dryer. The particles are sized in micrometres and a few tens of micrometres with relatively wide size distribution. With respect to stirring, no significant differences were observed for shaft and magnetic options.

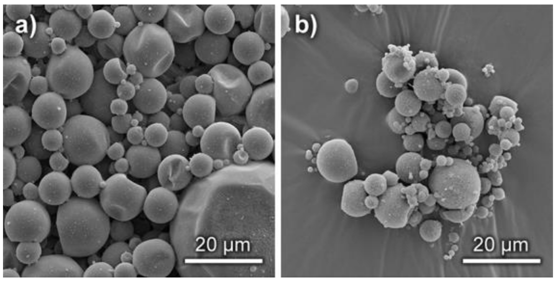

Figure 1: Sample X0 before (a) and after (b) drying.

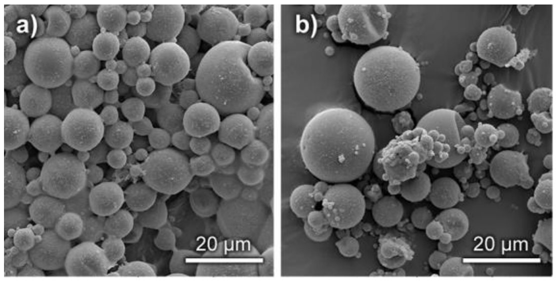

Figure 2: Sample X1 before (a) and after (b) drying.

In case of sample X2, spherical microcapsules still can be observed, however, their stability seems to be lower than the stability of X0 and X1 samples, as demonstrated by higher number of broken microcapsules (Figure 3a) or empty (Figure 3b) microcapsules. All samples prepared with emulsifiers based on styrene-maleic anhydride copolymer (X3, X4, X5, X6) exhibit very rough surface of microcapsules. From the micrographs before and after drying it can be concluded that not all of the thermochromic core is encapsulated (see Figure 4). Sample X3 was impossible to dry in spray dryer due to the nozzle clogging. Powders of samples X2, X4, X5, and X6 collected in cyclone had pale colour. These samples also stuck more on the walls of the drum in the spray dryer. It is thus expected that the ratio of the wall forming material and the core is higher than in case of X1 sample. However, the size of microcapsules is comparable with samples X0 and X1.

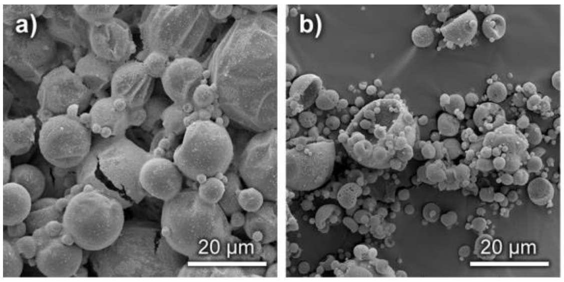

Figure 3: Sample X2 before (a) and after (b) drying.

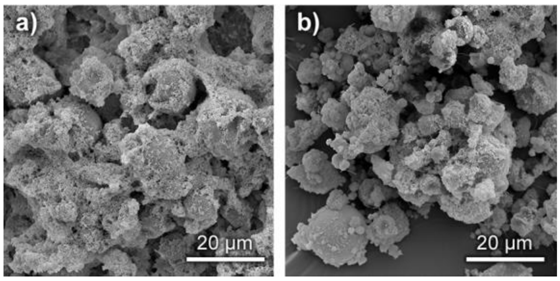

Figure 4: Sample X4 before (a) and after (b) drying.

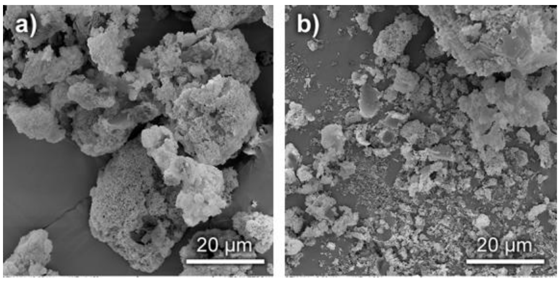

Figure 5: Sample X5 before (a) and after (b) drying.

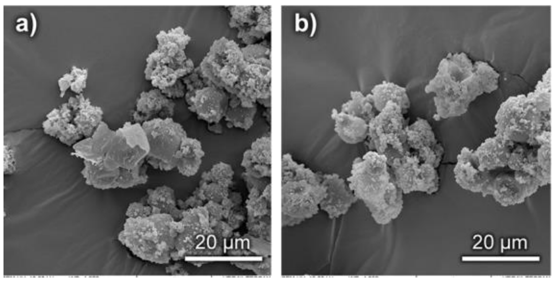

Figure 6: Sample X6 before (a) and after (b) drying.

Smallest particles were obtained in case of samples C1 and C2. The final suspension of these two samples was very thick. As it can be seen in Figure 8, the as-prepared sample contains large amount of nonencapsulated core material that was removed during drying, resulting in microcapsules with the size of a few micrometres. Samples P1 and P2, which were prepared using polyvinyl alcohol emulsifier, had less regularly shaped microcapsules. When the PTS 70 prepolymer was used, the microcapsules seemed to be more separated, however with small beads on the surface. The drying of P1 and P2 samples completely destructed the microcapsules and unmeasurable mixture of the core and the wall material was collected in the spray dryer.

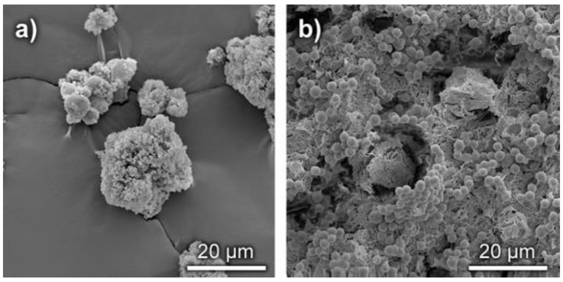

Figure 7: Samples X3 (a) and C2 (b) before drying.

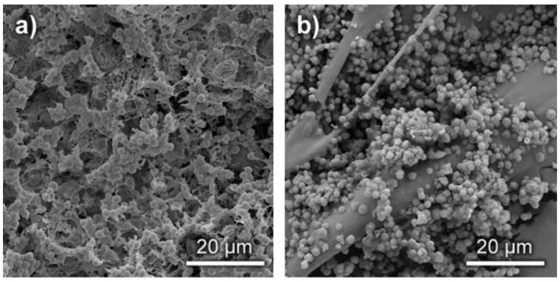

Figure 8: Sample C1 before (a) and after (b) drying.

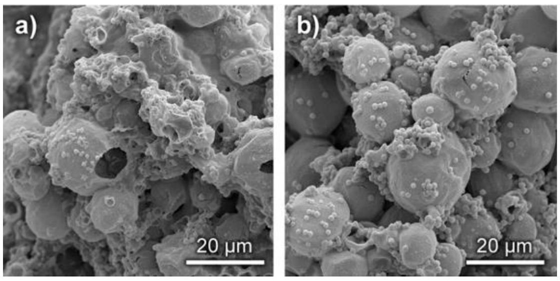

Figure 9: Samples P1 (a) and P2 (b) before drying.

3.2 Colorimetric analysis

Powders of C1 and C2 samples became decoloured immediately after mixing with the water-based as well as solvent-based binder. The colour of the ink with the X5 sample pigment coated on standard paper had very low intensity. It was concluded that these pigments do not have sufficient resistance to the binder environment and therefore they were not analysed in temperature dependent colour measurements. In case of all the other samples, the dynamic colour change is different for individual inks, with significant difference between X1 and remaining pigment samples (Figures 10 and 11). The path specifying the colour change upon heating differs between the pigments incorporated into water-based and solvent-based formulations, as shown in Figures 10a and 11a, respectively. Similarly, the dynamic colour change represented by $\Delta E_C(T)$ differs between corresponding water-based and solvent-based formulations of X2, X4, and X6 pigment samples and the colour contrast of water-based formulations is larger than for solvent-based ones (Figures 10b and 11b, respectively). Due to the low colour contrast of these samples, their characteristic temperatures could not be found according to the procedure described in section 2.4.

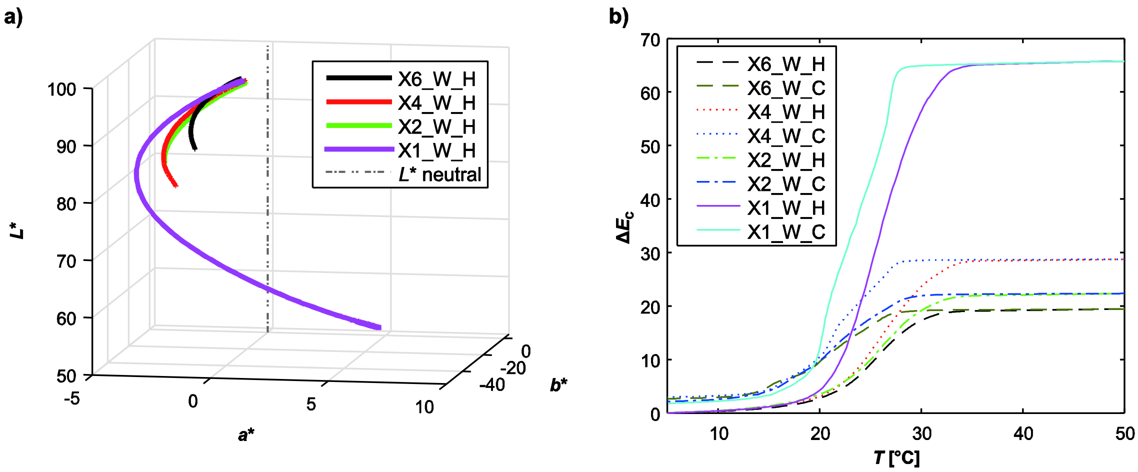

Figure 10: The colour path in CIELAB space (a) and cumulative colour difference (b) of water-based inks; W – water-based ink, H – heating, C – cooling.

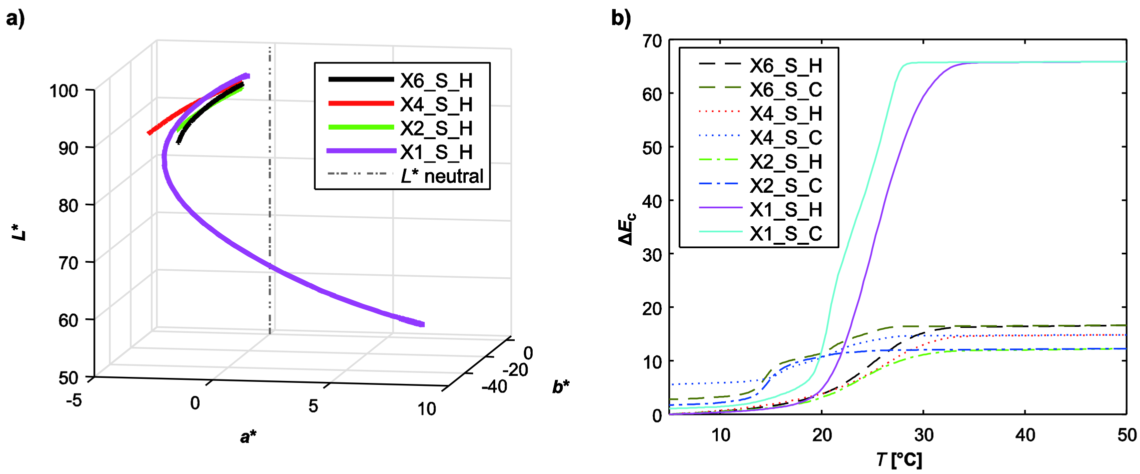

Figure 11: The colour path in CIELAB space (a) and cumulative colour difference (b) of solvent-based inks; S – solvent-based ink, H – heating, C – cooling.

Even though the path in CIELAB space differs when comparing the X1 pigment in water-based and solvent-based binder, the dynamic colour change represented by $\Delta E_C(T)$ is very similar, with very good match in characteristics shown in Table 2. Characteristic temperatures of printed formulation with X1 pigment sample have much lower values than those of bulk TC system, especially at decolouration limits. This might be due to the fact that the TC system is in microcapsules separated in small volumes. The colour contrast of the bulk TC system represents the contrast of 100 % mass of functional material. Considering that the pigment contains some ratio of this functional material to the shell material, that the pigment is mixed in certain concentration into the binder, and that the coated layer has certain thickness, the resulting contrast of coated thermochromic formulations based on X1 pigment can be evaluated as very good.

Table 2: Characteristics of dynamic colour change (see section 2.4); W – water-based ink, S – solvent-based ink.

Sample	*CC*	T_{DS}	T_{DE}	T_{CS}	T_{CE}
TC system [5, 24, 25]	148.6	21	38	36	20
X1_W	65.8	18.9	33.0	28.1	17.2
X1_S	65.9	18.8	32.7	28.3	17.3

4. CONCLUSIONS

Thermochromic system containing crystal violet lactone, bisphenol A and 1-tetradecanol was microencapsulated by eleven methods that varied in emulsifier type, concentration and stirring. Samples were analyzed by SEM microscopy before and after drying in spray drier. Dried powder was incorporated in water based and solvent based binder and coated onto a standard IGT paper. Only four samples were analyzed in temperature controlled regime. The best result was obtained in case of application of poly(ethylene-alt-maleic anhydride) copolymer as emulsifier. Prepared microcapsules were regularly shaped sphered with smooth surface. The conditions applied in spray drier did not change the appearance of the microcapsules. The characteristics of dynamic colour change characteristic of water based and solvent based formulation was almost identical. However, characteristic temperatures of coated thermochromic inks were much lower than those of the bulk thermochromic system. To obtain smaller size and narrower size distribution of prepared microcapsules other parameter influencing the microencapsulation should be modified and tested.

5. ACKNOWLEDGEMENTS

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COLORIMETRIC PROPERTIES OF REVERSIBLE THERMOCHROMIC INK ON DIFFERENT PAPERS

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Abstract: *The colorimetric properties of one, leuco dye-based thermochromic (TC) ink at 27^{0}C activation temperature on four different paper samples were studied. The paper samples are: filter paper, bulky paper, recycled paper and synthetic paper. The each sample was heated from the 15 ^{0}C to the 60^{0}C and then cooled back to the 15^{0}C. The colour of the ink was dependent on temperature as well as the thermal history of the sample, which gives rise to colour hysteresis. Four characteristic temperatures were determined from L*(T) hysteresis and they are the same for TC ink print on all examined papers. The differences in colour that occur on the TC print during the process of heating and cooling at the same temperature, are the highest in the case of TC print on filter paper.*

Key words: thermochromic ink, papers, characteristic temperatures, colour difference

1. INTRODUCTION

Thermochromic (TC) materials respond to changes of temperature by colour change. Thermochromic printing inks have become increasingly important for various applications in graphic art such as smart packaging, security printing and marketing activities (Kulcar et al. 2010). Composite thermochromic pigments consist of three components: leuco dye (colour formers), colour developer and co-solvent. To achieve the desired effect the components are mixed in specific rations and usually encapsulated to protect the system in subsequent applications. The normal colour change is from coloured to colourless state but, by careful selection of dye, it can also be from one colour to another (Bamfield 2001). A thermochromic printing ink is a mixture of thermochromic pigments and a binder (Kulcar et al. 2010). The microcapsules size ranges are typically 3 – 5 μm which is >10 times larger than conventional pigment particles (Kulcar et al. 2010). TC inks with activation temperatures ranging from 15^{0}C up to 65^{0}C are commercially available in all major ink types for applications on paper, plastic, metal and textiles. Discoloration of the TC ink typically occurs at higher temperatures than coloration. In the intermediate region, the colour of a TC sample depends on the temperature and also on the thermal history, which results in a colour hysteresis (Friškovec et al. 2013). Despite the relatively well known functionality of thermochromic leuco dye-based inks, very little has been published about their colorimetric characteristics. These are of significance from an application perspective. The most important characteristics are their temperature-dependent properties and the degree of its reversibility. This paper concerns the colorimetric properties of blue leuco dye-based thermochromic ink with an activation temperature of 27^{0}C on different paper substrates. The influence of paper substrate on colour hysteresis, reversibility of the thermochromic process and the characteristic temperatures has been presented.

2. METHODS

In preparation of the experiment four different paper samples were used: filter, recycled, bulky and synthetic. Filter paper Whatman was used to simulate 100% pure cellulose paper without any additives or fillers, recycled paper containing 100% of recycled fibres Evercopy+Clairefontaine. Bulky paper Munken Print White (80g/m^2) was also used. It contains wood free pulp and more than 10% mechanical wood pulp. According to the producer, YUPO synthetic paper (73 g/m^2) is 100% recyclable, waterproof and wood-free. It consists of a base layer and paper-like layers laminated on both sides, extruded from polypropylene pellets. This type of synthetic paper is commonly used for different graphic products such as posters and book covers or in packaging application.

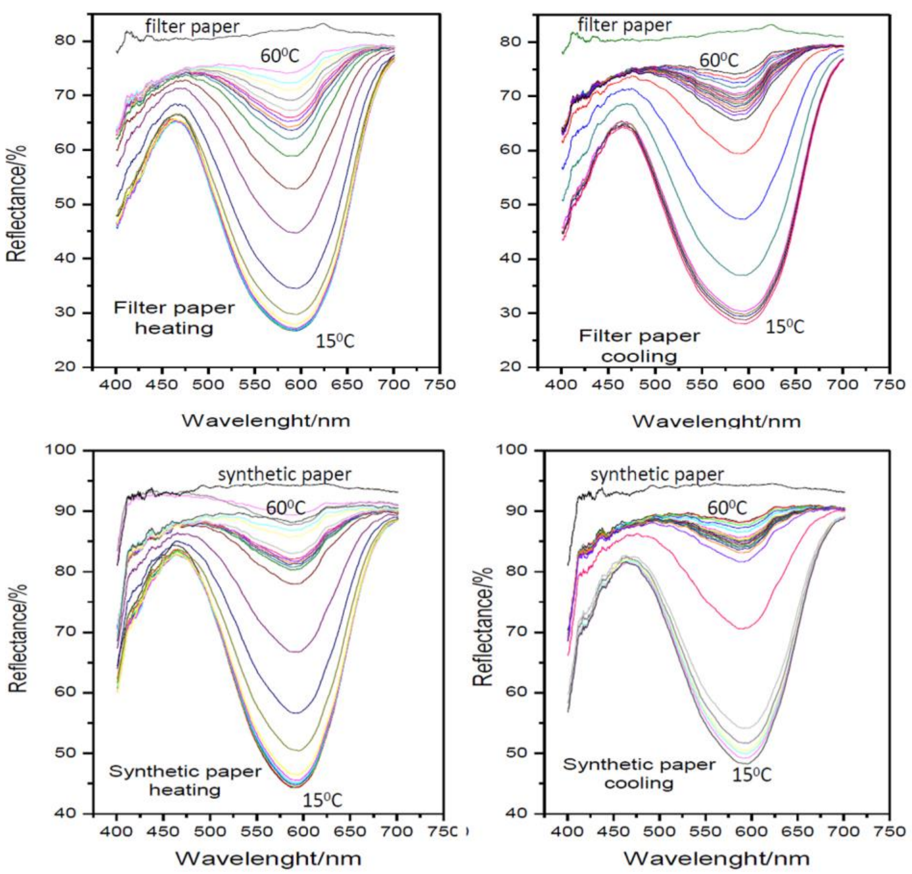
One commercially available offset ink with an activation temperature of 27^{0}C in blue color shade was applied (CHAMELEON). The printing trials were carried out using the Prüfbau Multipurpose Printability Tester. The quantity of 1 cm^3 of ink was applied on the distribution rollers while printing was carried out

with the printing force of 600 N. The papers were printed in full tone. Thermochromic ink was 30% pigmented, and the particle size of the pigment was 6 μm.
The colorimetric properties of thermochromic samples were described in the *CIELab* color space. Temperature-dependent colorimetric properties were measured using Ocean Optics USB2000+ spectrophotometer and Ocean Optics SpectraSuite software for the calculation of the *CIELab* values L^*, a^*, b^* and C^* from measured reflectance in the spectral range of 400-700 nm (in 1 nm steps). The D50 illuminant and 2^0 standard observer were applied in these calculations. The colour difference between the samples at low and high temperature, as well as degree of discoloration was calculated using the formula CIEDE2000 (CIE Central Bureau 2004), compared to the paper on which the print was obtained. Each sample was heated by the Full Cover water block (EK Water Blocks, EKWB; Slovenia). The temperature of the copper plate surface was varied by circulation of thermostatically controlled water in channels inside the water block, which was assured to be up to 1^0C accurate in the applied temperature region. In each cycle the sample was heated from the 15^0C to the 60^0C and then cooled back to the 15^0C. Between 19 and 35^0C the reflectance spectra were measured in 1^0C intervals. Between 15 and 19^0C the reflectance spectra were measured in 2^0C intervals and between 35 and 60^0C the reflectance spectra were measured in 5^0C intervals. Heating/cooling rate was of about 0.5^0C/min.

3. RESULTS AND DISCUSSION

3.1 The curves of the spectral reflectance and discoloration of the samples at the highest temperature (60°C)

Thermochromic ink shows colour at lower temperatures (blue colour) and it's discoloured at higher temperatures. As it can be seen from the curves of spectral reflectance, thermochromic ink applied on all paper samples lost its colour when heated and again it during cooling. Reflection spectrophotometric curve is not the same for the same sample at the same temperature for heating and cooling (Figure 1.).



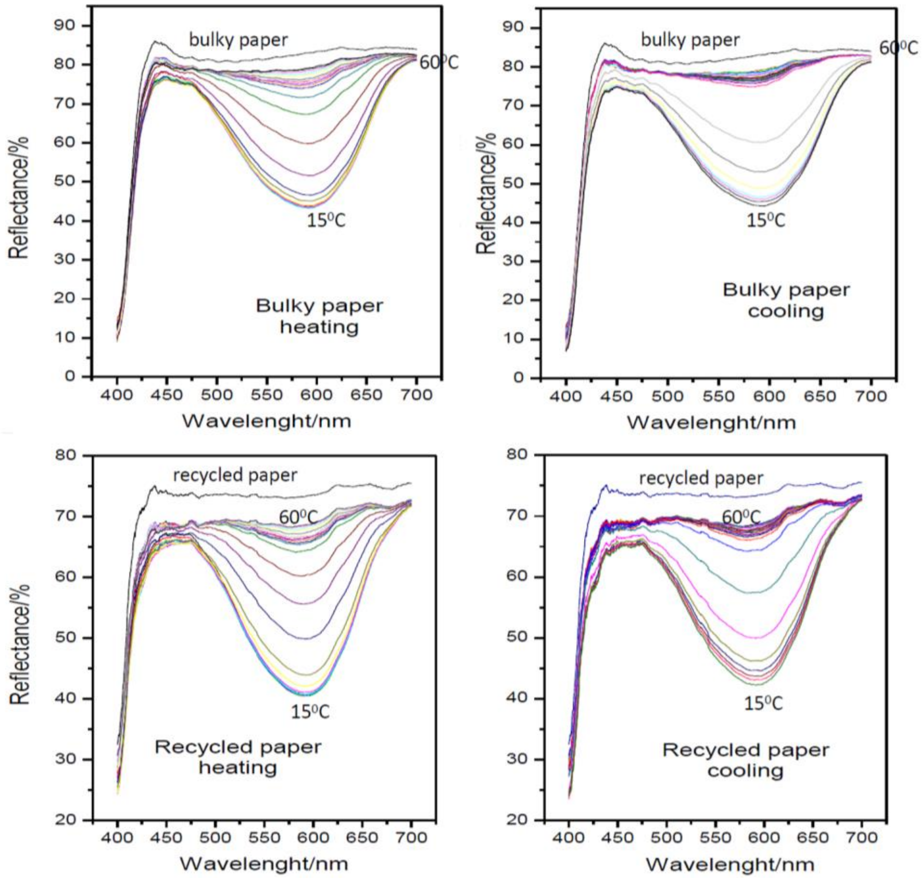


Figure 1: Reflectance spectra

On the thermochromic ink spectral reflection curves may be noted that none of the samples reaches the spectral reflectance of neat paper on which TC ink was printed. Decolourization is not complete even when the highest temperature was applied, which is significantly beyond the activation temperature. In order to determine decolourization of the TC prints at the highest temperature, in addition to the curve of spectral reflectance, the colorimetric parameters *L*, a*, b** and *C** of neat and printed papers were also measured. The results are presented in Tables 1 and 2.

Table 1: L, a*, b*, C* values of TC print at 60^{0}C on examined papers*

	L*	a*	b*	C*
Bulky paper	91.2	0.8	1.4	1.6
Synthetic paper	95.6	-0.3	1.3	1.4
Recycled paper	86.6	0.1	1.6	1.6
Filter paper	89.5	0.2	1.5	1.5

Table 2: L, a*, b*, C* values of original papers*

	L*	a*	b*	C*
Bulky paper	92.7	1.3	0.6	1.4
Synthetic paper	97.7	-0.3	0.9	0.9
Recycled paper	88.7	0.4	0.4	0.5
Filter paper	92.4	0.6	0.8	1.0

Based on the values of colorimetric parameters, the difference between the colorimetric parameters of neat and printed paper were determined (Figure 2).

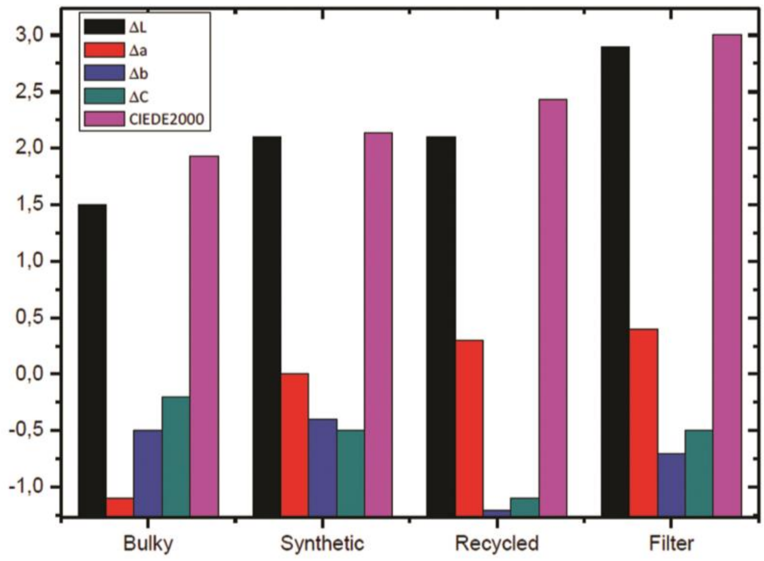


Figure 2: CIEDE2000, ΔL, Δa*, Δb* and ΔC*values between original papers and printed paper samples at 60^{0}C*

All prints at 60 ^{0}C have lower *L** values compared to the *L** values of neat paper. All prints retain a shade of yellow (positive *b** values, Table 1) which differs from the neat papers (Table 2).
The highest *L** value has a synthetic paper, while the lowest has recycled paper (Table 2). For the synthetic paper the colour migrate into the area of green (*a** = - 0.3), and the other samples of paper into the area of red (positive *a** values). Figure 2 shows that the *ΔL** values between the neat and printed paper at 60°C increase in a row: filter paper> synthetic> recycled> bulky. This means that the brightness of the prints at the highest temperature are the most different from the brightness of the neat paper in the case of filter paper, and the lowest in the case of bulky paper. *CIEDE2000* values increase in a row: filter> recycled > synthetic> bulky. *Δa*, Δb** and *ΔC** values haven't been changed by a specific rule.

3.2 The characteristic temperature

Figure 3 present *L** values for samples during heating from 15^{0}C up to 60^{0}C and cooling down to 15^{0}C. The characteristic temperatures have been determined according to Figure 4 (Kulcar et al. 2010).

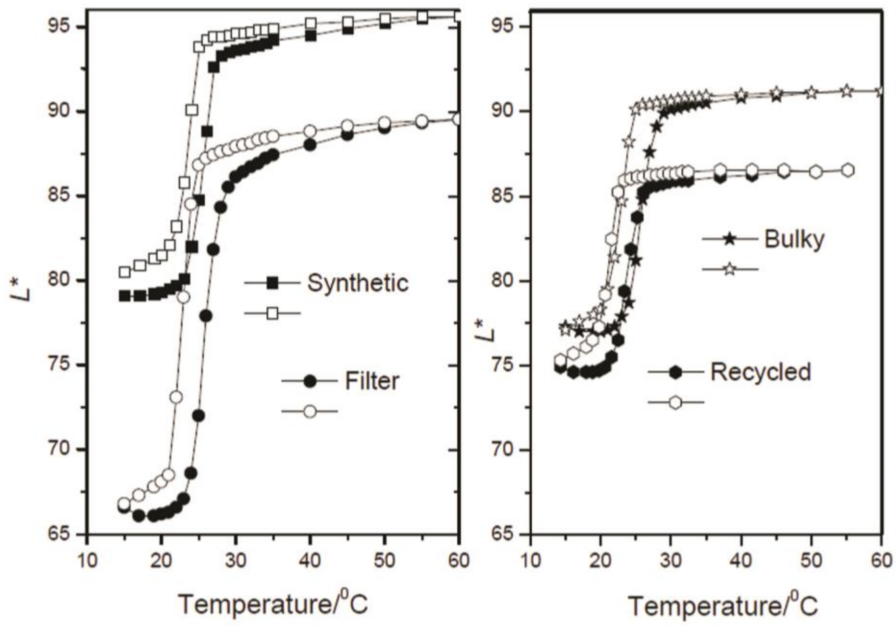


Figure 3: L values for samples during heating from 15^{0}C up to 60^{0}C and cooling down to 15 ^{0}C*

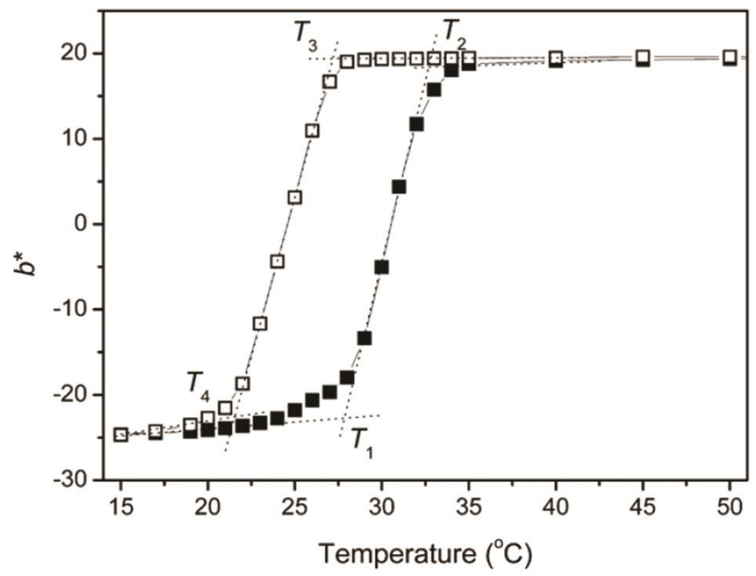


Figure 4: An example of the characteristic temperature determination. Transparent signs indicate the process of cooling and while coloured indicate the process of heating [1]

These temperatures can be determined from any two-dimensional graph, in which the hysteresis colour, *a* * (T), *b* * (T), *L* * (T) or *C* * (T) is shown. The characteristic temperatures determined from of *L*(T)* hysteresis is presented in Table 3.

Table 3: The characteristic temperature of TC prints

	T_1	T_2	T_3	T_4
Bulky paper	23.1	28.5	25.3	20.4
Synthetic paper	23.7	27.5	25.4	21.2
Recycled paper	23.1	27.5	24.5	20.4
Filter paper	24.5	28.0	25.0	20.9

The process of decolourization is presented by T_1 and T_2, ie. by the initial and final achromatic temperature, and reversible reaction using T_3 and T_4, ie. by the initial and final chromatic temperature (Figure 4). All these graphs generally give the same characteristic temperatures. As it is evident from the Table 3, the activation temperature given by the producers is in between the temperatures T_1 and T_2, more likely closer to T_2. Two long-term metastable complex in thermochromic composite are formed as a result of two competitive reactions, dye-developers and cosolvent-developer. At low temperatures there is interaction dye-developer, which forms a dye-developer complex. When the high temperature solvent dissolves, solvent-developer interaction destroys dye-developer complex and thermochromic composite is transformed into a colourless state. Coloured complex predominates at temperatures below T_4 and decolorized complex above T_2, regardless to the thermal history of the sample. Between these temperatures, the system passes through changes depending on its thermal history. Between T_1 and T_2 discoloration occurs, while between T_3 and T_4 system again returns to coloured state (Kulcar et al. 2010). It is obvious that all four characteristic temperatures for the TC footprint are the same, regardless of the type of tested paper.

3.3 Colorimetric parameter differences (CIEDE2000 ΔL^*) between the samples in heated and cooled state depending on the temperature

The differences between the *L** values of samples in a heated and cooled state as a function of temperature are shown in Figure 5. Figure 6 shows the *CIEDE2000* total colour difference. As it is evident from the Figure 6, the highest colour difference between the sample in a heated and cooled state is present in TC print on the filter paper. The highest colour difference was obtained in temperature range from 20 to 28^{0}C at a temperature of cca 25^{0}C. At a temperature of 25^{0}C, ΔL^* value was -14.8 (Figure 5). Also the highest changes in TC prints obtained on other papers are noticed in the same temperature range, at the same temperature. In Figure 3 it can be seen that trajectory of samples obtained by heating are not equivalent to those obtained by cooling. The surface area defined by the two trajectories indicates how similar the colour is while the sample passes through a cycle of heating and cooling. If the trajectories were identical, the surface area would be zero. Larger hysteresis areas show that there is a greater difference in colour that occurs in the sample during the process of heating and cooling. The surface of the colour hysteresis can be presented by using the total colour difference (*CIEDE2000*) between the sample in the heated and the cooled state, as a function of temperature. From Figures 5 and 6 it can be seen that the largest surface area of previously mentioned curves are in the case of TC print on the filter paper.

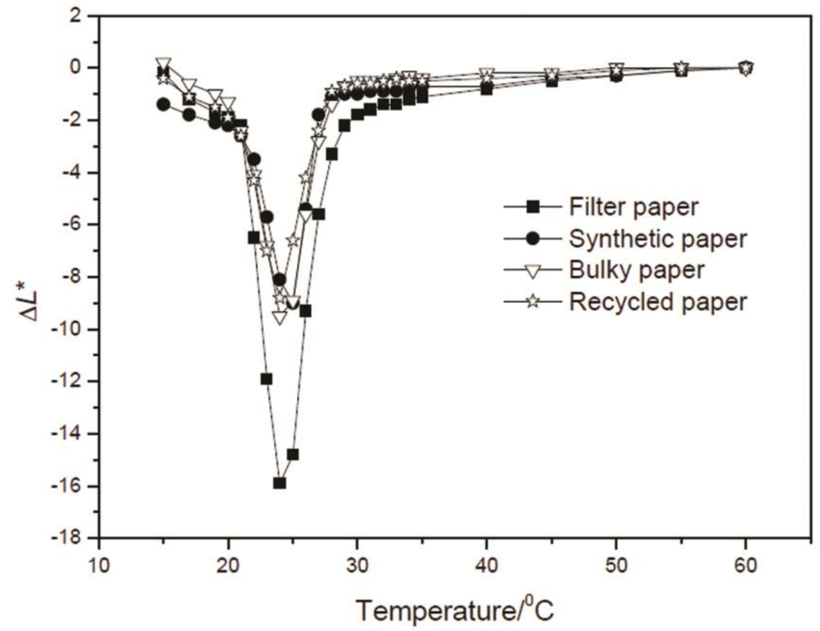


Figure 5: ΔL^* differences between the samples in heated and cooled state as a function of temperature

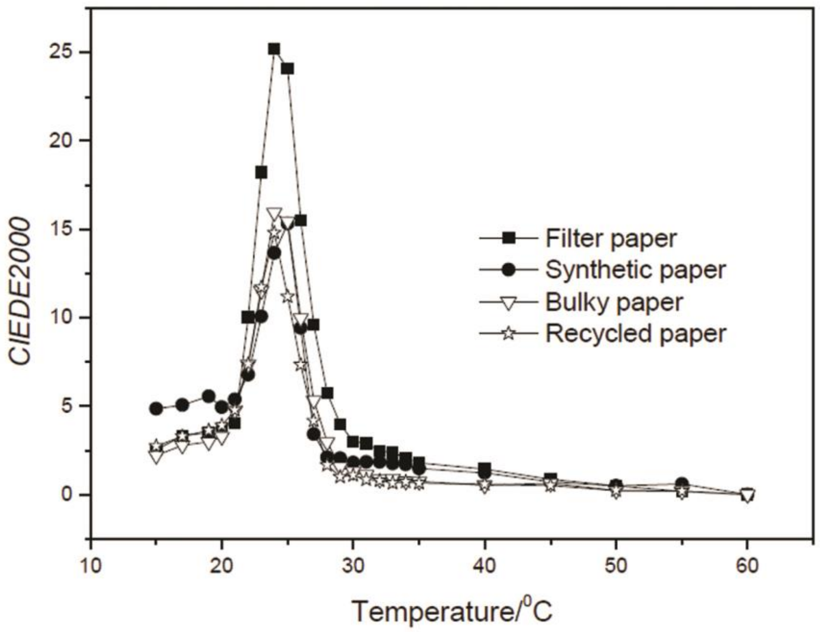


Figure 6: CIEDE2000 differences between the samples in heated and cooled state as a function of temperature

4. CONCLUSIONS

From the obtained results it can be concluded that the different physical and chemical properties of paper doesn't affect the value of the thermochromic ink characteristic temperature. But the shape of the thermochromic ink hysteresis curve varies depending on the applied paper. Trajectories obtained by heating and cooling of the TC samples mostly differ in the case of TC print on filter paper, pure cellulose. In the case of TC prints on other papers, differences in brightness and color upon heating and cooling at a specific temperature are lower.

5. ACKNOWLEDGMENTS

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COLOR REPRODUCTION QUALITY IN MULTI-PASS INK JET PRINTING

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Abstract: *Relying on its flexibility and suitability for short run lengths, digital printing is gaining a strong foothold in the print industry, complementing and often rivaling the conventional printing techniques. The use of digital printing can be seen in various market areas, where its application in printing large formats is especially emphasized. As in all other printing techniques, quality and control of print reproduction is particularly important, regardless of printing substrate or digital printing principle. One of the mostly used digital printing technique for printing large formats is ink-jet printing technique, which can be utilized in single or multi-pass mode. When the printing substrate, as well as print product end-use, require multi-pass printing, optimal print quality is not just aesthetic but also an economic issue. Thus, in this paper, changes in CIELAB values of 25%, 50%, 75% and 100% TV of cyan, magenta, yellow and black regarding the number of passes during printing have been discussed. We used six different printing substrates of similar whiteness index and multi-pass printing concept with six, eight and ten passes for each color and tone value. The number of multiple passes was chosen as being the most commonly used in cases when printing is performed on the chosen substrates. The ΔE^*_{ab} value was employed to express the changes in CIELAB coordinates influenced by the variation in number of passes during printing. The results indicate that the variations are much more noticeable on solid tones (100% TV) comparing to the halftone patches. The ΔE^*_{ab} difference showed notably decreasing tendency with the increase of passes. Also, the results showed that the changes in the color difference between eight and ten passes were up to 3.5, which can be used as a benchmark for further defining the optimal higher bound of multiple passes' number, and contribute to savings in time and material consumption.*

Key words: multi-pass printing, ink jet, color reproduction quality

1. INTRODUCTION

The new tendencies in the printing industry resulted in rapid development of digital printing techniques which are, due to print quality, end costs and suitability for short run lengths, perfect to be utilized in various areas of the market. One of the main advantages of digital printing techniques, especially ink-jet printing, is the ability to print on great number of different printing substrates, with no limitation regarding the print format (Kašiković et al, 2015). Some recent studies have showed that using digital printing technique will enable better visual effects, as well (Schmidt and Weckbecker, 2009; Kašiković et al, 2015). On the market, there are variety of digital printing solutions which offer the incredibly high resolution and exceptional homogeneity of the prints, the reproduction of tonal values without any loss of image information and natural color rendition with vivid color shades pretty similar to the originally taken ones. Sometimes, the visual effect of more saturated, brilliant and sharp prints is gained at costs of tone value differentiation and detail accuracy. Also, some digital printing machines perform a quite obvious yellow or red shift of skin shades. This problem, still, can be compensated with flat mid-tone gradation and the well balanced homogeneity of the prints (Schmidt and Weckbecker, 2009). It is also worth mentioning that most production digital printing processes depend on the use of certified paper to perform to their best capacity (Chung and Rees, 2007).In digital printing, the print quality is influenced by the various printing parameters, whereas dot shape, screen resolution and printing substrate are established as the most influential ones (Nayak et al, 2014).

If the standard recommendations are going to be used for the evaluation of the digital image quality, then there are two standards whose recommendations could be utilized: ISO 13660 and ISO 19751. Still, those standards are only applicable for the black-and-white digital printing. Earlier studies though showed that many elements and tolerances of the ISO standard for offset printing ISO 12647-2 could be easily applied to digital print (Chung and Rees, 2007). The digital print quality evaluation and control is particularly important when the multi-pass printing is required. In that case, optimal print quality is not just aesthetic but economic issue, as well.

Thus, in this paper, we have discussed the changes in L*a*b* values of 25%, 50%, 75% and 100% tone value (TV) of cyan, magenta, yellow and black regarding the number of multiple passes during printing. The printing was performed on six different printing substrates with six, eight and ten passes for each tone value and color. The ΔE^*_{ab} values were used to express the changes in L*a*b* coordinates influenced by variation in passes during printing.

2. MATERIALS AND METHODS

For the purpose of the research, appropriate test chart was created (Figure 1). It consisted of 36 color patches (5x5 cm) for cyan, magenta, yellow and black color, of 25%, 50%, 75% and 100% tone value. The printing was performed on six different, white substrates, applying six, eight and ten passes during printing. Used printing substrates, mainly tended to be used for outdoor applications, were (Table 1): ink –jet photo paper, silicone coated paper, paper for city lights applications (Citylight Paper 1200), paper with satin coating and PVC laminated banner.
Ink-jet photo paper is usually used for folders, art and illustrated books and poster ink -jet latex printing (FortunaDigital, 2016). Orajet, silicone coated paper is best to use for brilliant and colorful short- and medium-term outdoor applications (Orafol, 2016). Citylight Paper 1200, paper with high quality coating, exhibits good printing characteristics with solvent inks and it is recommended for city light applications due to paper structure translucence (GM media, 2016). HP White Satin Poster paper, high quality paper, can be utilized for varieties of indoor/outdoor advertisings, promotions, city light posters, bus shelters and billboard applications (HP, 2016). 440GSM PVC Frontlit Laminated Banner is suitable choice for general banner applications, short term and exhibition advertising (exterior and interior) and it performs well with solvent, eco solvent, UV-C, screen and latex inks (Sign, 2014).
The printing machine used in experiment was high quality, calibrated ink jet printer HP 310 Latex, with printing ink Latex HP 831, recommended for large format media printing. The ICC profiles used were recommended by the manufacturer, CMYK based and adjusted in accordance to number of multiple passes. The applied drying time was defined according to the printing substrate (Table 1).
The colorimetric measurements were performed using spectrophotmeter Technon SpectroDens. The L*, a* and b* values of color patches were measured on black backing, with D50 illuminant and 2^0 observer. Each color patch was measured five times (Figure 1). In result analysis, the averaged values were used.
Color difference value ΔE^*_{ab} was calculated as following (Ohta and Robertson, 2005; Gulrajani, 2010; Fairchild, 2013):

$$\Delta E^*_{ab} \text{ (CIELAB, } \Delta E76\text{) color difference: } \Delta E^*_{ab} = [\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}]^{1/2} \quad (1)$$

where:
ΔL^* - the lightness difference: $\Delta L^* = L^*_1 - L^*_2$,
Δa^* and Δb^* - chromaticity differences: $\Delta a^* = a^*_1 - a^*_2$, $\Delta b^* = b^*_1 - b^*_2$
L_1 a_1, b_1 - lightness and chromaticity coordinates of sample 1; L_2, a_2, b_2 - lightness and chromaticity coordinates of sample 2.

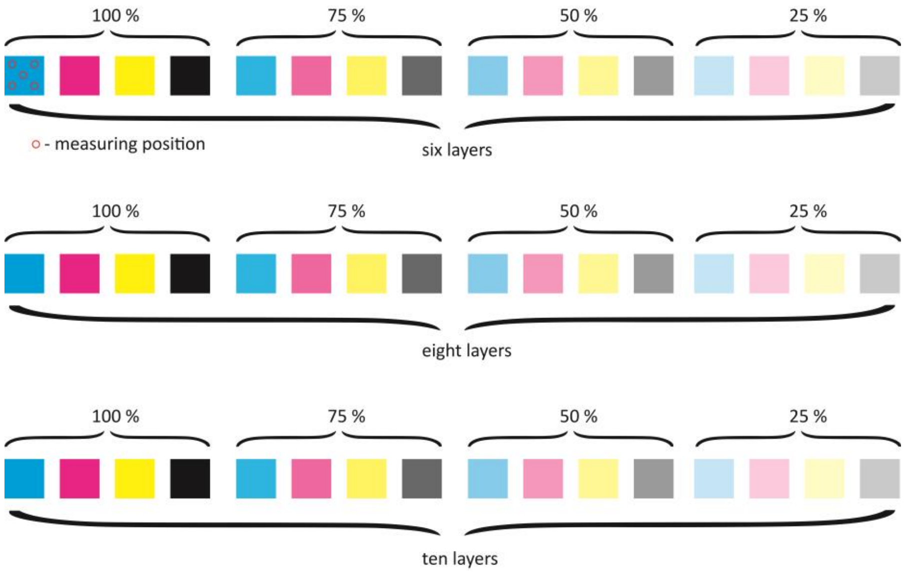

Figure 1: Test chart

Table 1: Printing substrates and their basic characteristics

	Printing substrate (Acronym)					
	Ink - jet latex photo paper (IJP)	Soft PVC film ORAJET 3164 glossy (OR/G)	Soft PVC film ORAJET 3164 matte (OR/M)	City Light Paper 1200 (CL)	440GSM PVC Frontlit Laminated Banner (FLB)	HP White Satin Poster paper (WSP)
Finishing	gloss	gloss	matt	matt	gloss	satin
Basis weight (g/m^2)	200	135	135	150	440	136
ISO Opacity (%)	98	/	/	98	/	95
CIE whiteness (%)	95	100	101	117	107	110
Drying temp. (^0C)	80	116	116	80	110	80

3. RESULTS AND DISCUSSION

On figures 2-5 are given calculated color differences according to Equation (1). The values presented on graphs are based on L*a*b* values measured on each color patch and each substrate, and they represent color differences for each process color (cyan, magenta, yellow and black) and each tone value (25%, 50%, 75% and 100%), separately. In compliance with the aim of this paper, we have calculated color differences between patches printed using different number of passes during printing. The notations on graphs 6/8, 6/10 and 8/10 correspond to color difference calculated using L*a*b* values measured on color patches printed with 6 and 8, 6 and 10 and 8 and 10 passes, respectfully.

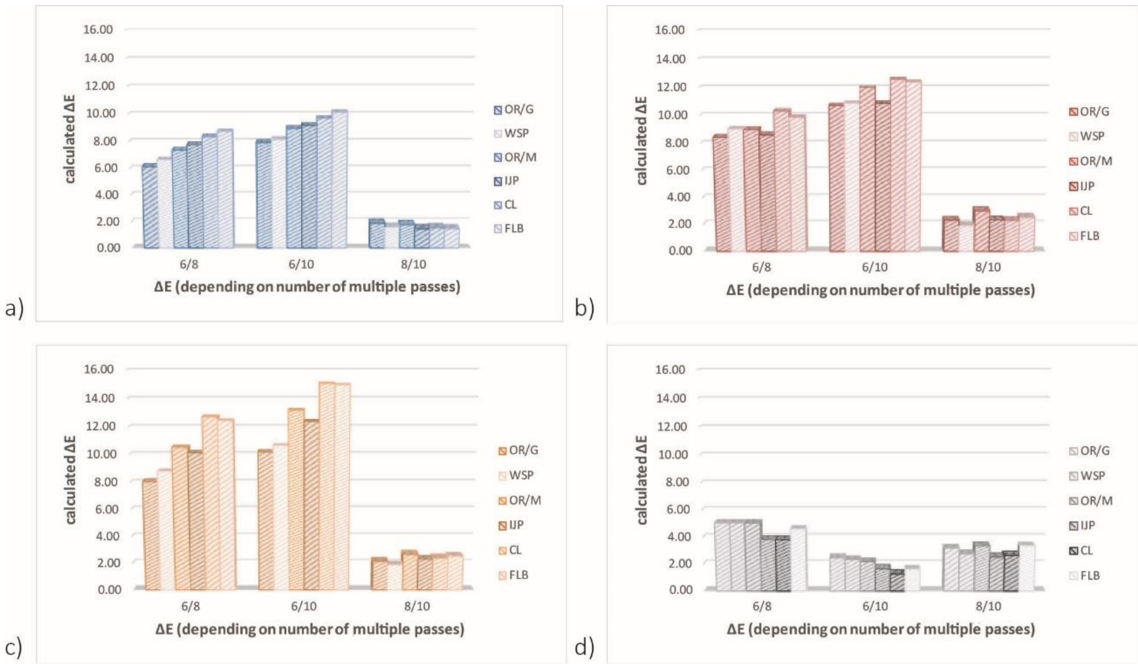

Figure 2: Color difference values in dependence of number of multiple passes, solid tone (100% TV): a) cyan, b) magenta, c) yellow and d) black

On Figure 2 are presented color differences for solid tones of four process colors. As it can be seen from the graphs, the highest color differences are calculated in case of yellow, while the lowest ones were in case of black. In case of cyan, magenta and yellow, and each printing substrate, the highest color differences were calculated between patches printed with 6 and 10 passes while the lowest ones were between patches printed with 8 and 10. In case of black process color, contradictory, the lowest color difference values were between patches printed with 6 and 10 passes, while the highest ones were between those printed with 6 and 8 passes.

It is evident that preserving the same relative ratio between multiple passes (two), will not result in the same color difference: the color differences between patches printed with 8 and 10 passes are several times smaller than those between the patches printed with the 6 and 8 passes.
According to substrate, the smallest differences in color are perceived in case of black color ink, then cyan and magenta, and then yellow. The substrate with the lowest color differences is Soft PVC film ORAJET 3164 glossy, with the exception of black, where City Light Paper 1200 performed the best.

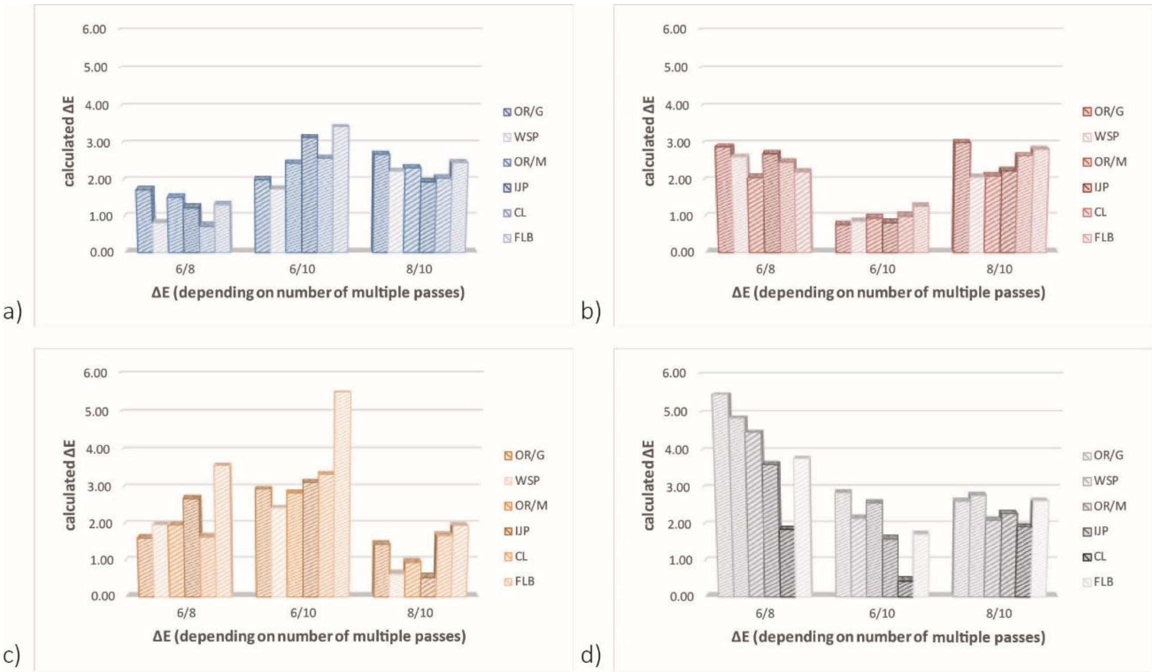

Figure 3: Color difference values in dependence of number of multiple passes, 75% TV: a) cyan, b) magenta, c) yellow and d) black

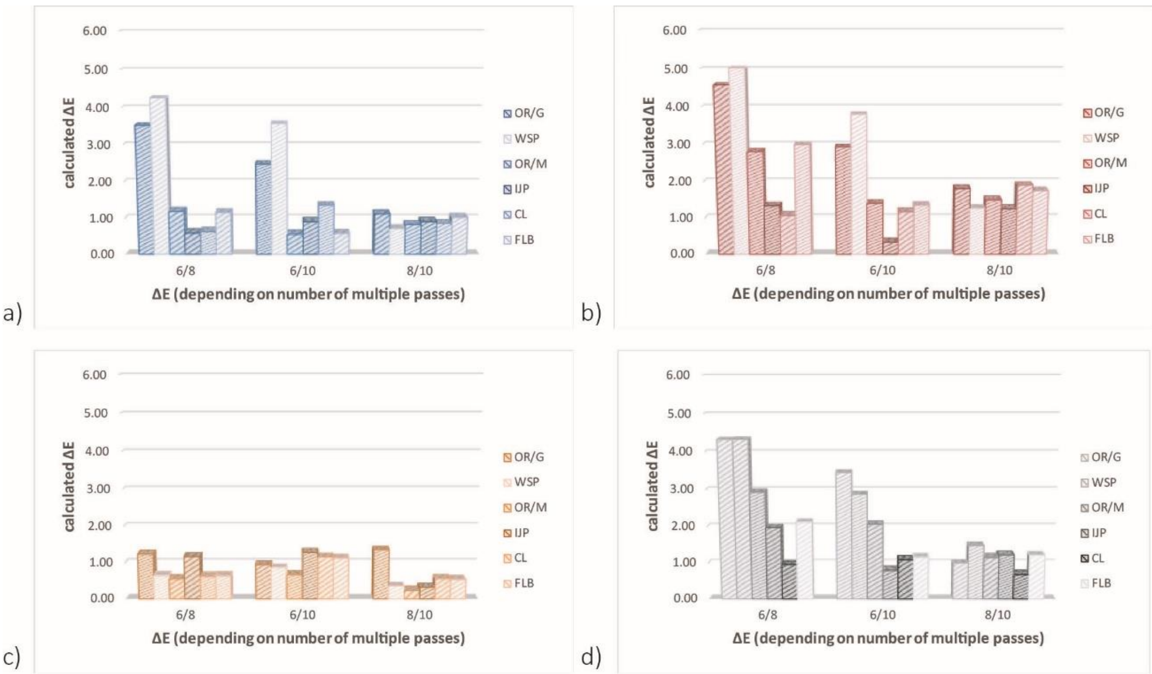

Figure 4: Color difference values in dependence of number of multiple passes, 50% TV: a) cyan, b) magenta, c) yellow and d) black

On Figure 3 are given color differences for color patches of 75% tone value. The highest color differences are calculated in case of yellow and black color ink, between patches printed with 6 and 10, and patches printed with 6 and 8 passes, respectfully. In case of cyan, the similar color difference values were calculated between patches printed with 6 and 10, and 8 and 10 passes, while the lowest ones were between patches printed with 6 and 8 passes. For process color magenta, similarity was noticed in case of printing with 6 and 8, and 8 and 10 passes, while the lowest color difference values were between patches printed with 6 and 10 passes. The results have showed that preserving the same relative ratio between multiple passes (two), will not result in the same color difference.

On Figure 4 are given color differences for color patches of 50% tone value. From the presented graphs it can be seen that the color difference is less influenced by the number of multiple passes than with the color and substrate itself. The highest color difference is calculated in case of black and magenta, and for Soft PVC film ORAJET 3164 glossy and HP White Satin Poster paper.

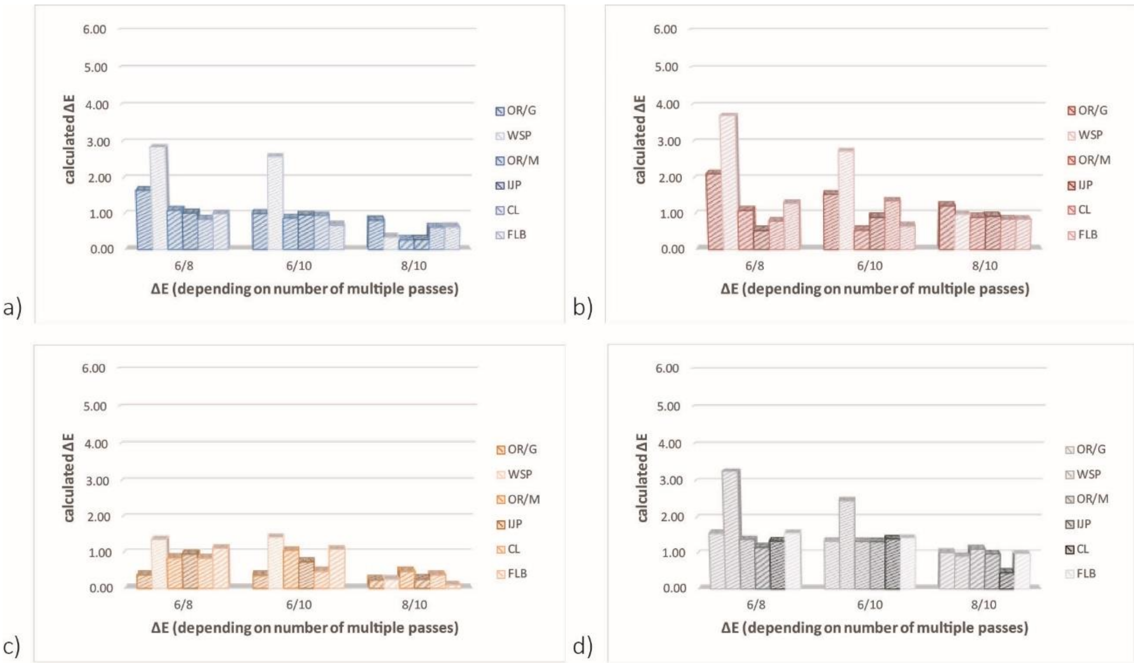

Figure 5: Color difference values in dependence of number of multiple passes, 25% TV: a) cyan, b) magenta, c) yellow and d) black

On Figure 5 are presented color differences for color patches of 25% tone value. As it can be seen from the given graphs, the color difference is less influenced by the number of multiple passes than with the color and substrate itself.

The highest color difference is calculated again in case of black and magenta. Generally, color difference value does not exceed 1.5 ΔE^*_{ab}, with the exception of printing substrates Soft PVC film ORAJET 3164 glossy and HP White Satin Poster paper (for black, cyan and magenta process color).

4. CONCLUSIONS

In this paper, using color difference formula, we have shown the changes in L*a*b* values of 25%, 50%, 75% and 100% of cyan, magenta, yellow and black process color regarding the number of multiple passes. We have used six different printing substrates of similar whiteness index and multi-pass printing with six, eight and ten passes. The results have showed that the variations in the number of multiple passes will have much more influence on solid tone rather than on half tone areas.

In case of solid tones, the ΔE^*_{ab} difference has notably decreasing tendency with the increase of passes during printing. For halftone areas, this trend might be assumed, however it is less expressed as the tone value decreases and suspected to be less influenced by the number of multiple passes than with the color and substrate itself. Also, the results have showed that the changes in color difference between eight and ten passes were up to 3.5 ΔE^*_{ab}, which can be used as a benchmark for further defining the optimal higher bound of multiple passes' number, and contribute to savings in time and material consumption.

5. ACKNOWLEDGMENTS

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INFLUENCE OF BLACK GENERATION ON GRAY COMPONENT REPLACEMENT EFFICIENCY

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Abstract: *In four color printing, gray component replacement is a useful technique of replacing the achromatic part of a mixture of chromatic inks (CMY) with a corresponding amount of the black ink (K). It reduces ink consumption, which is beneficial in commercial and environmental sense. Many papers describe various approaches to gray component replacement (GCR). They are mainly focused on the methods of calculating CMYK solutions for a fixed K amount, but pay little attention to determination of K amount, i.e. black generation. Black generation is a procedure of determining the amount of black ink corresponding to the amount of gray component in a CMY mixture that we wish to replace. Due to imperfections of printing inks and printing processes, black generation is a challenging task. If the amount of gray component in a given CMY mixture is overestimated, the new GCR solution will not match the original color. This paper compares the efficiency of three black generation algorithms in terms of colorimetric accuracy and achieved ink savings in digital images. Regarding the colorimetric accuracy, it was found that the examined algorithms do not significantly differ in central tendency error measures. However, they do differ in 90th percentile error as some are more prone to overestimating the amount of gray component for a small subset of device inputs. It was also found that they differ in the ability to maintain colorimetric accuracy at higher replacement rates, i.e. at higher ink savings.*

Key words: black generation algorithm, gray component replacement, ink saving

1. INTRODUCTION

In four color (CMYK) printing, gray component replacement (GCR) is a method of replacing the achromatic part of a mixture of chromatic inks (C, M and Y) with a corresponding amount of black ink (K). In addition to ink saving, GCR shortens ink drying time, helps avoid back trapping, may improve the image definition, and reduces gray balance variation (Kang 1994); (Kang et al. 2002). Various GCR methods have been developed. They can be divided in two categories, static and dynamic. Static methods (Littlewood et al. 2002); (Tsukada & Tajima 1995); (Mestha et al. 2009) replace chromatic inks with a predetermined amount of black ink, regardless of image content. Dynamic methods (Kisilev et al. 2011); (Shapira & Oicherman 2012) vary the amount of replacement depending on image content in order to avoid the appearance of visible artefacts in smooth image areas. The delicate part of GCR is the black generation (BG), i.e. a method of determining the new black ink amount. Many methods perform this step by calculating the new black ink amount from smallest device input min {C,M,Y}. This calculation usually leads to large colorimetric differences between the initial input and the new solution. The choice of BG algorithm depends on the mechanics of the GCR method. Many methods use simple color transform models for conversion between device space (CMYK) and color space (CIE L*a*b*). Since the relationship between these two spaces is quite complex, it does not provide us with clear information about ink mixing and possible replacements of chromatic inks with black ink. Therefore, the BG step in such methods usually requires determination of black ink range for which the aimed color is inside a subgamut (Tsukada & Tajima 1995). This paper compares performances of three BG algorithms in terms of colorimetric accuracy and ink savings. The GCR method used in the experiment works with colorimetric densities which, in addition to color specification, provide information about ink mixing. The relationship between ink amounts and colorimetric densities is fairly simple compared to CIE L*a*b* variables (particularly a* and b*). This makes the BG step easier and more accurate. However, the relationships between ink amounts and colorimetric densities are not linear. Therefore, BG has shown to be quite demanding task with this approach also. Three BG algorithms were tested in this paper. Two are based on relatively simple estimations of replaceable densities in device inputs. It was determined that due to complex ink mixing behavior, both lack control over achieving the aimed result. The third method is based on radial basis functions (RBF) model. The results presented in this paper show its outstanding performance in achieving colorimetric accuracy and suggest that it provides the desired control of replacement amount. However, it still requires more thorough testing of accuracy in achieving the aimed replacement amounts on large data sets.

2. METHODS

The GCR model used in this paper is displayed in Figure 1. To clarify terms and theoretical concepts used in this paper, readers are advised to see (Donevski et al. n.d.). Given a printing device CMYK input $\mathbf{p_I}=[C_I\ M_I\ Y_I\ K_I]^T$, the model outputs new device input $\mathbf{p_O}=[C_O\ M_O\ Y_O\ K_O]^T$, such that $C_O<C_I$, $M_O<M_I$, $Y_O<Y_I$, $K_O>K_I$. The color of an input is calculated using color transform model (CTM), and is specified using colorimetric densities, $\mathbf{d_S}=f_{CTM}(\mathbf{p_I})$. In this paper, ICC profile was used as CTM. The next step is black generation (BG), where new black ink amount is determined. The black ink amount is specified as Z colorimetric density D_{KZ}. Having the desired color and black ink amount specified, the inverse additive model (IAM) calculates the amounts of C, M and Y inks (specified using colorimetric densities) needed to achieve aimed color at fixed black ink amount. The IAM is a set of linear masking equations. For more details, see (Donevski et al. n.d.). Since linear model is inaccurate due to ink density additivity and proportionality failures, the additivity correction model (ACM) corrects IAM outputs to final solution. We used radial basis functions (RBF) model (Broomhead & Lowe 1988) with third order polyharmonic splines as ACM. Finally, 1D piecewise linear functions are used to obtain device inputs from colorimetric densities. These were set using process characterization data. Let's denote them as $C_O=f_C(D_{CX}),\ldots,K_O=f_K(D_{KZ})$.

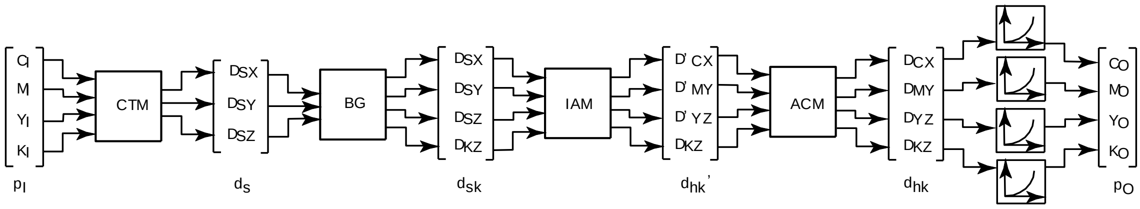

Figure 1: Gray component replacement (GCR) model used in the experiment

First BG algorithm (Algorithm A) - Given a CMYK input $\mathbf{p_I}=[C_I\ M_I\ Y_I\ K_I]^T$, contribution of each of the four pure primaries (C_I, M_I, Y_I, K_I) to three colorimetric densities (D_{SX}, D_{SY}, D_{SZ}) is determined by calculating a matrix $\mathbf{D_p}$:

$\mathbf{D_p}=(dp_{ij})\in\mathbb{R}^{4\times3}$

$$dp_{i*}=[\ D_{SX}\ \ D_{SY}\ \ D_{SZ}\ ]=[f_{CMT}(\mathbf{p_I})]^T, \tag{1}$$

where all except the i^{th} element of $\mathbf{p_I}$ are set to zero. Indices $I*$ denote all elements of the i^{th} row.
Minimum chromatic ink is determined and a "logical vector" is set,

$\mathbf{d_v}=(dv_i)\in\mathbb{R}^3$

$$\mathbf{d_v}=\begin{cases}[\,1\ \ 0\ \ 0\,], & \min\{C_I, M_I, Y_I\}=C_I\\ [\,0\ \ 1\ \ 0\,], & \min\{C_I, M_I, Y_I\}=M_I\\ [\,0\ \ 0\ \ 1\,], & \min\{C_I, M_I, Y_I\}=Y_I\end{cases} \tag{2}$$

The new black ink density is determined by adding the replaceable (minimum chromatic ink) density, weighed by factor g (fraction to be replaced) to black ink density,

$$D_{K\phi1}=\|\ dp_{4*}\circ\mathbf{d_v}+\mathrm{g}\cdot dp_{i*}\circ\mathbf{d_v}\ \|;\ \ [\ I\ \ \Phi1\ ]=\begin{cases}[\,1\ X\,], & dv_1=1\\ [\,2\ Y\,], & dv_2=1\\ [\,3\ Z\,], & dv_3=1\end{cases} \tag{3}$$

where $\mathbf{a}\circ\mathbf{b}$ denotes Hadamard (element-wise) product of vectors **a** and **b,** and $\phi1$ denotes colorimetric density (CIE X, Y or Z).
Finally, D_{KZ} is calculated by multiplying $D_{K\phi1}$ by the corresponding density proportionality constant.
Second BG algorithm (Algorithm B) - The second algorithm is similar to the first one, but it has several modifications. In the first algorithm, minimum chromatic ink is determined based on input (device CMYK) values. However, it may not be the case that the smallest input will result in smallest density. For example, it may be that $D_{CX}(C_I=50)<D_{YZ}(Y_I=45)$. Further, maximum density values typically differ, $\max(D_{CX})\neq\max(D_{MY})\neq\max(D_{YZ})$. Therefore, minimum component is determined from three colorimetric densities weighed by their maximum values. The replaceable density is determined from $\mathbf{d_S}$ and grayness weighing is used. Given the complexity of this algorithm, it will not be described in details in this paper. Detailed description can be found in (Donevski et al. n.d.).

Third BG algorithm (Algorithm C) - The third algorithm uses RBF model to determine the new black ink value for a given input $\mathbf{p_I}$. In our experiment, it was trained with replaceable colors (C_I, M_I, $Y_I > 0$, $K_I < 1$) from the ISO Uncoated Yellowish characterization data set. Let $\mathrm{P_{IR}}$ denote a set of those replaceable input vectors $\{\mathbf{p_{IR}}\} \subset \{\mathbf{p_I}\}$. The desired replacement factor g is calculated using a third order spline function f_{SPL} of input "area coverage", $g = f_{SPL}(C_I + M_I + Y_I + K_I)$, where C_I, M_I, Y_I, $K_I \in \mathbf{p_{IR}}$. In this experiment, f_{SPL} was set for three points $p(C_I + M_I + Y_I + K_I, \mathrm{g})$: $p_1(0, 0.1)$, $p_2(3.2/2, 0.8)$ and $p_3(3.2, 0.4)$. For very small inputs, only around 10% of replaceable density is replaced. At half of maximum ISO Uncoated Yellowish process area coverage, we aim to replace 80% of replaceable density. At maximum 3.2 area coverage, we aim to replace 40%. The replacement was set to decrease toward highest inputs since for those inputs all four (C_I, M_I, Y_I, K_I) inks are quite high, and already high K_I has small range for increase. The RBF was trained as in the following pseudo code:

```
For each pIR ∈ PIR
    DKZ=max
    dsI=fCTM(pIR)
    dsh=(dpii); i=1,...,3        %See Equation (1)
    a=1 - g·dsh                  %Aimed densities vector
    range=DKZ/2
    Do While OK≠TRUE
        dsk=[DSX DSY DSZ DKZ] %Vector dsI augmented with DKZ
        dhk=(fACM ∘ fIAM)(dsk)    %Composition of functions, see Figure 1
        dhw=fW(dhk)       %Weigh by maximum colorimetric densities
        I= ind(min{ x∈dhw })   %Find index (position of minimum density)

        If xi=I ∈ dhk == yi=I ∈ a and DKZ ≤ max
            OK=TRUE
        Else If xi=I ∈ dhk == yi=I ∈ a and DKZ > max
            OK=FALSE
            DKZ =DKZ – range
        Else If xi=I ∈ dhk > yi=I ∈ a and DKZ == max
            OK=TRUE
        Else If xi=I ∈ dhk > yi=I ∈ a and DKZ<max
            OK=FALSE
            DKZ=DKZ + range
        Else If xi=I ∈ dhk < yi=I ∈ a
            OK=FALSE
            DKZ=DKZ – range
        End If
        range= range/2
    Loop
Next pIR
```

The two previously described BG algorithms (A and B) estimate the amount of replaceable density in an input and add it to black ink density. However, due to ink additivity failure, this estimated amount of replaceable density is not exact and may in fact significantly differ from real value. Further, when the GCR method solves for C, M and Y amounts (C_O, M_O, Y_O) given the aimed color and black ink amount, the minimum component may change. For example, if the minimum component in $\mathbf{p_I} = [C_I\ M_I\ Y_I\ K_I]^T$ was Y_I, the minimum component in $\mathbf{p_O} = [C_O\ M_O\ Y_O\ K_O]^T$ may be C_O. Therefore, the third BG algorithm uses iterative approach, adjusting black ink amount D_{KZ} and solving for C, M and Y until either one of them converges to its respective aimed density (replacement) amount.

The performance of the GCR method was tested with three BG algorithms (denoted A, B and C). To inspect how the method using different BG algorithms performs compared to state of the art, it was compared with a commercial solution, GMG Ink Optimizer (denoted as D). According to (Sharma & Starr 2010), GMG Ink Optimizer is one of the best commercial ink saving solutions. Performances were compared in terms of colorimetric accuracy and ink savings on a set of 25 digital images. Images were converted using the described methods, and converted images' pixels were compared to original images' pixels in terms of ΔE_{00} colorimetric difference and average area coverage difference. Performances were tested for ISO Uncoated Yellowish printing process, using its ICC profile.

3. RESULTS

The performance results of tested algorithms are displayed in Figure 2. In terms of colorimetric accuracy, it can be seen (Figure 2 left) that Algorithm A performs quite poorly. While for most images it has quite low median of ΔE_{00} errors, for some images containing many "problematic" pixels, i.e. those for which replaceable ink amount is overestimated by Algorithm A, even the median of errors gets quite large. The 90^{th} percentile and maximum error further reveal that Algorithm A tends to overestimate the replaceable density amount, producing very large errors. The other two BG algorithms (B and C) perform quite satisfactory compared to GMG Ink optimizer (D). Closer inspection of 90^{th} percentile and maximum error distributions reveals that Algorithm C performs better than Algorithm B.

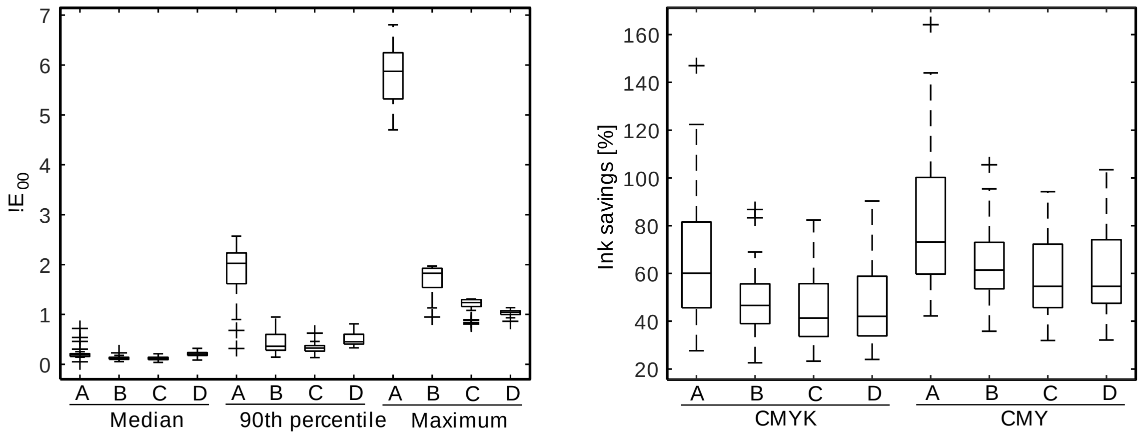

Figure 2: Colorimetric accuracy (left) and ink savings (right) of GCR model using different BG algorithms on a set of 25 images

In terms of ink savings, it can be seen (Figure 2 right) that Algorithm A achieved largest ink saving. This confirms the earlier statement that Algorithm A overestimates replaceable density amount for some inputs. Algorithm B achieved somewhat larger savings than C and D, but this came with the penalty regarding the colorimetric accuracy (larger 90^{th} percentile and maximum error). Algorithm B was far more accurate than Algorithm A, but it also shows the tendency of overestimating the replaceable density amount for some inputs (although far fewer than Algorithm A). Algorithms C and D performed similarly, although Algorithm C is a bit more conservative regarding ink savings.A part of one image from the 25 images set is displayed in Figure 3. By visual inspection, both the Algorithm B image (left) and Algorithm C image (right) look quite similar to the original image (center). However, further inspection of pixels contained within the red circle mark reveals one problematic aspect of Algorithm B. Grayness weighing does not provide sufficient control when estimating replaceable density amount in an input. This has led to cyan ink being removed completely. Although maximum GCR setting is perfectly valid theoretically, it is undesirable in practical applications. Algorithm B estimates the replaceable density using grayness weighing, but provides no means of controlling the amounts of chromatic inks in the final solution. On the other hand, Algorithm C was set to replace 80% of replaceable density at 1,6 area coverage input. The original image input was C + M + Y + K = 0,25 + 0,58 + 0,56 + 0,22 = 1,61. The Algorithm C solution is C=0,06, which is ¼ (75% reduction) of the original C=0,25 value. Although we should inspect densities rather than device CMYK inputs, and do that on a large set of pixels, we can already see that this result, at least roughly, matches the desired behavior. Nevertheless, Algorithm C still requires a more thorough testing.

C=0,00 M=0,50 Y=0,45 K=0,40 | C=0,25 M=0,58 Y=0,56 K=0,22 | C=0,06 M=0,52 Y=0,47 K=0,37

Figure 3: Visual inspection: Algorithm B image (left), original image (center) and Algorithm C image (right)

4. DISCUSSION

In the experiment presented in the previous section of this paper, three BG algorithms were compared. Additionally, the performance of the GCR method using those three algorithms was compared with state of the art commercial solution, GMG Ink Optimizer. A fair comparison of different algorithms' performances is hard to accomplish due to their differences, i.e. difficulty of setting their parameters in such way that all of them achieve equal ink savings. However, the results presented in previous section reveal some crucial aspects. Algorithm A was set to maximum replacement. This resulted in highest ink savings, but also in visually unacceptable color differences. Let's consider a case presented in Table 1. The input $\mathbf{p_I}=[0{,}87\ 0{,}52\ 0{,}51\ 0{,}68]^T$ (second row from the bottom) was converted to output $\mathbf{p_O}=[0{,}00\ \ 0{,}00\ \ 0{,}00\ \ 0{,}96]^T$ (bottom row), their colorimetric difference being ΔE_{00}=5,82. The first thing to note is that in the new solution $\mathbf{p_O}$ all three chromatic inks equal zero. If the solution was correct, only the minimum component would equal zero. Let's examine what happened. The first four rows contain colorimetric densities of individual inputs. The fifth row contains sums of those densities. If the additivity rule held, these sums of densities would be equal to colorimetric densities achieved by applying all four inks (second row from the bottom). Clearly, the sums are larger than real densities achieved, which is known as the additivity failure. The minimum component is yellow (third row), and Z colorimetric density is its highest density. Adding yellow Z density $(0{,}91)$ to black Z density $(1{,}65)$ equals new black ink aim $D_{KZ}=2{,}56$. But the aimed color (specified as colorimetric densities) is that of the original input $\mathbf{p_I}$ in the second row from the bottom, where $D_{SZ}=2{,}36$. Clearly, the new black ink aim alone exceeds this value and mathematically, the only solution to such condition is that where chromatic inks take on negative values. The BG overestimated replaceable density, and the GCR model solved for a set of conditions for which real solution does not exist.

Table 1: Example of input values and GCR replacement

CMYK	D_{SX}	D_{SY}	D_{SZ}
0,87 0,00 0,00 0,00	**1,29**	1,07	0,30
0,00 0,52 0,00 0,00	0,51	**0,77**	0,70
0,00 0,00 **0,51** 0,00	0,11	0,09	**0,91**
0,00 0,00 0,00 0,68	1,64	1,65	**1,65**
SUM=	3,54	3,58	3,56
0,87 0,52 0,51 0,68	2,45	2,43	2,36
0,00 0,00 0,00 0,96	2,51	2,56	2,57

Algorithm A has several drawbacks. The most obvious is that when replacing densities, smallest density should be considered, rather than smallest device input. The second is that the ink which was smallest in the initial solution may not be smallest in the new solution.

Algorithm B was designed to reference the drawbacks of Algorithm A. Therefore, Algorithm B uses weighted densities to determine the minimum component and estimates replaceable density from $\mathbf{d_S}$, taking the additivity failure into account. Additionally, it uses grayness weighing when estimating replaceable density. To understand why grayness weighing is important, let's inspect three colorimetric densities of individual inks (first four rows in Table 1). Only the yellow ink is relatively "pure", with high Z density and low X and Y densities. The other two chromatic inks (C and M) have at least two high densities. The black ink has all three densities high. When replacing near-neutral color (gray), all three chromatic inks are high. Therefore, taking only the density of the smallest component, when estimating replaceable density, would underestimate it since the other two inks also contribute significantly. That is why for near-neutral colors, replaceable density is multiplied by factor greater than one (grayness weighing). Even though Algorithm B performed significantly better than Algorithm A, it is still prone to slightly overestimating replaceable density for some colors. Applying grayness weighing is a rather inexact approach. Algorithm C was designed to reference all the apparent issues. Given an input color, it calculates the new black ink amount, such that in a new solution, whichever of the three chromatic inks becomes smallest, it reaches its new aimed value (replacement amount). Since this approach is model based, it provides accurate solutions for sets of values the model was trained with. It was not yet tested thoroughly, and deviations of smallest component density values from their aims for independent data sets are yet to be assessed. However, the results presented in this paper suggest that this algorithm is promising in being able to provide controlled results and accuracy comparable to state of the art.

5. CONCLUSIONS

This paper presents performance evaluation results of three black generation (BG) algorithms. Their performances were also compared with state of the art commercial solution. It was shown that the choice of black generation algorithm greatly influences the colorimetric accuracy in gray component replacement (GCR). Regarding the ink savings performances, fair comparison of algorithms is hard to perform due to their differences in controlling replacement amounts. However, this control over achieving clearly defined replacement amounts is a crucial feature of a well-designed BG algorithm. Only one of the three tested algorithms, the model based Algorithm C, offers this control. This makes it superior over the other two algorithms. It does not overestimate replaceable density amount, which ensures high colorimetric accuracy in GCR. Colorimetric accuracy is very important for avoiding the appearance of visible artefacts in digital images, namely banding and contouring. In addition to that, the initial tests suggest that it provides control over the amount of ink replacement. This is a very important feature because too much replacement can cause the appearance of visible artefacts during printing, namely graining in smooth image areas. However, the Algorithm C requires a more thorough testing of accuracy in achieving aimed replacement amounts, and this will be the subject of our next research.

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LIGHT PERMANENCE ORANGE AND VIOLET ELECTROINK PRINTS

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Abstract: *In production of high quality packaging reproductions of color based on multicolor printing process the EP machines can use six printing units, which except the CMYK process Ink contain two additional inks as well. Such a possibility has the HP Indigo machine which applies the liquid Electroink. In this paper, the durability of HP Indigo prints realized by using the original PANTONE colors (solid violet and solid orange) or the same violet and orange tones printed with raster mixing process colors (making double ink layer) were dealt with. The time period of aging (240 days) shows that results of color changes are sufficient. However colorimetric measuring observed the larger permanence of orange prints printed with the original PANTONE and violet ElectroInk prints printed with two layers (cyan and magenta).*

Key words: permanence of multicolor print, PANTONE Electroinks, violet tones, orange tones

1. INTRODUCTION

To realize the reproduction of color images it is necessary to do the halftone separation process and the printing process with inks. In other words they are transparent inks which are printed on the white surface and reflect 2/3 of the spectrum visible part (cyan color reflects light in blue and green area; yellow color reflects light in the green and red area, while magenta color reflects light in blue and red area of the electromagnetic field). Last color separation (printed ink) is black. With this application it controls the contrast of the color image, and realizes the uniform achromatic tones (Zjakić, 2007).
For particularly valuable reproduction (catalogs, art reproductions, monographs, production of exclusive packaging ...) standard color gamut is not enough, and it requires a wider range of tonal reproduction. Because of that we have to print the additional high pigmented spot printing inks (red, green and blue). For this purposes the highest quality printing using the printing machines with 6 and 7 printing units was done. In this case the additional spot color separation was realized with frequency modulated raster (Fry, 1999). The researches of many authors show that the use of additional separation of colors (spot inks) increased the volume gamut, which is especially important in the area of protection of print products and the reprint of old jobs (Dzik et al., 2012); (Lo et al., 2007); (Bartolić et al., 2013).
During the realization of RGB tones the choice of colorants in printing inks is very wide. It is possible with the use the different chemical formulations, different viscosity of the printing ink and with various particle sizes of pigment. Great ink option is particularly important for prints which must satisfy the longer life expectancy as well as the usage in different climatic conditions (high humidity, low temperature, high temperature, effects of sunlight). Therefore, testing and predicting the possible sustainability of printed products are standardized by various laboratory methods that are similar to the methods of testing printing substrates (Ufuk et al., 2010).
For prints on paper and cardboard the accelerated aging is the process which is performed in several ways: defined exposure exacting the high value humidity and temperature, and defined exposure samples exacting the energy radiation with constant temperature (ISO, 1997). In this way, the UV radiation directly affects the photochemical reactions of hydrolysis (changes in printing substrate) as well as the degradation of the components in printing inks. The final result is the accelerating process of the color prints degradation and bringing the prints in a new state (as it will be for a few months and years) (Možina et al., 2010); (Gregor Svetec and Debeljak, 2012); (Halinova et al., 2008); (Forgacs and Teishev, 2012).
HP Indigo presses work on the principle of indirect electrophotography (EP). In this printing process the liquid ink named Electroink is transferred from an organic photoconductor to hot intermediate blanket and then to the final printing surface. These types of machines have a special satellite construction which during the color printing they use only one printing unit (PIP cylinder, Intermediate blanket cylinder, impression cylinder, ROS writing head, scorotron, cleaner unit) as well as larger number of development units (BID). Thus, in formation of imprints on the printing substrate the HP press could do seven color separations (during rotation of impression cylinder 7 separations will be perform on paper with 7 installed BIDs). Now

it is possible to set additional PANTONE colors and the productivity of HP machine will directly depend on the number of printed separations.

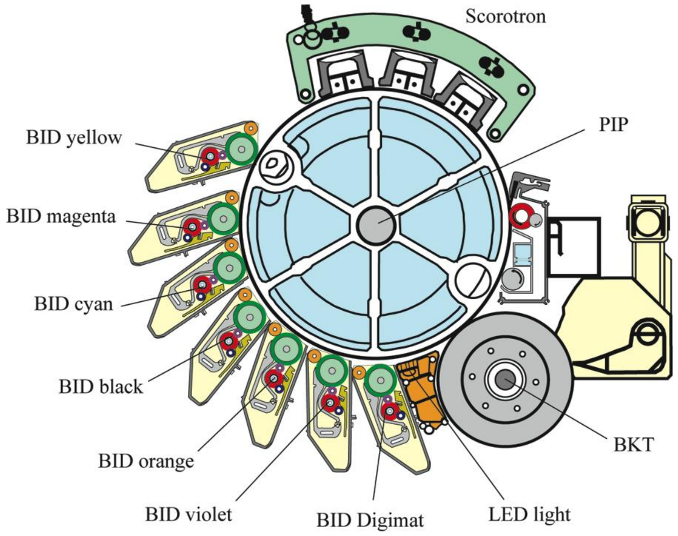

Figure 1: Schematic view of the printing unit on HP Indigo 5500 machine

2. METHODS

This paper investigated the impact of UV light on aging process of imprints produced with standard process Elektroink colors and two additional PANTONE Elektroink colors (orange and violet). The prints were printed on HP Indigo press series 5500, on 135 g/m2 fine art paper Magno Gloss. Testing of light permanence was done with the device for accelerated aging (Solar box 1500 E) in accordance with the norm ISO 12040:1997 in the time intervals of: 0h, 6h, 12h 24h, 48h, 96h, 160h and 244h (temperature of 50° C, power lamp of 550 W/m2, relative humidity 65% and Xenocrom filter 320).

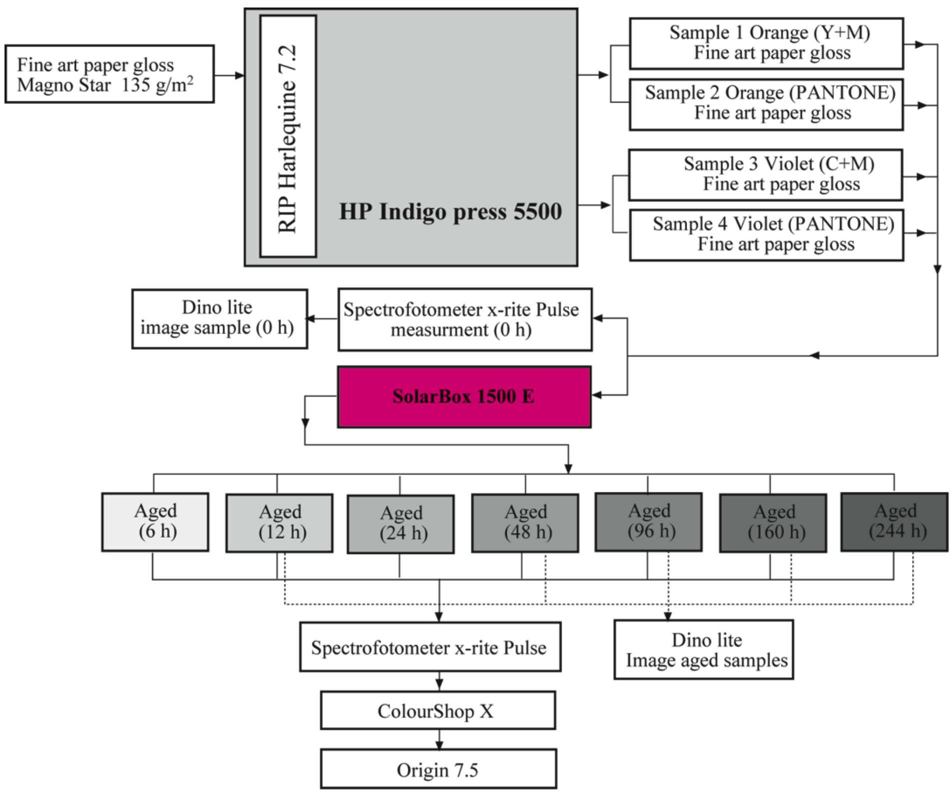

Figure 2: Schematic view of the performed experiment

Printing motive used in this investigation consists of CMYK and OV printing elements (10 fields of 10 to 100% tone value in the steps of 10% TV). The printing motive contained a microtext for microscopic investigation at intervals of 0h, 12h, 48h, 96h, 160h and 244h, (magnified photos used for visual evaluation). The results of change in color were detected using the spectrophotometer X-Rite Pulse (measured fields of 20% TV, 40% TV, 80% TV and 100% TV performed in six repeats). The patches of 40% TV and 100% TV, and the characteristic time intervals of 0h, 12h, 48h, 96h, 160h, and 244h were taken for microscopic analysis. The detailed analysis of color changes were made by means of the computer program Color Shop X. CIELAB 3D view and 2D view of deviation lightness ΔL, chroma ΔC and color deviation ΔE2000 were constructed from the obtained values. For that we used the additional computer program Origin Pro 8.0.

3. RESULTS

Of all the laboratory methods which could help in detecting changes in the properties of the prints the colorimetry was proved to be the most suitable one. With the measured L* a* b* values it was possible to detect the amount of color changes and the fading in color spaces (3D diagram). Figures 3, 4, and 5 showed the color changes in orange tones and the microtext on HP Indigo prints was created by printing with two Electroink inks (yellow and magenta), and the Indigo prints were printed with only one Electroink (PANTONE orange).

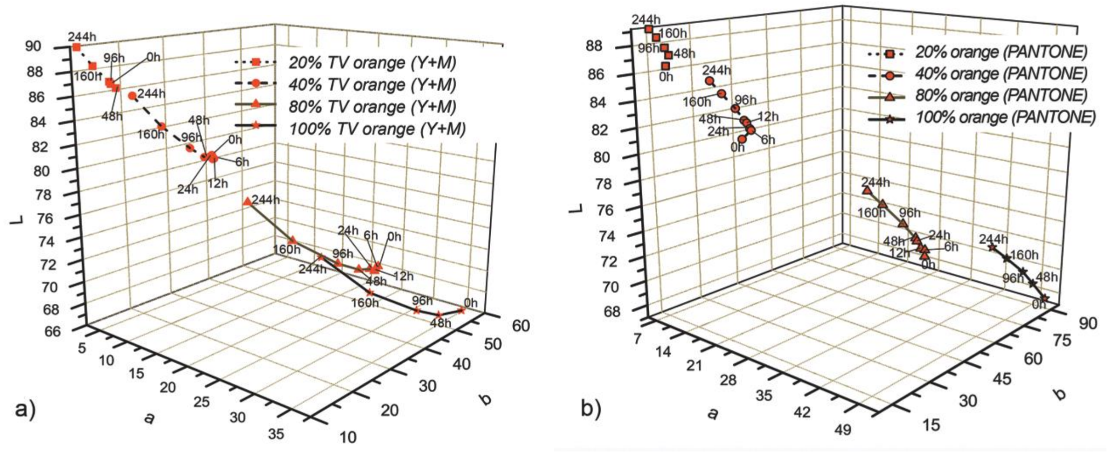

Figure 3: LAB 3D diagrams of color changes of orange tones during 244 hours: a) printed on HP Indigo 5500 (M + Y); b) printed on HP Indigo 5500 (O)

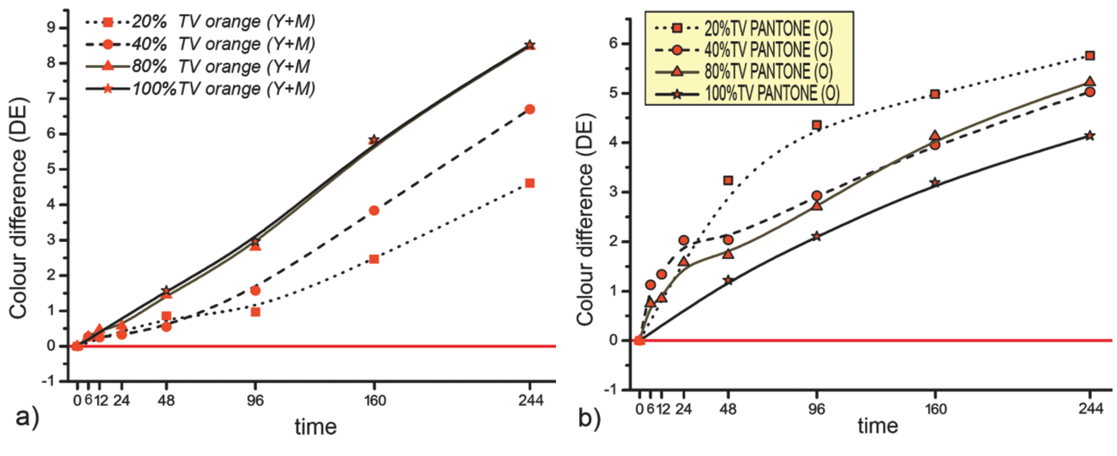

Figure 4: Dynamics of changes of orange tones (ΔE00) during experimental aging: a) printed on HP Indigo 5500 (M + Y); b) printed on HP Indigo 5500 (O)

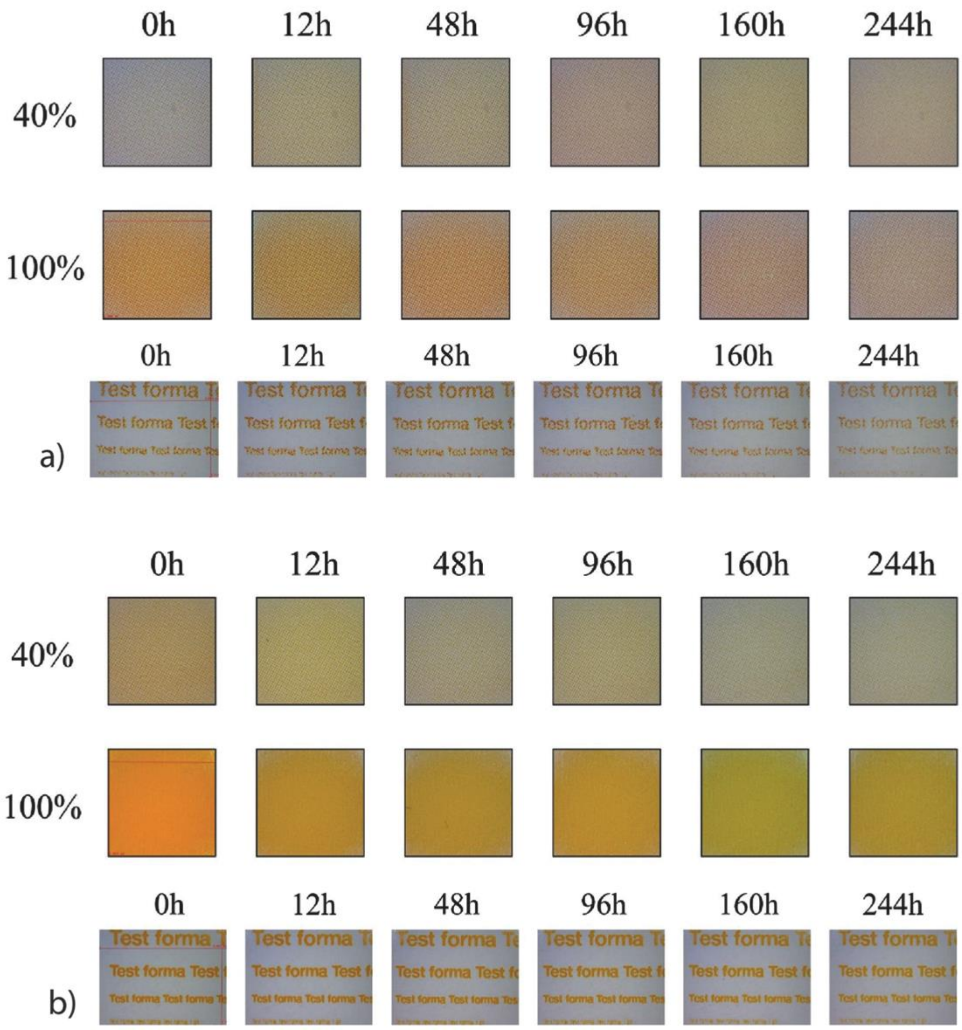

Figure 5: Magnified pictures of orange samples: a) printed on HP Indigo 5500 (M+Y); b) printed on HP Indigo 5500 (O)

Except the Spot orange shades the violet ones were often printed as well. Figures 6, 7, and 8 show the color changes of violet tones and the violet microtext. Samples were printed by combination of two Electroink inks (cyan and magenta), and only one Electroink ink (PANTONE violet).

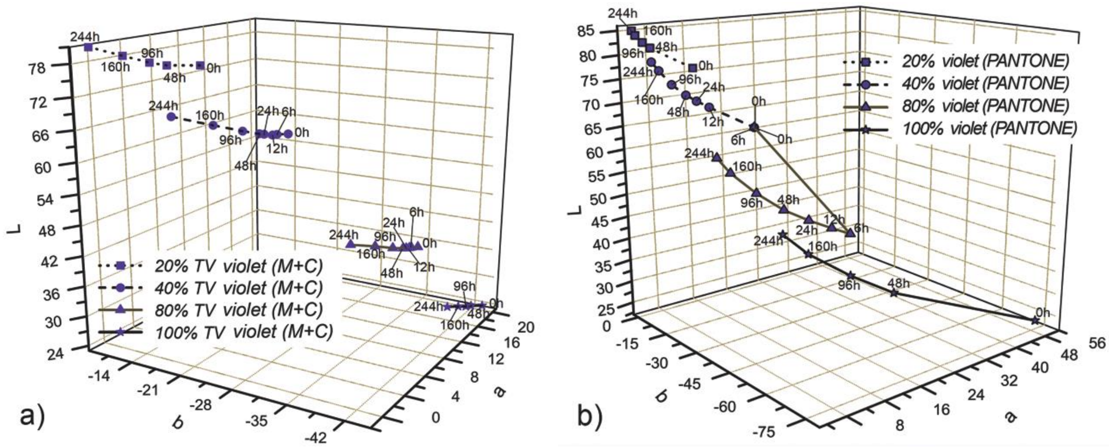

Figure 6: LAB 3D diagrams of color changes of orange tones during 244 hours: a) printed on HP Indigo 5500 (C+M); b) printed on HP Indigo 5500 (V)

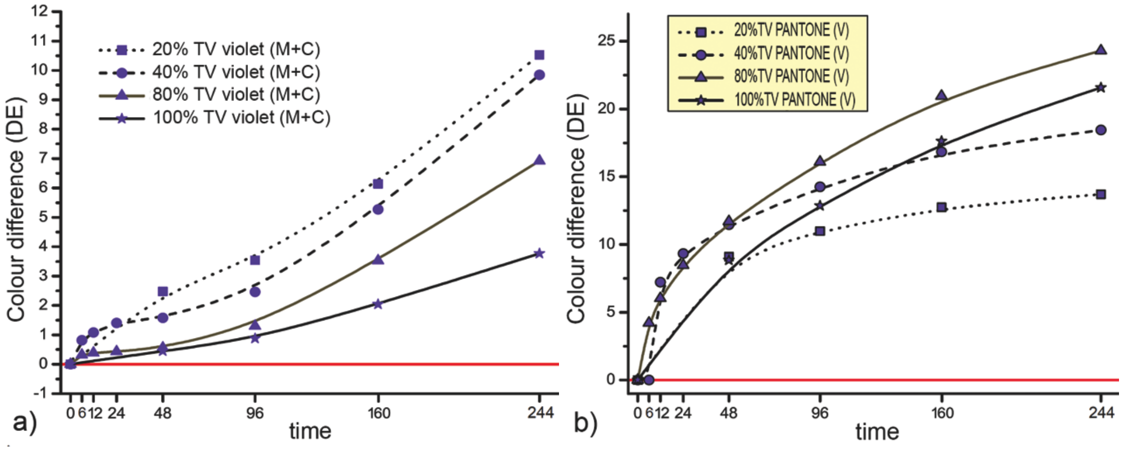

Figure 7: Dynamics of changes of orange tones (ΔE00) during experimental aging: a) printed on HP Indigo 5500 (C+M); b) printed on HP Indigo 5500 (V)

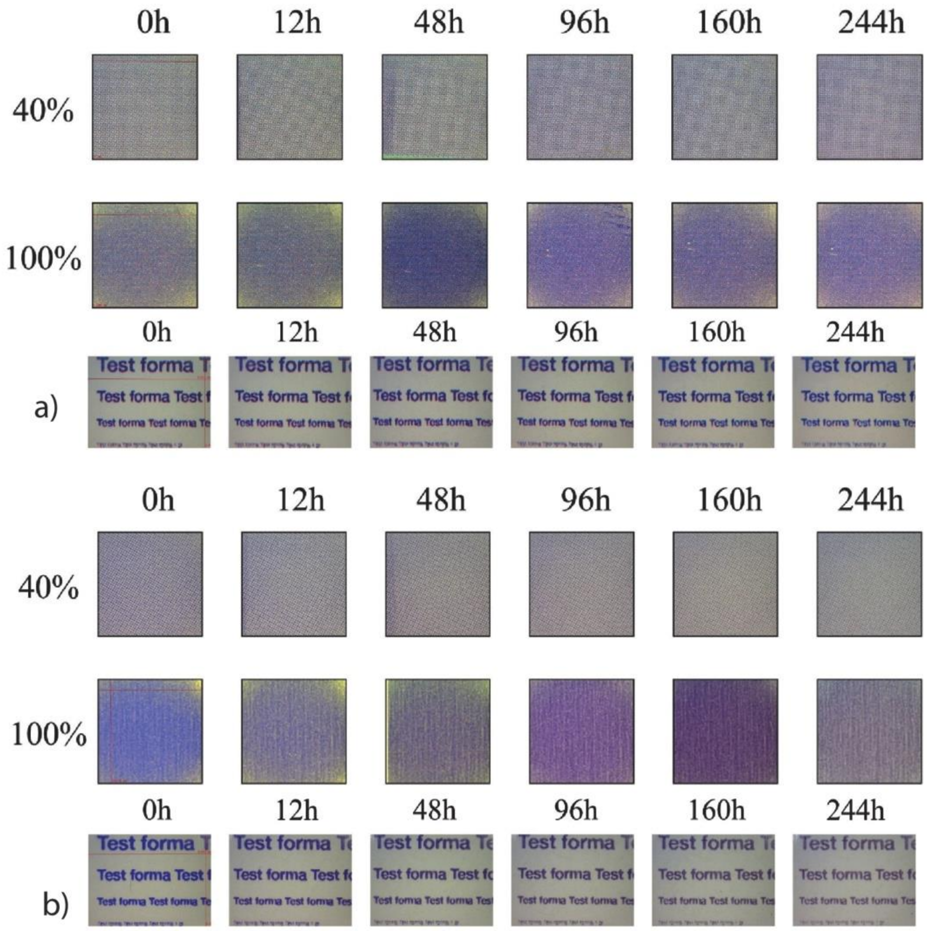

Figure 8: Magnified pictures of orange samples: a) printed on HP Indigo 5500 (C+M); b) printed on HP Indigo 5500 (V)

4. DISCUSSION

The orange tone value printed with CMYK inks, (Y+M) had more yellow features. Because of the poor stability of the yellow pigment, the printed orange one experienced a great degradation too. Such changes were visible in chroma value and lightness value of the measured tones (Fig. 3a). In the graph (Fig. 4a) it could be seen that after 96 hours of aging the visible degradation was achieved which rapidly expanded further. It showed a relatively linear curve correlation between the color differences and the aging time. The orange imprint that was printed with two inks had the visible tone value changes of 20% and 100%

after 48 hours. The low tone values of the image (20% TV) after 96 hours started with the slowest degradation, while the dark tone values of the image (100% TV and 80% TV) behaved similarly but the dynamics and the color changes value were the largest).
PANTONE orange imprint formed in one layer was more stable. This was evident from the results and the measured value with the exact grouping within the investigation color spaces (Fig. 3b). Slightly larger deviations can be noticed after 48 hours of aging. In that case, changes were ocurred in chroma. All curves of color changes had a slightly parabolic shape (fig.4b), which indicated that the changes came after 24 hours. The visible color differences in human eye occurred after 96 hours. Major exception was at 20% TV, where in the first 96 hours the tone difference was very large ΔE20% = 4,36. After that, the orange prints was stabilized and the dynamic of aging was slowed down ($\Delta E_{96h\text{-}244h}$= 1,4). Thus the Electroink orange pigments had proved to be a better choice in combination yellow Electroink pigment and Magenta Electroink pigment.
Visual analysis picture of PANTONE orange prints (Fig. 5), showed that colorants have tone degradation. However, the results were still good enough with regard to the extreme conditions to which they had been exposed. Better preserved tone which provided better readability was visible on PANTONE orange microtext. It could be noticed visually that the tone areas of 40% had major changes and greater degeneration of orange halftones. Therefore, it is necessary to avoid them.
It was very difficult to reproduce the solid violet tone with CMYK inks. The reason for that was the high layer of ink in the amount of 200% tone coverage (Cyan 100% and Magenta 100%). With the experimental aging process violet tones showed that small tone values had larger changes in color (Figure 7a). Thus the solid tone had the smallest color exchange. The detailed analysis showed that after 48 hours ΔE rapidly grew in the tone values of 20% and 40%. In other words, the violet tones in the first 24 hours degraded only slightly (although 20% TV and 40% TV printed from C + M had visible color changes after 12 hours). Areas with higher tone coverage (80% and 100% TV) achieved the same values after 48 hours of aging. After 244 hours of aging the smallest color difference would have the solid tone ($\Delta E_{100\%}$ = 3.77), while the largest one would have 20% TV ($\Delta E_{20\%}$ = 10,53). Imprints with two layers would be more stable if the upper surface was printed with stable cyan color.The aged PANTONE violet prints had an extremely large color changes (ΔE). It was evident on the graph in Figure 7a that these changes were greatest at 100% and 80% TV (they occurred in chroma and lightness). The human eye visible color difference occurred after 12 hours of experimental aging. That meant for all tested tone values regardless the coverage area with printing elements. The graphs showed the dynamics of color changes and had the parabolic shape. That meant that with time, there was the slowdown degradation process. In that case it was the delayed process because the Electroink Violet PANTONE print was deformed (there were no longer suitable to be used). The biggest tone changes were obtained on darker parts of images ($\Delta E_{80\%}$=18,46) and the lowest measured tone changes on the lighter tone patch ($\Delta E_{20\%}$=13,71). Compared with other Electroink prints it was definitely one of the most unstable inks and pigments.
The changes of violet prints caused by aging were visually visible on the image 60x magnified. After 244 hours prints were slightly gray, and text was faded. The most drastic changes were visible in smallest letters (microtext in the value of 1pt was gradually lost). On image fields of 40% and 100% TV the characteristic color changes after the accelerated aging could also be seen. They were completely new (different) color tones. ElectroInk after 244 hours aging was changed to unrecognizable. Therefore the recommendation is to print violet tones with process pigment (C+M) and then the printing product will have longer life span.

5. CONCLUSIONS

PANTONE orange prints obtained by a single pass, had much better results than orange ones derived from the process colors (M + Y). The results were twice as good where solid tone was printed with PANTONE inks ($\Delta E_{O100\%=}$4,14), than the solid tone printed with M+Y ($\Delta E_{100\%\ M+C}$= 8,52). Printing product which need the long-term quality and the exposed stability to sun, are recommended to be printed with PANTONE orange inks rather than the process inks (M+Y).
Violet prints obtained with process Electroink (C + M) had much better results than the violet prints obtained with PANTONE violet Electroink. PANTONE violet prints have more drastic change in tone ($\Delta E_{V100\%=}$21,58), than solid tone printed with two process ink ($\Delta E_{100\%M+C}$= 3,77). The prints obtained with process inks give six times better results. The use of process inks is recommended for the products which must have better quality. For the printing product which needs better permanence quality to usage of mixing process ink and the avoiding of PANTONE Electroink violet ink is recommended.

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Printing issues

IMPACT OF PRINT PARAMETERS ON AIR PERMEABILITY OF PRINTED KNITWEAR

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Abstract: *The heat and humidity of human body retain as layers of air before passing into the environment. This creates the characteristic microclimate between the skin and clothing which is defined as a feeling of comfort. In addition to comfort, clothing should meet the aesthetic requirements of the individual. Process of printing is often used for the increasing of the aesthetic value of clothing. The printed ink covers part of the surface material, and partly fills the pores between fibers in the yarn, creating an additional barrier to the process of transfer of heat and moisture from the body to the environment. The paper presents the research of the impact of digital printing parameters on sorption properties of printed textile materials. For research were used 100% knitted cotton fiber (100% CO), and 100% polyester fiber (100% PES), and as the essential parameters of the printing process were selected tone value and number of ink layers. The impact of print parameters on the sorption properties of the material has been tested using the air permeability as a parameter of sorption properties. Research results indicate that the printing process with its parameters have a significant impact on air permeability of printed cotton knitwear.*

Key words: air permeability, digital printing, textile materials, knitwear

1. INTRODUCTION

Nowadays from products in all aspects of life it is expected to fulfill personal requirements of individuals besides their basic function. One of the most common personal requirement refers to visual attractiveness of object. Therefore, today from selected clothes is expected to satisfy aesthetic and fashionable requirements, so it would in that way better portray personal character and lifestyle of individual (Mecheels, 1992). By printing clothes, in relatively simple way, its aesthetic value is being increased. In that way, printing process enables increase of perceived value of clothes, in a way that customer or user of product perceives higher utility of product compared to his price (Vladić et al, 2014). From technical aspect, process of printing clothes can be defined as process of transferring ink, which is carrier of information, on textile substrate (Kašiković et al, 2014). From the artistic point of view, process of printing clothes presents art and skill of transferring desired design on surface of textile material (Tippet, 2002). Currently the world's annual print of textile material is between 11 i 13% , that is more than 27 billion m^2 of textile substrates, with annual growth rate of 2% (Momin, 2008; Provost, 2009; Onar Çatal, Özgüney & Akçakoca Kumbasar, 2012). The value of textile material printing industry in 2010 was 165 billion US$. Textile material printing industry is under great pressure of constant changes. This market is seasonal and highly dependent on fashion trends (Gupta, 2001). Demands of customers are changing very fast, therefore the collections are changing frequently in two months (Özgüney, Özerdem & Özkaya, 2007). Trends on market, like: decrease in circulation, demands for higher print quality, rapid job change and short deadlines, unique and personalized print, have led to increased interest for digital printing in textile material printing (Kanik et al, 2004; Mikuž, Šostar-Turk & Pogačar, 2005; Stančić et al, 2013). Digital printing efficiency, as flexible way of ink transfer on substrate in the form of a desirable design, is primarily reflected in respect of costs and time needed for production of smaller circulations (Novaković et al, 2010). Besides that, digital printing technique enables faster response to market demands and mass individualization. Beside aesthetic demands, clothes shall also meet the ergonomic and physiological requirements (Mecheels, 1992). Does clothing meet aesthetic and ergonomic demands customer easily evaluates before or during first wearing. With physiological function it is different, and clothing with good physiological characteristics should make man does not feel heat or cold in different climatic conditions (Mecheels i Umbach, 1976). Comfort is basic and universal need of human being and presents one of the most important aspects of clothing. During clothes wearing, heat and humidity produced by body has been stopped as layers of air before passing in the environment, resulting in characteristic microclimate between skin and clothing, defined as the feeling of comfort (Yoo, Hu & Kim, 2000; Grujić, Geršak & Ristić, 2010). Thermal effects largely contribute to the comfort of the individual, whereby a complex physiological and psychological factors together with clothes play an important role in defining the complex phenomenon of comfort (Andreen, Gibson & Wetmore, 1953). Human body with the process of metabolism constantly transforms food chemical energy into work and heat. Produced heat is transferred through skin and further through clothing system to the environment. Heat exchange processes in dressed and undressed human are qualitatively equal, while quantitatively depend on the thermodynamic properties of clothing, which presents separating surface between body and environment (Mecheels, 1991; Grujić, 2010). The process of heat exchange between body and environment itself is done by processes of: conduction, convection, radiation, evaporation and respiration (Stoecker & Jones, 1982). Greatest part of heat exchange is done by the process of convection. With this process heat is transferred by the movement of gas or liquid. Quantity of heat lost by the convection is determined with difference between temperature of clothing surface and air, and also with convective heat transfer coefficient, which is, in turn, determined with speed of air movement through clothing system (Persons, 2003). The physiological properties of clothing, and thus wearing comfort, could be expressed, apropos quantified, through heat and sorption properties of material (Huang, 2006; Das et al, 2007). Among the most important sorption properties are: air permeability, water holding capacity and relative humidity.

Previous research showed that air permeability of textile material is conditioned by structural properties of material (Mezarciöz, Mezarciöz & Oğulata, 2014; Oğulata & Mavruz, 2010). However, during printing process layer of ink is transferred on clothing. Part of printed ink covers clothing surface, while other part of ink fills pores between fibers in yarn. Thereby, printed ink presents new layer of material, actually additional barrier for the movement of air through the clothing. In order to get new scientific knowledge, this study examined influence of printing process, as one of the methods for increasing visual attractiveness of clothes, on physiological comfort of printed textile materials. Thereby was examined influence of digital ink-jet printing parameters, tonal coverage and number of ink layers, on air permeability of cotton and polyester knitwear.

2. METHODS AND MATERIALS

Research of printing process influence on air permeability of printed knitwear was performed on purpose-made knitwear. Basic characteristics of examined knitwear are shown in Table 1.

Table 1. Characteristics of materials used in research

Sample	Material type	Type of weaves	Material composition (%)	Fabric weight (g/m^2)	Thread count (cm^{-1})
P-A	Knitwear	Single	Cotton 100 %	111,89	Vertical: Dv = 17 Horizontal: Dh = 17
P-B	Knitwear	Single	Polyester 100 %	114,12	Vertical: Dv = 12 Horizontal: Dh = 20
Method			ISO 1833-1	ISO 3801	ISO 7211-2

For research purposes special test image has been developed. Test image was created using Adobe Illustrator CS5 software application, and was consisted of twelwe patches dimension 20 x 20 cm, and coverage of 10%, 50% and 100% tonal values (TV) of four process colors: cyan, magenta, yellow and black (Figure 1.).Printing of samples was done using ink-jet printing system Polyprint TexJet. Samples were printed with one, three and five ink applications, without intermediate drying in case of printing with more ink applications. Printing of samples has been done with resolution of 720 x 720 dpi, using water-based pigment colors DuPont Artistri Pigment- 5000 Series (cyan, magenta, yellow and black). After printing process, prints were exposed to drying process and fixation of printed inks. Samples were dryed with heat effect at a temperature of 130 °C for 120 seconds, using device for drying imprints tp 4040s from manufacturer „Opremakv“.

Before laboratory measurements samples were air-conditioned for 24 hours at standard atmosphere (temperature of 20 °C and relative air humidity 60%). In order to achieve higher accuracy of the measurement results, more samples were measured with repetition on the individual samples. As measurement results were taken arithemtic means of ten times measured numerical values.

Term air permeability of textile materials means the permeability to air passage through the material. While air is passing through clothing, cooling of the body is being enhanced, because part of produced energy is being drained away. The passage of the air through clothing happens when the partial pressure at surface of clothing is higher than pressure in immediate environment of the surface of the skin.
Air permeability measuring is done according to standard ISO 9237:1995 (ISO, 1995). Researches were carried out at different places of material, and on 10 cm distance from the ends of the material. Measurings were done using device Karl Schröder KG Air Permeability Tester, which is shown in figure 1.

Figure 1. Air permeability measuring device

Obtained values of air permeability were recalculated into amount of passed air in m^3 during one minute, using expression (1) (ISO, 1995):

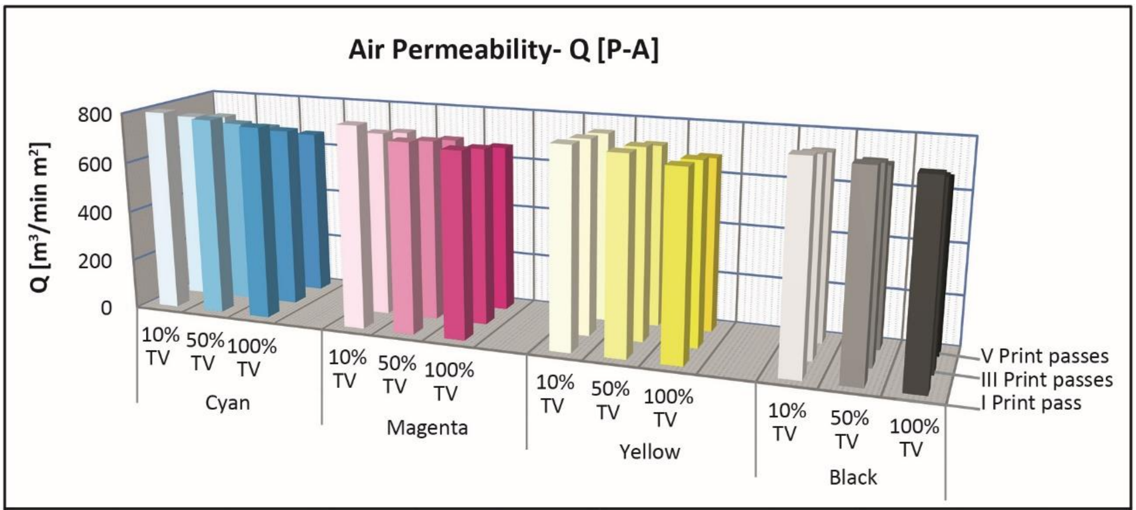
$$Q = \frac{q}{6 \cdot F} \qquad (1)$$

where:

- Q - amount of passed air for certain height of water pillar [m^3/min m^2],
- q - amount of air that is passing through surface of tested sample [dm^3/h],
- F - tested surface [cm^2].

3. RESULTS AND DISCUSSION

Results of air permeability of printed cotton knitwear research are shown in figure 2. Obtained values are showing that printed knitwear have lower values compared to values of unprinted cotton knitwear. Exceptions are only samples printed with one layer of ink with 10% tone values of cyan, magenta, yellow and black for which registered values are equal with values of unprinted cotton knitwear. With further observation of values from figure 2. it can be noticed that air permeability of printed cotton knitwear decreases with increase of tonal coverage. At the same time, increased number of layers in printing, also, leads to decrease of air permeability values. Listed trends in air permeability values are present regardless of whether the samples were printed with cyan, magenta, yellow or black ink.
With analysis of air permeability values for printed cotton knitwear it can be noticed that, with combination of tonal coverage and number of ink layers in printing, similar values of air permeability can be obtained. Thus, in case of samples printed with cyan ink, values of air permeability are same for samples printed with 100% TV (tonal values) with three layers of ink and 10% TV with five ink layers. In case of samples printed with magenta ink equal values occured in case of printing with 100% TV with one ink layer and 10% TV with three ink layers, and also in case of printing with 100% TV with three ink layers and 10% TV with five ink layers. When printed with yellow ink equal values of air permeability appeared in case of printing with 50% TV with one ink layer and 10% TV with three ink layers, then in case of printing with 50% TV with three ink layers and 10% TV with five ink layers, and also in case of printing with 100% TV with three ink layers and 50% TV with five ink layers. In case of black ink equal values of air permeability appeared during printing with 100% TV with one ink layer and 10% TV with three ink layers.



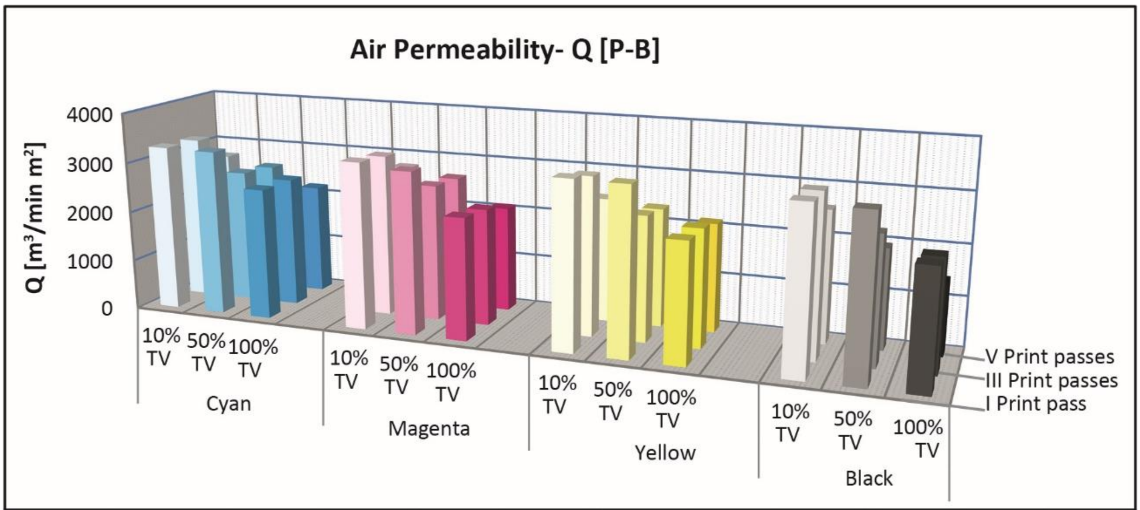
Air Permeability- Q [m³/min m²]											
Sample	Unprinted Material	Colour	I Print pass			III Print passes boje			V Print passes		
			10% TV	50% TV	100% TV	10% TV	50% TV	100% TV	10% TV	50% TV	100% TV
P-A	800	C	800	783	766	750	733	716	716	683	666
		M	800	750	733	733	716	700	700	683	666
		Y	783	766	733	766	750	716	750	716	683
		K	800	783	766	766	750	716	733	700	666

Figure 1. Air Permeability value of printed cotton knitwear

Obtained values of air permeability for printed polyester knitwear (Figure 3.) are showing that with the printing process in case of these knitwear, obtained values are also lower compared to values for unprinted knitwear. Exceptions are samples printed with one layer of ink with 10% tone values of cyan, magenta, yellow and black for which registered values are equal with values of unprinted polyester knitwear. Values from figure 3. are showing that air permeability of printed polyester knitwear, also, decreases with increase of tonal coverage. At the same time, increased number of layers in printing, again, leads to decrease of air permeability values. Listed trends in air permeability values are present regardless of whether the samples were printed with cyan, magenta, yellow or black ink.

Values in figure 3. show that also in case of polyester knitwear similar values of air peremability can be obtained with combination of tonal coverage and number of ink layers. Thus, in case of printing these knitwear values of air permeability are closely equal when printed with 50% TV with one ink layer and 10% TV with three ink layers, and in case of printing with 100% TV with three ink layers and 50% TV with five ink layers. In case of samples printed with magenta ink closely equal values occured in case of printing with 50% TV with one ink layer and 10% TV with three ink layers, and also in case of printing with 50% TV with three ink layers and 10% TV with five ink layers. When printed with yellow ink equal values of air permeability appeared in case of printing with 100% TV with one ink layer and 50% TV with five ink layers, and in case of printing with 50% TV with three ink layers and 10% TV with five ink layers, and also in case of printing with 100% TV with three ink layers and 50% TV with five ink layers. In case of black ink closely equal values appeared during printing with 50% TV with one ink layer and 10% TV with three ink layers. In order to determine dependence of air permeability of printed cotton and polyester knitwear, when printing with different tonal coverage (TV) and different number of ink layers (NP) and using different inks, mathematical dependence models were created using multiple regression analysis. In creating model, as independent variable value, printing process parameter values were used, i.e. values of ink layers number in printing and tonal coverage values. At the same time, as the dependent variable values were used experimentally obtained values of measuring air permeability of tested knitwear.

With research results analysis were obtained statistically reliable dependences of air permeability on the tonal values and number of ink layers, which are presented in tables 2. and 3.



Air Permeability- Q [m³/min m²]											
Sample	Unprinted Material	Colour	I Print pass			III Print passes boje			V Print passes		
			10% TV	50% TV	100% TV	10% TV	50% TV	100% TV	10% TV	50% TV	100% TV
P-B	3300	C	3300	3283	2600	3266	2650	2583	2733	2566	2200
		M	3300	3200	2400	3216	2700	2316	2783	2633	2100
		Y	3300	3283	2350	3133	2466	2316	2466	2350	2150
		K	3216	3166	2300	3183	2500	2183	2600	1966	1433

Figure 2. Air Permeability value of printed polyester knitwear

Table 2. Statistical analysis of Air Permeability values of printed cotton knitwears

Q (C) = 828,874 - 0,433 · TV - 23,667 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 828,874			b_1 = -0,433			b_2 = -23,667		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,989	5,399	4,579	181,026	$1,9171 \cdot 10^{-12}$	0,049	-8,860	0,000115	1,102	-21,48	$6,6517 \cdot 10^{-7}$
Q (M) = 804,724 - 0,490 · TV - 19,500 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 804,724			b_1 = -0,490			b_2 = -19,500		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,946	10,710	9,083	88,595	$1,3931 \cdot 10^{-10}$	0,097	-5,049	0,002	2,186	-8,920	0,0001 11

Table 2.- extension

Q (Y) = 806,676 - 0,620 · TV - 11,083 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 806,676			b_1 = -0,620			b_2 = -11,083		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,974	5,841	4,945	162,840	$3{,}6181 \cdot 10^{-12}$	0,053	-11,73	0,000023	1,192	-9,296	0,000088
Q (K) = 834,566 - 0,560 · TV - 20,833 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 834,566			b_1 = -0,560			b_2 = -20,833		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,978	7,314	6,203	134,549	$1{,}1367 \cdot 10^{-11}$	0,066	-8,451	0,000150	1,493	-13,95	0,000008
Note: the mark TV represents tone value, NP number of passes, C Cyan colour, M Magenta colour, Y Yellow colour, K Black colour										

Table 3. Statistical analysis of Air Permeability values of printed polyester knitwears

Q (C) = 3598,109 - 7,110 · TV - 140,333 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 3598,109			b_1 = -7,110			b_2 = -140,333		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,886	152,640	129,453	27,795	$1{,}4345 \cdot 10^{-7}$	1,382	-5,145	0,002	31,158	-4,504	0,004
Q (M) = 3580,055 - 9,289 · TV - 115,333 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 3580,055			b_1 = -9,289			b_2 = -115,333		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,932	128,980	109,387	32,728	$5{,}4126 \cdot 10^{-8}$	1,168	-7,954	0,00021	26,328	-4,381	0,005
Q (Y) = 3551,040 - 7,749 · TV - 163,917 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 3551,040			b_1 = -7,749			b_2 = -163,917		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,827	219,145	185,855	19,106	0,000001	1,984	-3,91	0,008	44,733	-3,664	0,011
Q (K) = 3785,007 - 11,419 · TV - 223,583 · NP										
Multiple reg. coef.	Std. Error of the Estimate	b_o = 3785,007			b_1 = -11,419			b_2 = -223,583		
R^2	s	Std. Error	t	p	Std. Error	t	p	Std. Error	t	p
0,931	185,261	157,118	24,090	$3{,}36 \cdot 10^{-7}$	1,677	-6,81	0,000492	37,583	-5,912	0,001

4. CONCLUSIONS

In the presented research, influence of digital ink-jet printing process parameters on sorption properties of printed clothes, apropos on parameters of physiological comfort of printed clothes was tested. In that purpose, dependence of air permeability of printed cotton and polyester knitwear on variable factors of printing process was tested, i.e. from different tonal coverage and different number of ink layers.
Measured values of air permeability for tested knitwear behave in a manner that with increasing the number of ink layers in printing, and also increasing the tonal coverage, leads to air permeability value decrease. Also, based on experimentally obtained results mathematical dependence models of air permeability on printing parameters were created. These models could be used in real production conditions, during printing clothes made from these materials, and in order to adjust printing process parameters to get clothes for different purpose, with optimal both aesthetic and sorption properties, and all of that in order to get clothes with optimal comfort properties.
With printing process part of printing ink is transferred on material surface, and other part penetrates the interior of material and fills pores between yarn as well as pores between fibers. In this way in textile material is created additional barrier, which disturbs the free passage of air through textile material. Decreasing the value of air permeability by increasing tonal coverage and number of ink layers in printing is explained by the fact that increasing of these parameters leads to application of larger amount of ink on and in printed material. This leads to covering the larger quantity of fibers, and thus to reducing possibilities for free passage of air through textile material.
Measured values of air permeability also shows that closely equal values of air permeability can be obtained with combination of number of ink layers in printing and tonal coverage. This fact is, in turn, important from an economic point of view, because it shows that similar values of sorption parameters can be obtained with smaller number of ink layers in printing by increasing tonal coverage. In this way it is possible to achieve an increase in productivity, because time needed for printing process is being reduced, without affecting the values of sorption properties of printed cotton knitwear, and also the comfort of the clothes made from these materials.
Summarizing the results of the research it can be concluded that printing parameters have great influence on air permeability, as one of the important parameters of clothes comfort. In order to obtain further knowledge, in future research it is planned to test the impact of materials of different composition. Also, done research should be carried out, besides knitwear, on fabrics. Besides that, all researches can be expanded on other sorption parameters, and also on the parameters of the thermal properties of clothing.

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INFLUENCE OF PAPER STRUCTURE AND POROSITY ON THE PRINTABILITY

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Abstract: *Pulp structure in papermaking process, surface roughness, and strength of electricity, moisture, thickness, thermal conductivity and optical properties are important parameter that influences printing quality. The ink should not exceed to the reverse side during at the print process is an important printability properties. Opacity value of print under material is most important factor affecting the printability. Printability is a parameter related with the level of paper quality when it is printed. Many factor influence the occurrence of density in prints. Density is a value that shows pigment excess on the print under material. The goal of this work was to examine the influence of porosity of different types of paper (from mechanical and chemical pulp). Printability of these paper was analysed using IGT and Gurley from which porosity and surface properties were calculated high opacity and low print density value had a strong negative impact on the print quality and printability. Different composition of pulp of paper can increase or decrease print quality. Paper as a printing substrate its high opacity and porosity variations may cause print non-uniformity. In this research, print was application on the mechanic paper and chemical paper samples by laboratory type offset printer. Cyan colour ink was used for print. Density value of printing paper samples were determinate and results were compared with opacity value.*

Keywords: Printability, density, porosity and print quality

1. INTRODUCTION

Paper is the most important raw material of printing technology. Communication is almost synonymous with paper. Various other substrates including board, metallic and plastic films, textiles, and semiconductor materials are also printed.The performance of paper in printing depends on its runnability, printability, and information capacity (Gullichsen, J., Paulapuro. H., 1998). According to Table 1, it showed European unofficial paper grade classification.

Table 1: European Unofficial Paper Grade Classification

Printing and writing papers	Paperboards	Tissue	Air-laid paper	Specialty paper
Mechanical printing paper	Cartonboards	Hygiene products	-	-
Woodfree printing and writing paper	Containerboards	Other tissue products	-	-
	Special boards		-	-

Print quality of whole this papers andprintability is equivalent to the quality potential of paper in printing. Printability is not the same as printed quality because other factors influence printed quality. These include pre-press, printing press, and printing factors (Juric 2014).
High levels of density and wide colour range are not possible without a glossy printed surface. Gloss is a measure of surface smoothness (Gullichsen, J., Paulapuro. H., 1998).
Paper surface is not only influenced by the quality of the fibers but also the chemicals added in the wet end section, coating application condition effects the structure. Results show that the average print density values of paper samples increased (Isabel M. T. 2007, Sönmez S. 2011 and Biricik Y. 2011).
Because of paper which contains 70% air in total content, is a highly porous material.Porosity is a paper property as necessity for offset paper runnability. Structure of paper has a varying degree of porosity.Porosity of paper indicate the ability of resistance of fluids. Therefore, porosity affects directly printability properties of papers. Table 2 showes paper and fibergrades.

Table2: Paper and fibergrades

Paper grades	Short fibers for printability	Long fibers for runability
Mechanical grades	GW, PGW, TMP, BCTMP, DIP	Long fiber softwood(BSKP)
Woodfree grades	BHKP, DIP	
Non-wood grades	Several non woods(bagasse, wheat straw etc.)	Bamboo, kenaf etc.

Mechanical papers contain mechanical and chemical pulp besides filler. Certain grade of printing paper was evaluatedas comparing printability and runnability properties. Numerous printing mechanical and woodfree paper samples was made. In this paper it is discussed in terms of the control of the paper ink interaction with these samples.

2. METHODS

We used four different commercially available paper in this research. Paper samples are uncoated. Firstly, cellulose properties of paper samples fixed.In table 3 are presented some paper properties (grammage and cellulose structure). After, they were printed using a laboratory type offset print and cyan color. Density andCIE L*a*b* values were measured by Gretag Macbeth SpectroEye instrument (45/0°). The gloss values of samples were determined using a BYK Portable glossmeter according to ISO 2813. Finally, the Delta gloss of samples were evaluated form gloss values of samples before / after print. Roughness values of samples were measured using aL&WBendtsen Tester as Tappi T 479 om – 91. Porosity values of samples were measured by a L&W Air Permenance Tester according to TAPPI T 460 om – 88.

Table 3: Properties of paper sample

Sample Paper	Grammage(g/m^2)	Cellulose structure (%)	
		Chemical	Mechanical
1	61.25	90	10
2	63.88	30	70
3	63.66	0	100
4	90.00	100	0

3. RESULTS

Print Density, Print Chroma, gloss, delta gloss, roughness and porosity values of printed samples paper were measured using TAPPI Test Methods. Results of test of printed-papers sample has been figures.

3.1 Surface Roughness

Figure 1 showed that Samples 4 had lower roughness value than another samples. So, Samples 4 obtained a good print quality because of having smoothness surface. Figure 1 demonstrated Sample 1 and sample 2 had the same surface roughness.

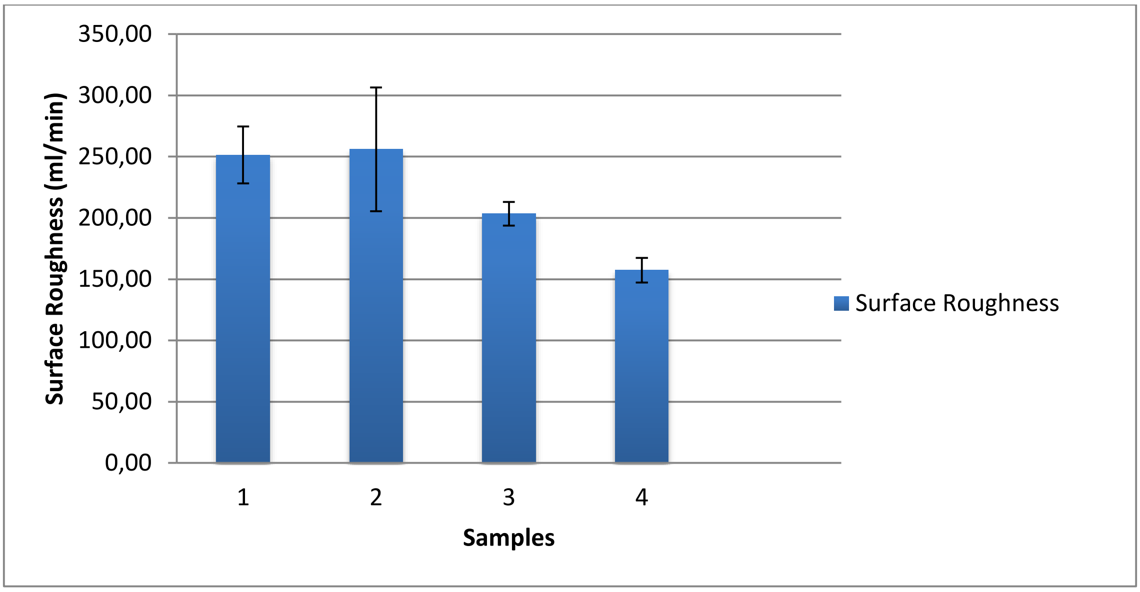

Figure 1: Surface Roughness

3.2 Porosity

Porosity is the most important factor for obtaining a good print. Increased this value, increased air permeability. Therefore, after printing, the remaining pigment amount on substrate is decreased.
While Sample 1, 2 and 4 had almost the same porosity values; Porosity of Sample 3 was lower than them (Figure 2).

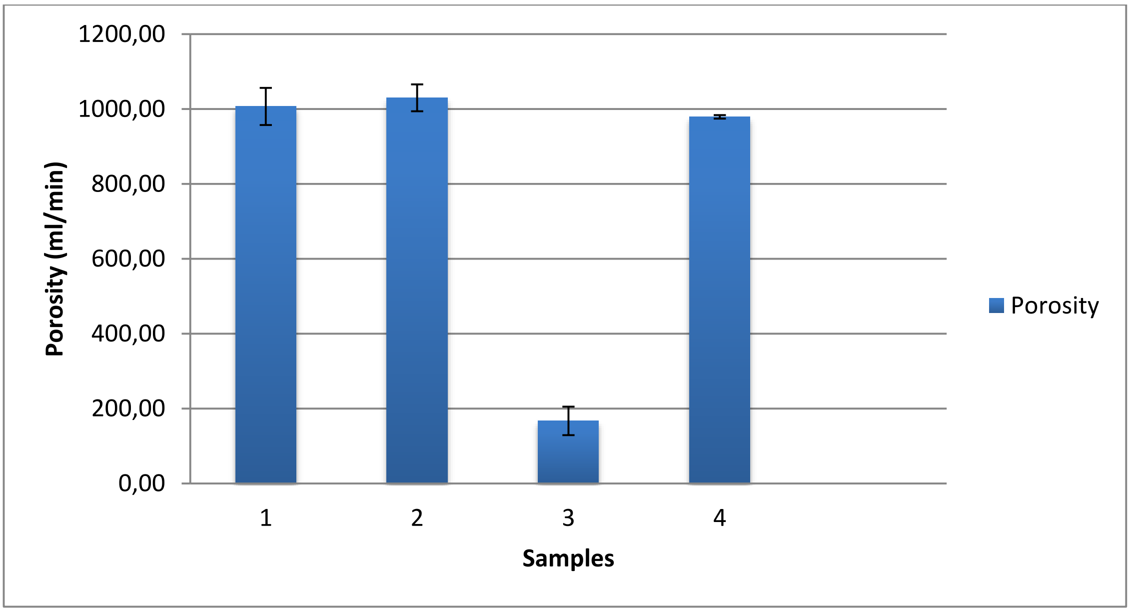

Figure 2: Porosity

3.3 Print Density

Figure 3 showed that Sample 3 had higher print density value than other samples. Others had almost the same density value.

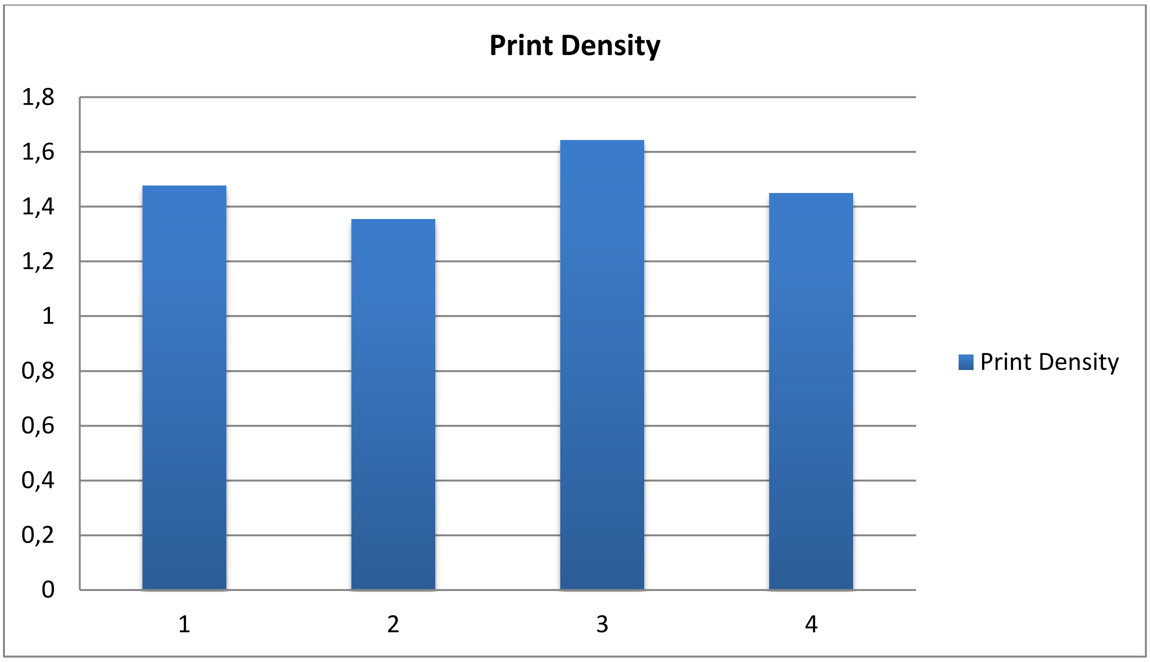

Figure 3:Print Density

3.4 Print Chroma

While, Sample 4 had highest print chroma value, Samples 1 had lowest print chroma.
So, obtained the colour space of Sample 4 is larger than other samples (Figure 4). It is an important point for getting a quality print.

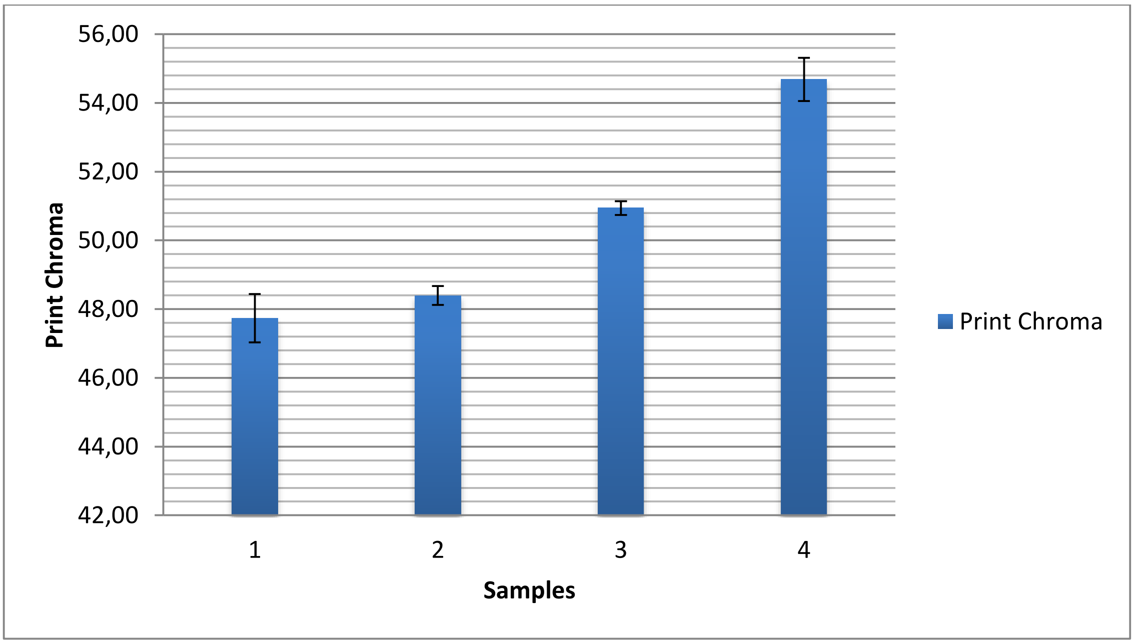

Figure 4:Print Chroma

3.5 Delta Gloss

Delta gloss is difference between gloss values before print to glossy print value after print. Figure 5 showed that gloss value of all samples before printing was higher than after printing. Especially, Sample 3 and 4 were lost gloss value after printing. Samples 1 had a glossy print another samples.

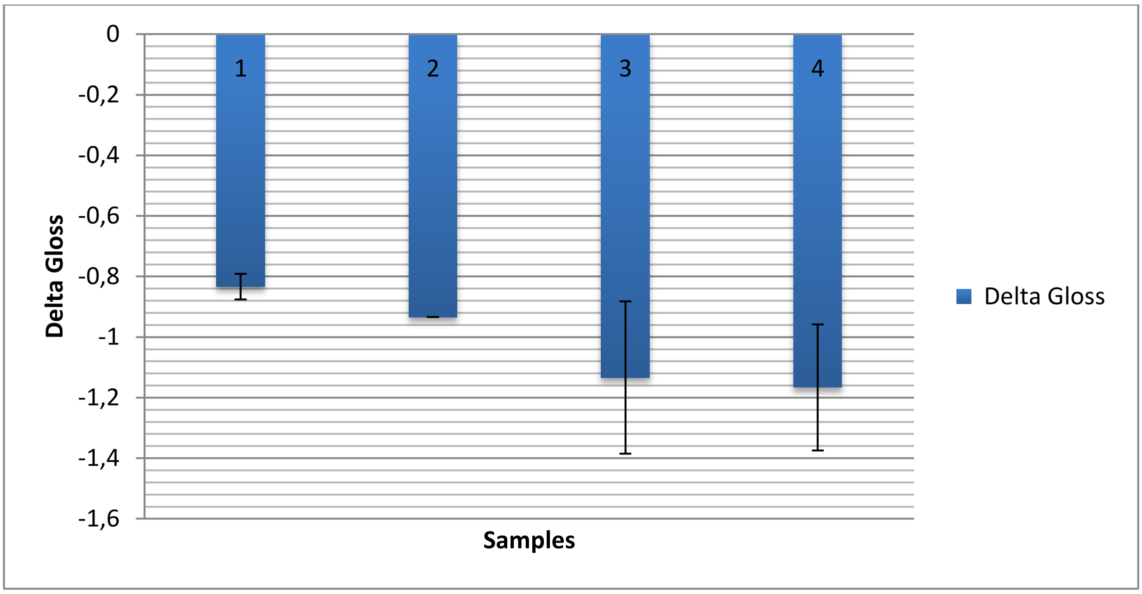

Figure 5: Delta Gloss

4. CONCLUSIONS

In this paper we investigated the printability influence of woodfree and mechanical paper which have different porosity and roughness. Porosity correlates with almost all physical paper properties and is important for printability. Additionally printability is a term that indicates paper quality. Porosity is the most important factor for obtaining a good print. Increased this value, increased air permeability. Therefore, after printing, the remaining pigment amount on substrate is decreased. While Sample 1, 2 and 4 had almost the same porosity values; Porosity of Sample 3 was lower than them (Figure 2).

5. ACKNOWLEDGMENT

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Colour in digital media

THE EFFECT OF SCANNING RESOLUTION AND DISPLACEMENT VALUE ON THE GLCM-BASED FEATURES FOR PAPER TEXTURE CHARACTERIZATION

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Abstract: *In image analysis and segmentation, texture is often categorized through the features based on Grey-Level Co-occurrence Matrix (GLCM). Results of this analysis depend on orientation and displacement between neighbor pixels, where the effect of the later parameter is more emphasized. In order to characterize texture of paper samples, they need to be digitized, meaning that the accuracy of the image analysis depends on the resolution of an imaging device as well. For the practical application, samples are usually being scanned; therefore, the resolution of a scanner dictates the accuracy of texture description. In this study we assessed the effect of the displacement value and scanning resolution on texture features based on GLCM. Sample set consisted of eight papers with similar grammage and whiteness values, chosen to form a scale in accordance to their surface roughness. Samples were scanned in three resolutions and the GLCM parameters were calculated with respect to four different displacement values. We choose to assess five features which were shown to have good correlation with texture perception: Homogeneity, Entropy, Sum Average, Sum Variance and Sum Entropy. The results indicate that the change in the displacement value does not affect the features assessed in this study. The resolution, on the other hand, was shown to have a significant effect on all observed features, except Homogeneity.*

Key words: paper texture, GLCM, resolution, displacement

1. INTRODUCTION

Besides color, texture is one of the most important visual cues which define the appearance of an object and enable its discrimination. Hence, in image analysis much effort has been made to characterize texture in a unique and unambiguous way. Over the years many different approaches for texture characterization have been proposed. They can be categorized to structural, statistical, model-based and transform (Materka & Strzelecki, 1998). The choice of specific approach and the corresponding texture descriptors depends on the final application, which is usually related to the image segmentation and classification. With the expansion of computer vision, it becomes important to define texture features which enable texture description with respect to human perception of it.

In many of the previous works (Julesz, 1962; Gebejes et al, 2012; Gebejes et al, 2013a; Abd Latif et al, 2015) it was shown that the approach based on Grey-Level Co-occurrence Matrix (GLCM) provide texture features which correlate well with human perception of a texture. Even though this approach dates back to 1973 (Haralick et al, 1973), it is still used for many applications related to image processing (Soh et al, 1999; Sassi et al, 2012; Zulpe & Pawar, 2012; Abd Latif et al, 2015). The GLCM approach belongs to the second-order methods, meaning that the interaction between neighboring pixels (and not only their values) is assessed for defining the texture features. Namely, GLCM is built by taking into account the frequency of occurrence of two neighboring gray level pixel combinations (Haralick et al, 1973, Gebejes et al, 2012). In this approach only the lightness component of an image is observed, since the perception of a texture mostly depends on the change of its lightness (Haralick et al, 1973). From GLCM one can obtain 22 different features. Since some of them describe the same property, in practical application only few are used to describe the certain texture.

In order to build GLCM it is necessary to define number of gray levels in an image (Ng), distance of the GLCM (so called the displacement value – d), and orientation (Θ). The number of gray levels is generally determined by the process of quantization. In this case, using a large number of gray levels leads to a bigger GLC matrix. In order to avoid that GLCM created from an image is bigger than the image itself, it is recommendable to use a lower number of gray levels. It is stated (Albergsten, 2008) that quantization into 16-bits per channel is sufficient for texture description, while in the practical applications 8-bits representation is most commonly used (256 levels per channel).

Distance is the displacement between two pixels whose repetition is examined. This parameter was shown to affect the results obtained from GLCM because different textures exhibit different spatial distributions of neighboring pixels (Chen et al, 1989). Using a big displacement value with fine textures leads to the loss of texture information, and vice versa (Soh et al, 1999). Furthermore, it was shown that the image classification improves if the displacement value has the same size as texture element (Dickshit, 1996). Hence, the choice of displacement value is usually arbitrary and may be guided by the coarseness of a texture being examined. In the study of texture perception it was suggested to use the displacement value which provides the maximum contrast for the majority of the samples in the chosen set of textures (Gebejes et al, 2012).

For a given distance it is necessary to define the orientation which represents the angular position of the line that connects two neighboring pixels with respect to the horizontal. Usually, four different orientations are used: 0°, 45°, 90° and 135° (Haralick et al, 1973; Soh et al, 1999; Albergsten, 2008). The orientation influence to some extent the values in GLCM, and consequently texture features obtained from it (Haralick et al, 1973; Soh et al, 1999; Hu et al, 2013). If the goal is to avoid the dependence of direction it is recommended to calculate an average matrix of four GLCMs (one for each of the abovementioned angles) (Albergsten, 2008).

In this study, we were interested in texture characterization of paper samples. In order to obtain their images, samples have to be digitized. In this process, it is important to specify the image resolution which in most cases depends on the resolution of the imaging device. Since this parameter can influence image quality, we assumed that it can also influence image analysis or, more specifically, texture features obtained from GLCM. Hence, this influence was further analyzed.

Along with resolution, we addressed the influence of displacement value on texture features, since there is no clear suggestion on how to select this parameter in case of textures of a paper. Comparing to the other types of materials papers usually do not exhibit strong surface roughness, meaning that their texture can be regarded as very fine. Since the previously mentioned studies (Dickshit, 1996; Soh et al, 1999; Gebejes et al, 2012) were based on different types of textures there is not enough evidence that the same results would be obtained in the case of paper samples.

Therefore, the goal of this paper was to assess the influence of resolution and displacement value on GLCM—based texture parameters which were shown to correlate well with human perception of a texture. Characterizing this influence would lead to determining the optimal parameters for texture characterization based on GLCM features.

2. METHOD

Samples used in this study consisted of eight non-printed papers with similar grammage and whiteness (Table 1), but different textures (where the textures were formed in the process of paper production) (Figure 1). Grammage was defined by the manufacturer, while the whiteness value for each one of the chosen samples, defined with respect to the CIE norms (ISO, 2004), was obtained by spectrophotometer Eye-One Pro and the Babel Color CT&A software.

Table 1: Samples' specifications

Sample number	Type	Grammage	Whiteness (CIE)
1	Natural Evolution FSC White	320 g/m²	100.08
2	Astroprint Canvas	280 g/m²	103.32
3	Modigliani Candido New	320 g/m²	103.97
4	Dali Candido New	285 g/m²	102.04
5	Dali Candido New	360 g/m²	102.28
6	Astroprint Juta	280 g/m²	103.80
7	Astroprint Fili	280 g/m²	103.28
8	Astroprint Bag	280 g/m²	103.45

The defined paper set was selected with respect to their surface roughness, where different types of textures were chosen. As seen from Figure 1, the chosen set consisted of both regular and stochastic patterns. In practical applications, paper samples exhibit both types of textures, hence in this study they were not processed separately.

Surface roughness was measured with TR200 roughness tester and expressed in a form of arithmetic average of absolute values (Ra) (Whitehouse, 2012). The cut-off length was set in accordance with the obtained magnitude of the measurements (for all samples this value was 2.5 mm) and the evaluation length was defined as five cut-offs. Following the ISO recommendations (ISO, 1996) for filtering the data (to separate the waviness and the roughness), we chose Gaussian filter. In this manner we did not detect waviness (evident for samples 5-8, but not for the rest of the set) and characterized only roughness of each sample.

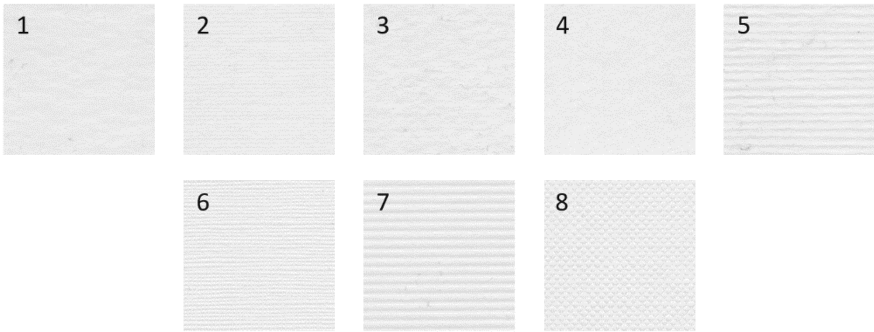

Figure 1: The sample set used in the study

In order to avoid the effect of texture orientation on the measured values, measurements were performed in four directions – horizontal, vertical and two diagonal. For each sample, we performed three measurements in each direction, where the mean value of twelve measurements was regarded as the measure of sample's roughness. Obtained roughness values for the chosen sample set are shown in Figure 2. As can be seen in Figure 2, chosen sample set enabled forming a satisfactory scale with respect to their surface roughness.

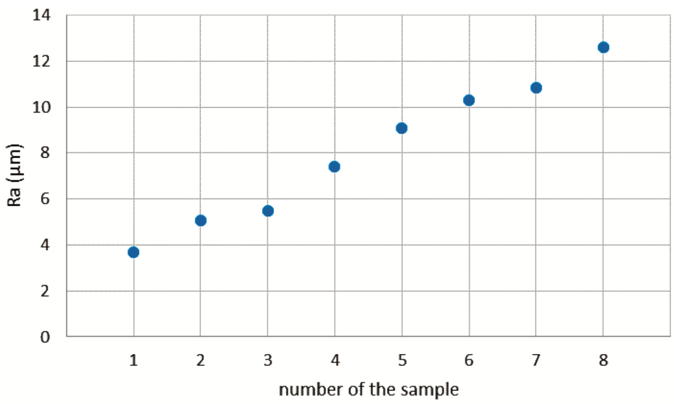

Figure 2: Paper samples' surface roughness

The paper samples were scanned with Canon CanoScan 5600F flatbed scanner in 8-bit per channel RGB color mode. When deciding the scanning resolution we relied on the guidelines provided by ISO/IEC 13600:2001 (ISO, 2001) which are applicable for the measurement of image quality attributes for hardcopy output. This standard, as well as the work related to image quality assessment (Briggs, 1999), recommend digitizing samples at resolution of 600 ppi. Hence, we chose to scan our samples at three resolutions – the one regarded as optimal for image analysis (600 ppi) and the two additional (chosen to be lower and higher than the optimal one - 300 ppi and 1200 ppi). Being the optical resolutions of given scanner, chosen settings enabled obtaining a true representation of paper samples since no interpolation was employed. The region of size 2x2 cm was selected from each of the scanned images and saved as TIFF file without compression. Images obtained in this manner were further processed in MATLAB R2011a (Uppuluri, 2010) in order to obtain GLCM-based texture features.

As mentioned before, from GLCM twenty-two different features can be obtained. In this study, we place our focus on those that were shown to correlate well with visual perception of a texture (Gebejes et al, 2012; Gebejes et al, 2013). From the suggested features we decided to use five - *Homogeneity*, *Entropy*, *Sum Average*, *Sum Variance* and *Sum Entropy*. These features are most commonly used for describing texture since they provide the description of its spatial disorder (*Entropy* and *Sum Entropy*, in particular), as well as its homogeneity. All the features were calculated in accordance with (Haralick, 1973; Uppuluri, 2010).

In order to avoid the effect of orientation, an average of the four possible directions (horizontal, vertical and two diagonals i.e. 0°, 90°, -45° and 45°) was taken into account. This approach ensures that the samples' texture features were obtained in the same manner as their surface roughness values.

For evaluating the effect of displacement value on the GLCM-based features, chosen features were calculated with respect to four displacement values - 5 px, 10 px, 20 px and 40 px. It was suggested that the displacement value should be chosen with respect to the size of texture element (Soh et al, 1999; Dickshit, 1996). Hence, we decided to choose distances that encompass the range of the texture elements' sizes of our sample set. The biggest distance was set to 40 px, being the size of the texture element of sample 8 scanned at resolution of 1200 ppi. The rest of distances were chosen in a way that the following distance was always two times smaller than the previous one. In that way we were able to assess whether significant changes in displacement values influence the final result of their characterization. Since the parameters were calculated for different resolutions, for each sample twelve values of the chosen texture feature were obtained.

In order to assess the influence of both image resolution and displacement value on the texture features, we conducted the statistical analysis involving two-way ANOVAs for each of the chosen features. In this analysis, texture feature value was set as a dependent variable, while the fixed factors (independent variables) were resolution and the displacement value. Due to the small number of the samples in the set, the significance level was set to 0.1 (Stevens, 1996; Pallant, 2007). Results and Discussion are given as follows.

3. RESULTS

The results of two-way ANOVA in the case of *Homogeneity* show that neither resolution ($F(2,84)=1.574$, $p=0.213$) nor displacement value ($F(3,84)=0.257$, $p=0.856$) have a significant effect on the mentioned texture feature. Their interaction was also shown to be statistically insignificant ($F(6,84)=0.212$, $p=0.972$). By analyzing the *Homogeneity* values obtained for one resolution and different displacements it was noticed that the change in the displacement value had no influence on the results. Similar was observed in the case of resolution, as shown in Figure 3.

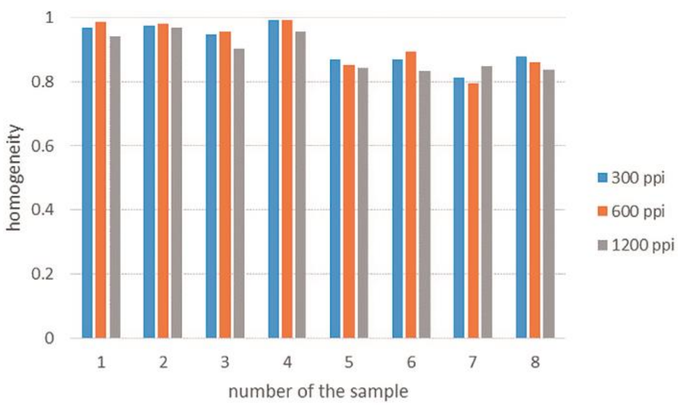

Figure 3: Samples' Homogeneity for the chosen resolutions (d=10 px)

As the range of *Homogeneity* is 0-1, where higher values denote more homogeneous samples, Figure 3 also shows that all the paper samples used in this study can be categorized as very uniform. A bit lower *Homogeneity* is observed in the case of samples 5-8, whose texture pattern is more noticeable (see Figure 1).

Samples 5-8 also exhibit higher *Entropy* in comparison to the rest of the samples. Since the *Entropy* is the measure of spatial disorder, where higher values imply less organized textures, this means that the mentioned samples were detected as somehow less organized comparing to the others. The reason for such an interpretation lies in the choice or orientation. Namely, the areas with regular textures exhibit small *Entropy* values in the texture direction and the perpendicular direction and relatively larger values in the direction of 45° and 135° to the texture (Hu et al, 2013). Since in this study we used the mean value of four possible orientations, it is possible that the *Entropy* values corresponding to the unordered direction contributed to the larger *Entropy* overall. Also, *Entropy* measures the randomness of the image texture meaning that the *Entropy* value is lower for the homogeneous images. Taking into account the homogeneity of samples 1-4, their low *Entropy* values are expected.

Assessing the influence of two defined variables on *Entropy* led to the conclusion that displacement has no effect on it ($F(3,84)=0.003$, $p=1$), while the influence of resolution was shown to be statistically significant ($F(2,84)=3.074$, $p=0.051$). The significance of this influence can be defined as medium (partial $\eta^2=0.068$). This can be confirmed by Figure 4a, where the Entropy values of all the samples are presented (obtained with respect to the displacement value of 10 px). For all the samples highest *Entropy* was obtained in the case of highest image resolution. Mean *Entropy* values, shown in Figure 4b, confirm the big difference in *Entropy* for image resolution of 1200 ppi, comparing to the rest of the chosen resolutions.

Furthermore, the difference in *Entropy* was not so accentuated if the resolution was changed from 300 ppi to 600 ppi (Figure 4a and 4b). To assess whether this difference is statistically significant we conducted Tukey's HSD post hoc test. The results confirmed that the mean features' values obtained from the images with resolution of 300 ppi ($M=0.58$, $SD=0.33$) do not differ significantly ($p=0.967$) from those obtained from 600 ppi images ($M=0.56$, $SD=0.37$).

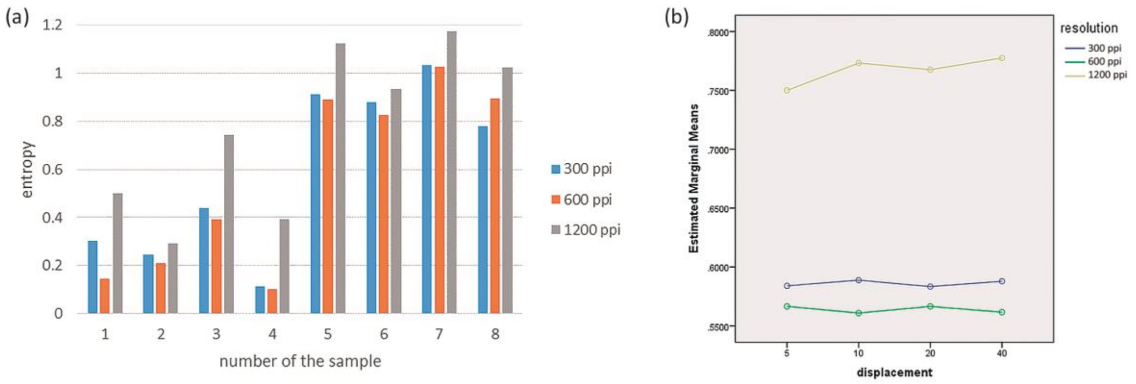

Figure 4: (a) Samples' Entropy for the chosen resolutions (d=10 px), (b) estimated marginal means for Entropy

Two-way ANOVA performed for *Sum Average* revealed that the displacement has no effect on this feature ($F(3, 84)=0$, $p=1$). However, the influence of resolution was shown to be significant ($F(2, 84)=3.008$, $p=0.055$). Based on the partial eta squared value ($\eta^2=0.067$), this influence can be categorized as medium significant. From the results presented in Figure 5, it can be seen that *Sum Average* for all the samples was lowest in the case of the highest scanning resolution (1200 ppi) (please note that the scale for *Sum Average* is much larger comparing to previously shown parameters). On the other hand, it is also evident the difference in *Sum Average* obtained for images of 300 ppi and 600 ppi is negligible. This was confirmed by Tukey's HSD post hoc test ($p=0.999$).

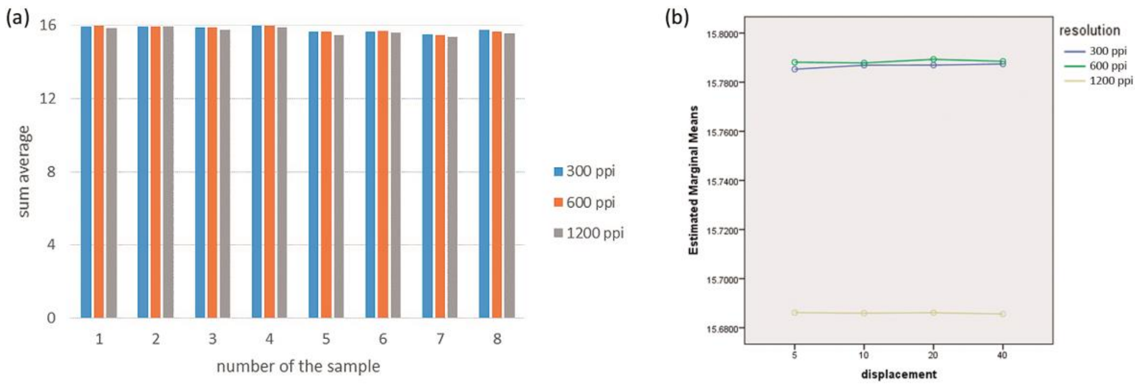

Figure 5: (a) Samples' Sum Average for the chosen resolutions (d=10 px), (b) estimated marginal means for Sum Average

The displacement was also shown not to have any effect on the change of *Sum Variance* ($F(3, 84)=0.005$, $p=1$), while the effect of resolution was statistically significant ($F(2,84)=3.372$, $p=0.039$). In fact, the resolution was shown to have a medium effect on *Sum Variance* (partial $\eta^2=0.074$). The lowest values of *Sum Variance* were obtained in the case of highest resolution (Figure 6). Similar to *Sum Average*, the difference in *Sum Variance* was shown to be minimal if image resolution was changed from 300 ppi to 600 ppi. The results of Tukey's HSD test showed that these differences can be regarded as statistically insignificant ($p=0.975$).

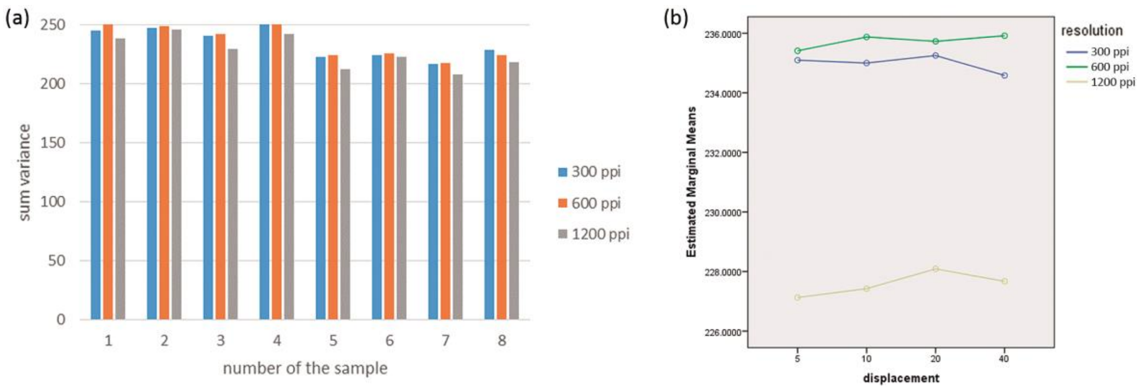

Figure 6: (a) Samples' Sum Variance for the chosen resolutions (d=10 px), (b) estimated marginal means for Sum Variance

Finally, the results of two-way ANOVA performed in the case of *Sum Entropy* led to the same conclusion as for the other features – the effect of displacement can be completely neglected ($F(3,84)=0.015$, $p=0.998$). As in the previous cases, the resolution was shown to have a significant influence on *Sum Entropy* ($F(2,84)=3.572$, $p=0.032$). This influence can be categorized as medium significant (partial $\eta^2=0.078$). For all the assessed samples highest values of *Sum Entropy* was noticed for the highest image resolution (Figure 7), while the lowest was obtained when image resolution was 600 ppi. The difference in *Sum Entropy* obtained for images with a resolution of 300 ppi and 600 ppi was small and statistically insignificant (according to the results of Tukey's HSD post hoc test - $p=0.946$).

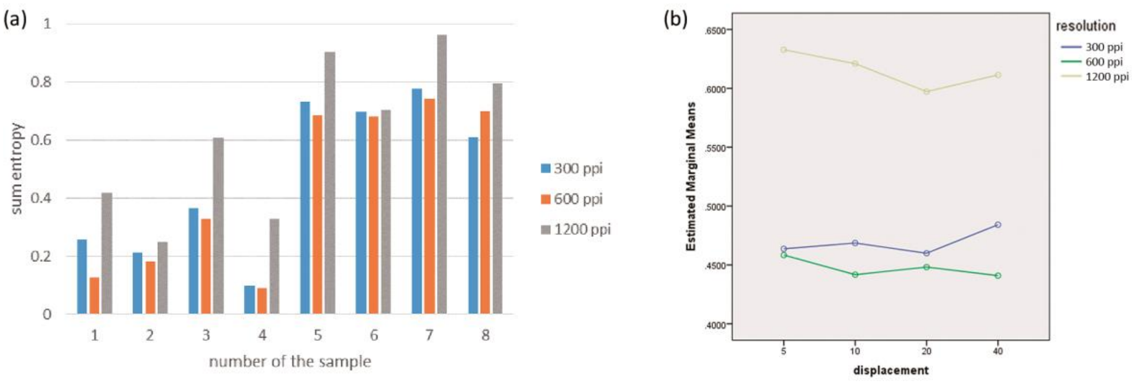

Figure 7: (a) Samples' Sum Entropy for the chosen resolutions (d=10 px), (b) estimated marginal means for Sum Entropy

4. DISCUSSION

As seen from the presented results none of the analyzed texture features were shown to be displacement-variant. This confirms the results presented in the former study (Gebejes et al, 2013b), where it was shown that *Homogeneity* and *Entropy* exhibit little change with the change of displacement value.

The resolution, on the other hand, was shown to influence all the features except *Homogeneity*. The *Homogeneity*, in essence, is the measure of the arrangement of texture structure, where the strong homogeneous textures usually contain repetitive structure. In the case of paper samples, this

repetitiveness is expected since most of the samples have a uniform spatial arrangement of texture elements. This repetitiveness was obviously well detected in all the chosen resolutions, leading to the small variations in *Homogeneity*.
In the case of *Entropy* and *Sum Entropy*, the highest values were obtained for the highest resolution (Figures 4 and 7). The entropy is the measure of disorder or, more precisely, the irregularity of a texture pattern. Taking this definition into account it can be assumed that from the images with high resolution more details can be detected which leads to more strict regularity assessment and, consequently, higher *Entropy* values.
The opposite effect was noticed for *Sum Variance* and *Sum Average*, where the highest resolution led to the lowest texture feature values. In the case of *Sum Average* almost identical results were obtained for the image resolution of 300 ppi and 600 ppi (see Figure 5a and 5b). The same trend was noticed for all the analyzed features – difference between features obtained from images of resolution of 300 ppi and 600 ppi were quite small (Figures 3-7). This observation was confirmed by the results of Tukey's HSD post hoc tests which proved that abovementioned differences were statistically insignificant.

5. CONCLUSIONS

Texture characterization still remains a big challenge in image processing mostly due to its complexity. An ideal texture descriptor should not be dependent on image content, or the other texture parameters. Also, it is important that the texture feature describes to the high extent human perception of the texture being analyzed.
In this study we placed our focus on texture characterization of paper samples, where the sample set consisted of papers with different surface roughness and texture patterns. In order to characterize their textures, we relied on the second order statistics or, more precisely, on features obtained from Grey-Level Co-occurrence Matrix (GLCM). These features principally depend on the distance between neighboring pixels (displacement) and the angular position of the line that connects them with respect to the horizontal (orientation). The effect of orientation can easily be avoided (by averaging GLCMs obtained for different angles), while the effect of displacement value is not easy to predict or control. Hence, we were interested in assessing this effect in the case of paper texture characterization. In addition, we evaluated the effect of image resolution, since it affects the image quality in general.
The choice of texture descriptors was driven by their correspondence to human perception. Therefore, to characterize paper samples used in this study we chose five different features - *Homogeneity, Entropy, Sum Average, Sum Variance* and *Sum Entropy*.
The results of statistical analysis showed that displacement does not have a significant influence on the chosen texture features. This result is very important since it suggests that for the paper texture characterization there is no need to estimate the optimal displacement value as suggested in (Gebejes et al, 2013b).
The effect of the resolution was insignificant in case of *Homogeneity*, which makes this feature suitable for characterizing textures from images of different resolutions. However, the resolution was shown to have a significant influence on the rest of the assessed texture features. It was proved that the differences between features extracted from images scanned at 300 ppi and 600 ppi were statistically insignificant, while the values of the features extracted from high-resolution images (1200 ppi) notably deviated from the others. If the resolution of 600 ppi is regarded as an optimal solution for assessing image quality (ISO, 2001), and the results obtained from images scanned at 600 ppi as the ground truth for the parameter being analyzed, this result indicates that for the texture characterization of papers there is no need to digitize samples in the resolution higher than 300 ppi. In order to generalize this finding, additional analysis had to be conducted on the more extensive sample set.

6. ACKNOWLEDGMENTS

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IMAGE QUALITY PARAMETER EVALUATION WITH SUBJECTIVE QUALITY ASSESMENT METHODS

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Abstract: *Image quality can be determined in two ways: we can use objective quality assessment methods, such as RMS, PSNR, SSIM and UQI or we can use subjective quality assessment methods. Subjective testing is usually done through the use of eye movement tracking or by determining of which of two or three images is the best. We developed a novel image test database that consists of 30 images. These images were carefully chosen based on colour, detail and motive versatility. We managed to develop an image database that is 57 % more complex than TID2008 which is commonly used in this type of research. The next step was to choose image quality parameters that are most common in everyday use. We have chosen: sharpness, contrast, noise, saturation, size manipulation and compression. Each of the parameters was applied in MATLAB R2014a in different ways and steps, so that 38 manipulations were made for each image. Our novel image database has 1140 images in 1920 × 1440 pixel resolution. The first step of the subjective quality assessment testing was conducted through the use of the eye tracking method. By showing images in order to test participants, we received an accurate information on how each of the image quality parameters affects the communication value of each image. In this way we were able to determine which parameters have greater impact on image perception. The second subjective quality assessment method involves the development of a web based application for crowdsourcing based testing. User had to determine which of two images is the best. Results also showed which of the parameters has greatest impact on image communication value. Finally, a correlation between the subjective method's results were implemented, comparing them to the results from the objective quality assessment methods in further research.*

Key words: image quality, assessment methods, image database, eye-tracking, crowd-sourcing.

1. INTRODUCTION

In 2015 (Ahtik, 2014) we introduced our novel image database. This was done with subjective quality assessment testing of image visual quality in mind. The most commonly used TID2008 (Ponomarenko, 2009; Winkler, 2015) is in our opinion not suitable for the job: the resolution of images it produces is not sufficient (640 × 480 pixels), images have to small detail coverage spread and their color gamut is also not big enough. The novel image database was developed with the help of a number of calculations. The coverage of details was measured with the help of *ImageJ* software where we used edge detection and threshold functions to determine how many details does each image has.
Images chosen for our database have 22 % to 99 % detail coverage and images in TID2008 have 46 % to 89 % – that is 57 % more complex (Figure 1).

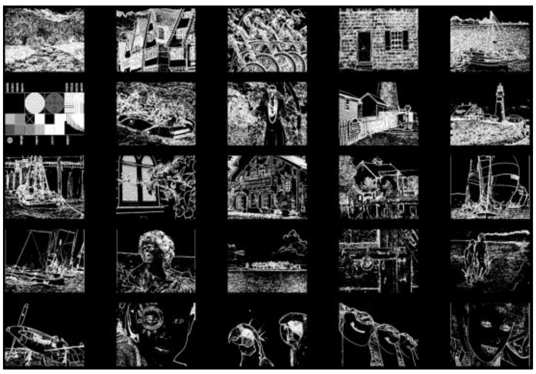
a)  b) 

Figure 1: Image complexity in TID2008 (a) and the novel image database (b).

We have also chosen images based on their average color so that the color gamut we would get for our database would be wider than in TID2008 (Figure 2).

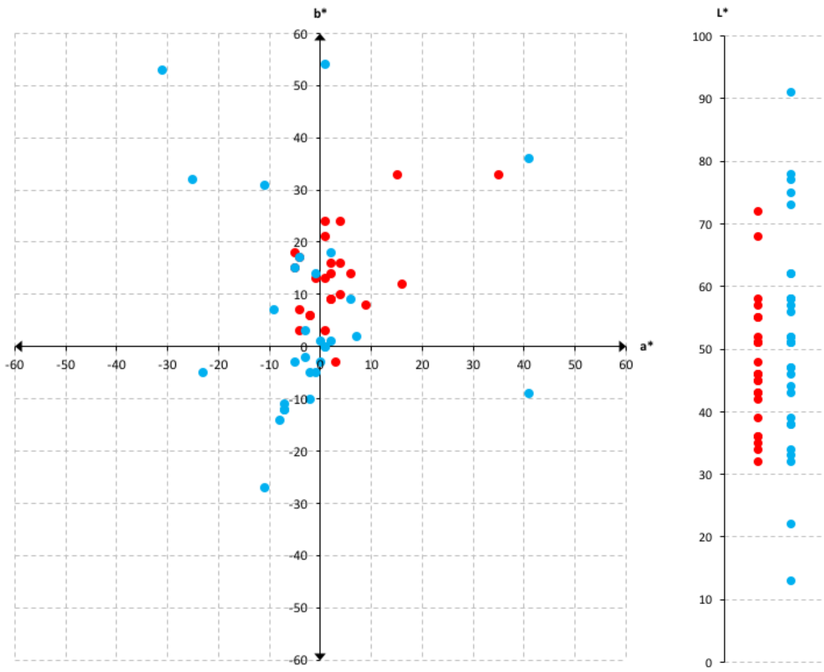


Figure 2: CIELAB color values of average color for each image in the novel image database (●) and in TID2008 (●).

The next step was choosing the image quality parameters that are most common in everyday use. We included: sharpness, contrast, noise, saturation, size manipulation and compression. Each of the parameters was applied in *MATLAB R2014a* in different ways and steps, so that 38 manipulations were made for each image. Our novel image database has overall 1140 images in 1920 × 1440 pixel resolution (for big screen testing).

In previous research, the image quality assessment was done with the use of objective methods (Keimel, 2009), such as:

- RMSE (root mean square error),
- PSNR (peak signal to noise ration),
- SSIM (structural similarity index) and
- UQI (universal quality index),

but in this study we wanted to develop some methods for the subjective quality assessment (Mohammadi, 2015), including observers into our testing. The real research problem appeared in not having a lot of previous research studies to base our work on, so we needed to develop our own methods . Two approaches were chosen:

- eye-tracking and
- crowd-sourcing.

2. METHODS

2.1 Eye-tracking

Using the eye-tracking method is nowadays very common in a variety of visual research studies. Our goal was to use this method do determine, how does a way of looking at the image changes according to its manipulation. In order to do this we used Tobii X120, a PC, controlled dark room environment and a *Tobii Studio 3.4.4* software.

The images that we choose from our database to later use in eye-tracking testing were those with the most visible manipulation to the human eye. For each of the 30 images we chose 10 manipulations, as well as the un-manipulated image, so 330 images were altogether included in the testing. We wanted to avoid one person seeing one image more than once, but at the same time, we wanted for each person to see as many different manipulations as possible. For that reason the images were carefully separated in groups (Table 1). One group was looking at un-manipulated images – we called that group a reference group.

Table 1: Test groups were divided into: a reference group A and groups B1–B10 (every color represents one group).

IMAGE NUMBER	IMAGE MANIPULATION: unmanipulated	lower contrast	higher contrast	lower lightness	higher lightness	lower sharpness	higher sharpness	unsaturated	JPEG compression	noise	resize
1.tif	REFERENCE GROUP A	B1	B10	B9	B8	B7	B6	B5	B4	B3	B2
2.tif		B2	B1	B10	B9	B8	B7	B6	B5	B4	B3
3.tif		B3	B2	B1	B10	B9	B8	B7	B6	B5	B4
4.tif		B4	B3	B2	B1	B10	B9	B8	B7	B6	B5
5.tif		B5	B4	B3	B2	B1	B10	B9	B8	B7	B6
6.tif		B6	B5	B4	B3	B2	B1	B10	B9	B8	B7
7.tif		B7	B6	B5	B4	B3	B2	B1	B10	B9	B8
8.tif		B8	B7	B6	B5	B4	B3	B2	B1	B10	B9
9.tif		B9	B8	B7	B6	B5	B4	B3	B2	B1	B10
10.tif		B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
11.tif		B1	B10	B9	B8	B7	B6	B5	B4	B3	B2
12.tif		B2	B1	B10	B9	B8	B7	B6	B5	B4	B3
13.tif		B3	B2	B1	B10	B9	B8	B7	B6	B5	B4
14.tif		B4	B3	B2	B1	B10	B9	B8	B7	B6	B5
15.tif		B5	B4	B3	B2	B1	B10	B9	B8	B7	B6
16.tif		B6	B5	B4	B3	B2	B1	B10	B9	B8	B7
17.tif		B7	B6	B5	B4	B3	B2	B1	B10	B9	B8
18.tif		B8	B7	B6	B5	B4	B3	B2	B1	B10	B9
19.tif		B9	B8	B7	B6	B5	B4	B3	B2	B1	B10
20.tif		B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
21.tif		B1	B10	B9	B8	B7	B6	B5	B4	B3	B2
22.tif		B2	B1	B10	B9	B8	B7	B6	B5	B4	B3
23.tif		B3	B2	B1	B10	B9	B8	B7	B6	B5	B4
24.tif		B4	B3	B2	B1	B10	B9	B8	B7	B6	B5
25.tif		B5	B4	B3	B2	B1	B10	B9	B8	B7	B6
26.tif		B6	B5	B4	B3	B2	B1	B10	B9	B8	B7
27.tif		B7	B6	B5	B4	B3	B2	B1	B10	B9	B8
28.tif		B8	B7	B6	B5	B4	B3	B2	B1	B10	B9
29.tif		B9	B8	B7	B6	B5	B4	B3	B2	B1	B10
30.tif		B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

2.2 Crowd-sourcing

For a crowd-sourced testing we developed a web application in which participants had to decide which of the two images looked better to them. A multilanguage application was developed using PHP, HTML5 and CSS3 and consisting of: an introduction screen, a data gathering screen (age, gender, location), the instructions, the test itself and a final page (Figure 3). For the testing we used same manipulated images as in eye-tracking, so we conducted 10 manipulations for each of the 30 images. The images were put in pairs automatically for each observer separately, but pairs were only built from manipulations of the same image. Each observer had to decide between 150 pairs of images. For the latter analysis all the data was automatically gathered in a CSV file.

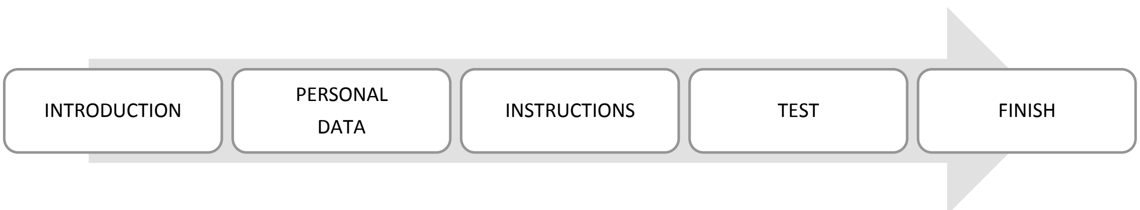


Figure 3: Organigram of the web application.

3. RESULTS

3.1 Eye-tracking

The developed testing method resulted in success. The data gathering was successful and the data was shown to be meaningful. Each testing took place in a dark environment with controlled light. Each test group of pictures (A and B1–B10) (Figure 4) was shown to 10 people, so the combined number of all participants was 110. From the 110 observers that took the test, 50 % were men and 50 % were women, 50 % were below 30 years and 50 % were 30 or more years old (the average age was 33). Approximately 10 % of observers were not accurately recorded, so those testings were repeated.

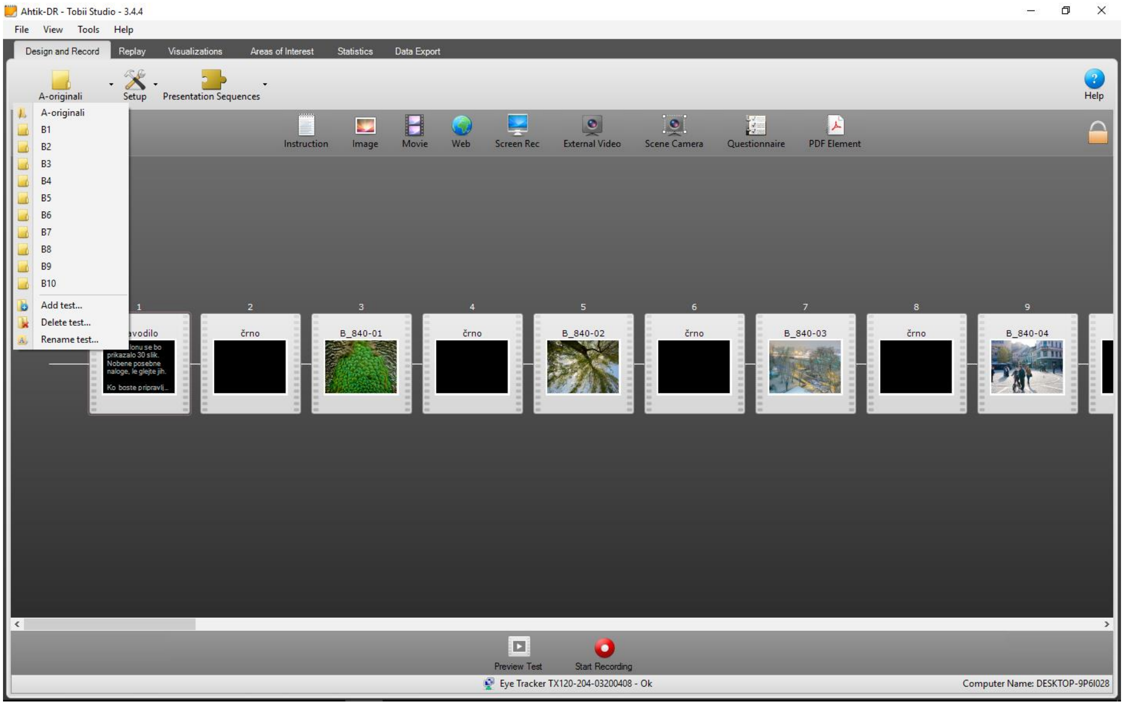


Figure 4: Test A in Tobii Studio 3.4.4..

The test began with short instruction, so that the observer could feel prepared and calm. These instructions were followed by 2 second's of darkness and then every image appeared in the middle of the screen for 5 seconds, with 2 seconds of darkness in-between. The instructions were just to look at the pictures calmly with nothing particular in mind (Figure 5).

a) b)

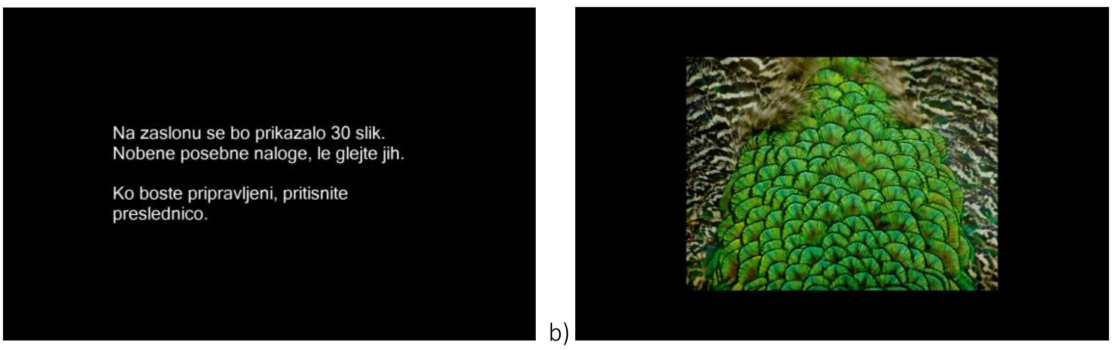


Figure 5: Two screens of Test A: Instructions page (a) and test page with image 1 (b).

The results can be presented clearly in a visual way (Figure 6) with the *Tobii Studio 3.4.4* that we used. Some further analysis and research will therefore be possible.

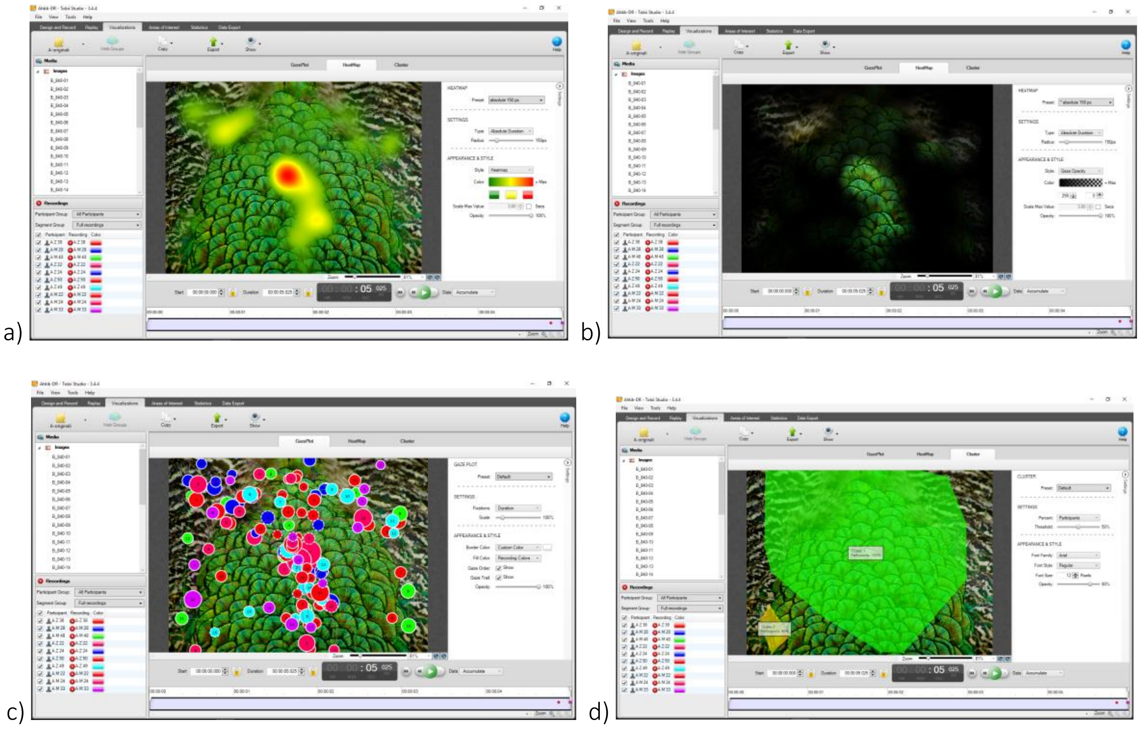


Figure 6: Visualization of recorded eye movement on image 1:
heatmap (a), gaze opacity (b), gaze plot (c) and cluster (d)

3.2 Crowd-sourcing

In web application, that we used, which we named *Fototeka* and was available on *www.fototeka.si*, proved a big success. In the three weeks during which that testing took place, we gathered results from 355 participants from 11 countries (58 % female, 42 % male, 44 % below 30 years old, 56 % 30 or more years old, average age 32).

The application was designed as being dark, with the goal to eliminate all unnecessary distractions from the view field (Figure 7). The testing was done in an uncontrolled user environment.

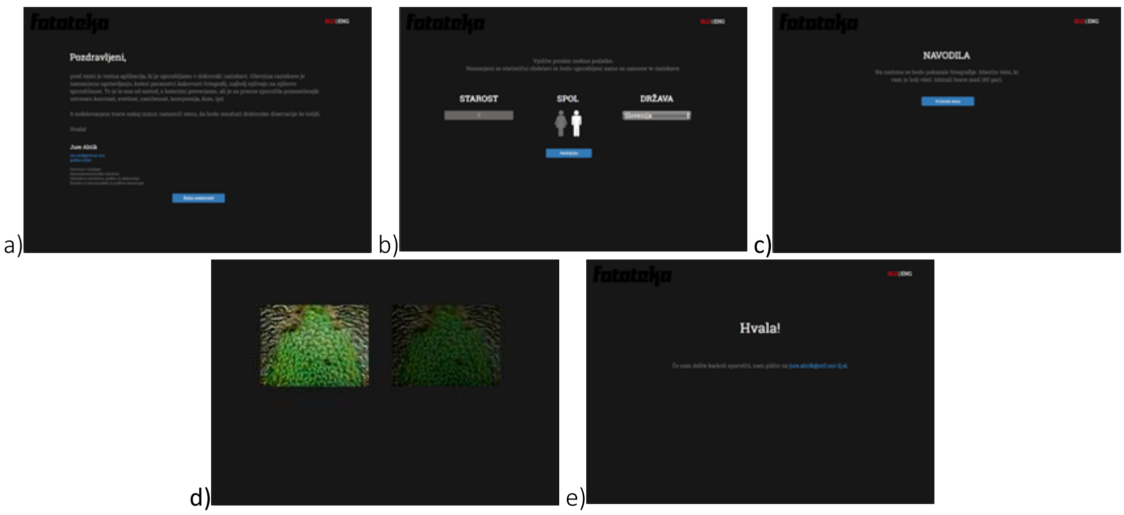


Figure 7: Screenshots of the web application Fototeka, used for testing
introduction page (a), data gathering page (b), instructions page (c), test page (d) and the final page (e).

Each of the 355 participants had to choose between 150 pairs, so altogether 53.250 decisions were made, in terms of which manipulation is acceptable. Results were promising.

4. DISCUSSION

As shown in the results, two different methods of subjective quality assessment data gathering were used – eye-tracking and web based crowd-sourcing. Regarding the eye-tracker recordings, it cannot be said that the method is completely subjective, as we used a device that objectively monitors and records all the data about participant's eye movements – participants therefore had limited influence on the test itself. On the other hand, the use of web application Fototeka was completely subjective, because users had to choose an image that they liked the most – so that their emotions, their experience and their environment were all fully involved. Both used method are very useful for gathering image visual quality data. They offer enough comfort, are not unpleasant, they do not take a lot of time (the eye-tracker takes about 3,5 minutes and web application about 6 minutes). The danger of errors is highly reduced when there is a big number of test participants (eye-tracker 110, web application 355), so any possible anomaly cannot have big influence on the final result

5. CONCLUSIONS

In future research we are planning to continue to use both methods. Analyzing the results and comparing them to results from an objective quality assessment method is planned for the future and we hope that with that we will be able to predict the communication value of an image. We are also confided about finding out more about the dependence of the type of image manipulation and its complexity.

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Original scientific paper

THE APPLICATION OF THE EYE-TRACKING METHODOLOGY FOR TESTING THE EFFECTIVENESS OF THE IMAGE ENHANCEMENT PROCESSING FOR USERS WITH COLOUR VISION DIFFICIENCIES

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Abstract: *The eye-tracking technology, designed for monitoring eye movement and measuring gaze during visual tasks, can be used for evaluating if image enhancement methods can benefit the colour defective observers. The presented behavioural evaluation method using eye-tracking data is task-based where task fulfilment depends whether the image enhancing algorithm successfully advances information accessibility in a map. Besides metro maps, as test images can be used other transportation maps, geographic maps, infographics or similar test images with content coded with colour. The proposed methodology can provide both quantitative and qualitative data for a thorough effectiveness verification of a certain daltonization method.*

Key words: colour vision deficiencies (CVD), colour deficient observer (CDO), eye-tracking, image enhancement, daltonization, accessibility

1. INTRODUCTION

Colour vision deficiency (CVD) represents a predominantly hereditary condition manifested with difficulties in colour recognition and differentiation. Colour defective observers (CDOs) are confronted on a daily basis with problems to retrieve the colour-coded information from content in the contemporary digital environment.

The well-established tools for simulating different types and severities of CVDs enable graphic and web designers to check the perception of CDOs and identify confusing colours. Based on simulations, numerous image enhancement methods are defined, called daltonization methods, which adapt the image content so CDOs can distinguish more details and see the content as much as similar to an average observer. However, the authors of these daltonization methods rarely provide a systematic and valid verification of method's efficiency or the metric for detecting the amount of improvement in the perceived image quality depending on the application (a type of visual task). The majority of research papers evaluated methods on a limited number of test images, mostly Ishihara plates, or images with a single red-green problematic combination that should be resolved (Milić et al. 2015). However, the wider investigation, including real life scenarios and images with complex content, was not conducted so far.

CIE TC 1-89 Technical Committee is established with following main objectives: to analyse existing image enhancement methods for a population of CDOs, to define procedure and criteria for their evaluation and to recommend an optimal method for every category of CVDs (CIE TC 1-89 Report, 2015).

Liedtke et al. (2013) have determined that the accuracy in retrieving information and the response time variation can be used as indicators of the image enhancement effectiveness. The same manuscript also revealed that participants (although they were normally sighted observers playing the role of "virtual daltonists") enjoyed solving tasks instead of usual rank-order or pair-wise image comparing.

In the following manuscript (Liedtke et al. 2015), the same authors confirmed that the accuracy rate represents the suitable metric for confirming the effectiveness of image enhancement for CDOs. Although no statistically significant difference in the response time was found, it was noticed that easily accessible images result with the reduced average and the lower variation in the response time.

2. METHODS

2.1 Observers

The Farnsworth-Munsell 100 Hue test was used for diagnosing the colour deficiency. The error score of FM 100 Hue test differentiates the type (protan, deutan or tritan) and the severity (mild, moderate or severe) of deficiency.
The experiment involved the test group of 15 participants with CVD who were classified based on results of the Farnsworth-Munsell 100 Hue test as follows:

- nine protan observers: four mild protanomals, three moderate protanomals and two severe protanomals (protanops);
- six deutan observers: three mild deuteranomals, one moderate deuteranomals and two severe deuteranomals (deuteranops).

However, the results from one deutan observer were excluded from the analysis since his correction glasses caused unwanted reflection. All other members of the test group had normal vision accuracy. Also, 16 participants with normal colour vision and normal vision accuracy were involved in the experiment as the reference group. Fourteen of them demonstrated superior colour discrimination on the Farnsworth-Munsell 100 Hue test results, while the remaining two had an average colour discrimination.

2.2 Test image

Metro map of Madrid with ten transportation lines was used in the experiment (Figure 1.a) in two versions: the initial map and map after the daltonization model suitable for anomalous trichromats (Milić, 2016). Hexadecimal colour values in the initial map are (Figure 1.b): line 1 (#5f92c5), line 2 (#e05e00), line 3 (#f7c615), line 4 (#a19a27), line 5 (#759c2a), line 6 (#999999), line 7 (#eda729), line 8 (#d97b9a), line 9 (#803b7d), and line 10(#00258a). Modified colours are presented in Figure 1.c.
All pairs of colours in the initial colour scheme (Figure 1.b) have colour difference $\Delta E>10$ that makes them satisfyingly distinctive for observers with regular colour vision. However, there are anticipated three sets of confusing colours for dichromatic observers on the initial map – those are the colours who share the same discrimination ellipse: the first one includes colours of lines 2, 3, 4, 5 and 7; the second one includes colours of lines 1, 6 and 8; and in the third ellipse are colours of lines 9 and 10.
The colour adaptation is defined with colour's initial position in a following manner: colours that trichromats and dichromats perceive as similar are the ones with the smallest transition like colours of lines 3, 4, 6 and 10 while colours with dominant red component (lines 2 and 8) or dominant green component (line 5) are altered in larger extent. Adapted colours end up closer to the spectral locus (more "scattered") manifested with higher saturation.
The subjects of both groups had the task to find inside the map, as quickly as possible, the line coloured the same as the target colour patch and track that line from one end to another. The target colour patch is presented simultaneously with the map in the top left corner. The task is considered unsuccessful in a case when the wrong line was traced or when the observer started to track the right line but switched after the crossroad. The observers had to trace metro lines 3, 4, 8 and 9 on both initial map and map after daltonization.
The Machado-Oliveira and Brettel-Vienot-Mollon simulation algorithms (Brettel et al. 1997) (Machado et al. 2009) were used for a preliminary check of task adequacy in advance.

2.3 Procedure

The experiment was conveyed in a completely dark environment on the working station with two monitors: the first one, properly calibrated EIZO ColorEdge CG241W monitor, for the participant and the second for the experiment supervisor. To avoid unwanted reflection, all shiny metal elements behind the participant were removed or covered. The eye-tracking camera was mounted centrally below the main screen and pointed at observer's eyes at distance of approximately 65 cm.
For characterisation of EIZO ColorEdge CG241W monitor were used i1Pro spectrophotometer and ColorNavigator software.

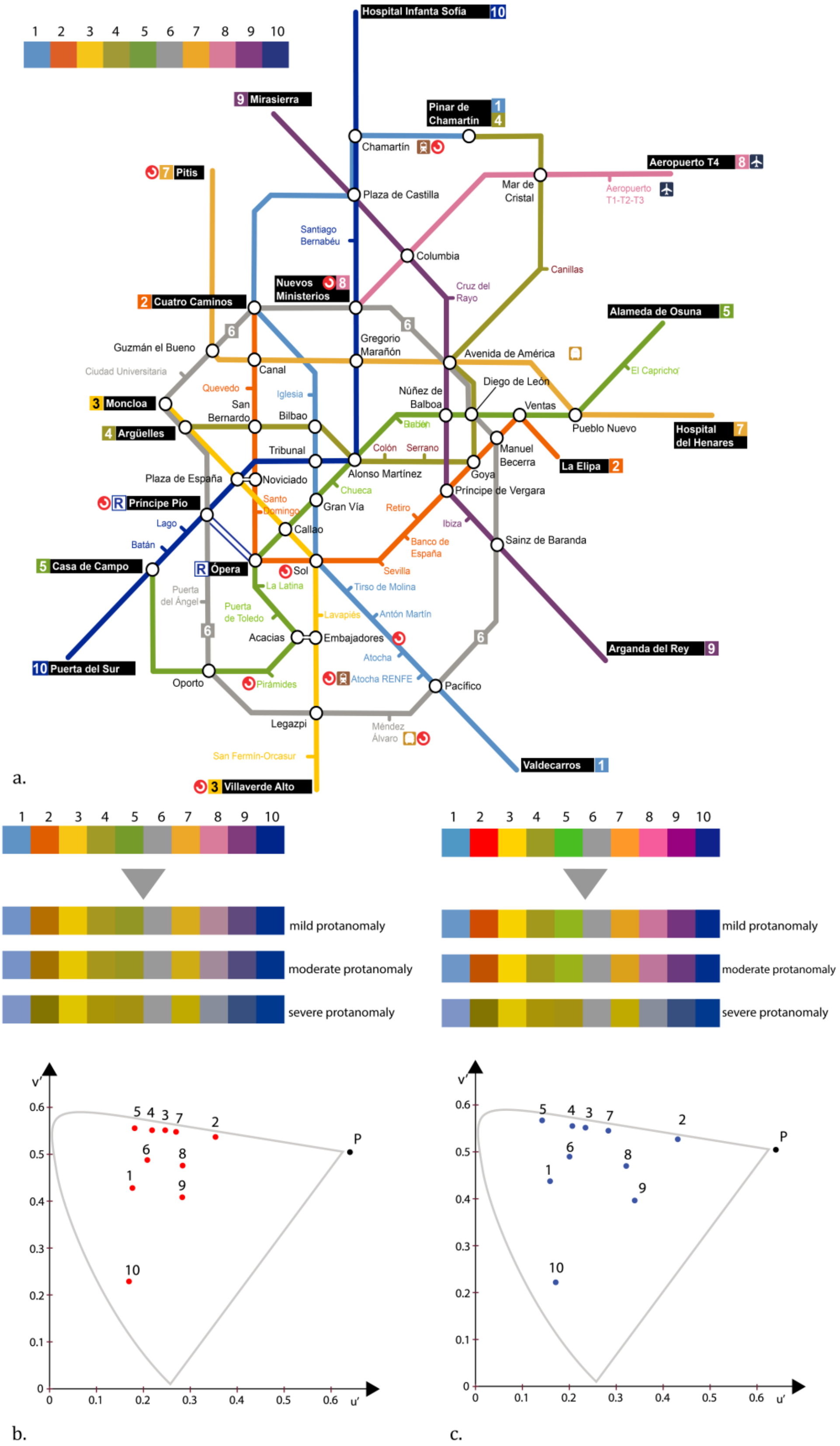


Figure 1: Test image: (a) the initial metro map; protan simulations of line colours and their positions in the CIE u'v' chromaticity diagram for: (b) the initial metro map and (c) the map after daltonization (red points are positions of initial colours and blue ones represent new positions of modified colours)

Characteristics of the used Gazepoint GP3 eye-tracking equipment are listed in Table 1.
The hardware is very simple and has only two components: infrared LED illuminant and infrared camera with the frequency of 60Hz which records as a video sequence the reflection from observers' eyes in infrared spectra. The more complex part is software which extracts eye movement data from the recorded sequence and reveals what areas of the image the observer had looked, how long and in which order.

Table 1: Characteristics of eye-tracking device (GazePoint Analysis Manual, 2015)

Characteristic	Value
Precision	0.5-1 degree of visual angle
Frequency	60 Hz
Calibration	calibration with 5 or 9 points
Software compatibility	easy to use and with open API standard
Eye-tracking area	25 cm x 11 cm (h x v)
Eye-tracking depth	±15 cm
Software for calibration and control	GazePoint Control
Software for creating projects and data analysis	GazePoint Analysis

Software GazePoint Analysis records:

- *gaze points*

The statistical data of gaze points' duration and location on the screen are saved.

- *fixation map*

The sequence of the fixations can be reproduced for every observer with fixation point size proportional to fixation duration.
Observing time for this type of task and image was determined in the preliminary research. The suitable duration for tracking line inside a metro map was 15 seconds. The overall evaluating session was no longer than 15 minutes in order to avoid the eyestrain.
As a preparation, participants were given an introductory talk with a demonstration of a test image and a task completion (approximately 5 minutes). Right before the experiment, the eye-tracking calibration procedure is conducted in the duration of approximately 15 seconds (in the case of an unsuccessful calibration, the procedure is repeated).
The evaluation experiment consists of following steps as shown in Figure 2.

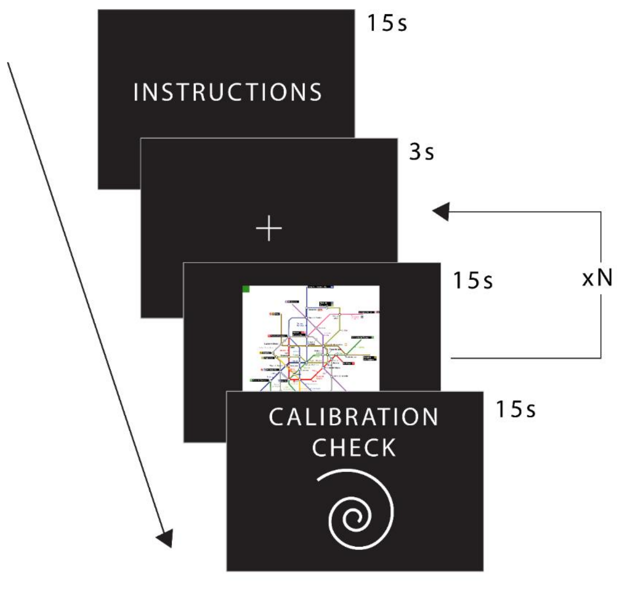
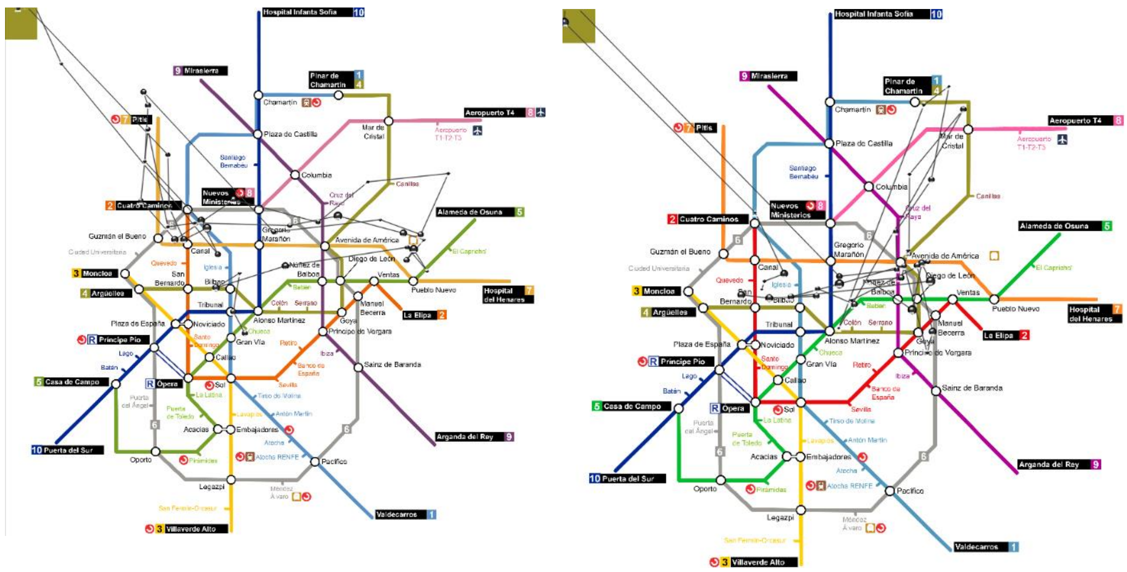


Figure 2: The eye-tracking experiment flow

Step 1: The instructions are firstly presented to the observer in a duration predetermined after reading at a slow reading rate. For example, 15 seconds for lines: “In following test images your task is to find a metro line as quickly as possible line coloured the same as the given patch in the left top corner and eye-trace the line from one end to other.”
Step 2: The preparation screen with the neutral (black) background is presented in a duration of 3 seconds.
Step 3: The task - test map with target colour patch - is showed in a duration of 15 seconds. The order of lines and the order of map versions (original, modified with an enhancement method, adapted with another enhancement method etc.) are both randomised.
Steps 2 and 3 are repeated N times where N = n (the number of tested lines) x m (the number of map versions).
Step 4: As the last task, the observer had to track the contour of the spiral shape from outside to inside in order to do post-experiment calibration check.

3. RESULTS

Main metrics as the result of this experiment are the task-fulfilling rate (accuracy) and task-fulfilling time (response time), which is a time needed for an observer to fulfil a certain task.
Examples of eye-tracking data are shown in Figure 3.



(a) unsuccessful task

(b) successful task

Figure 3: The task completion examples: (a) the CDO was unsuccessful in tracing line 4 on the original map (he followed the line 7 instead of line 4), (b) the CDO was successful in tracing line 4 on the enhanced map

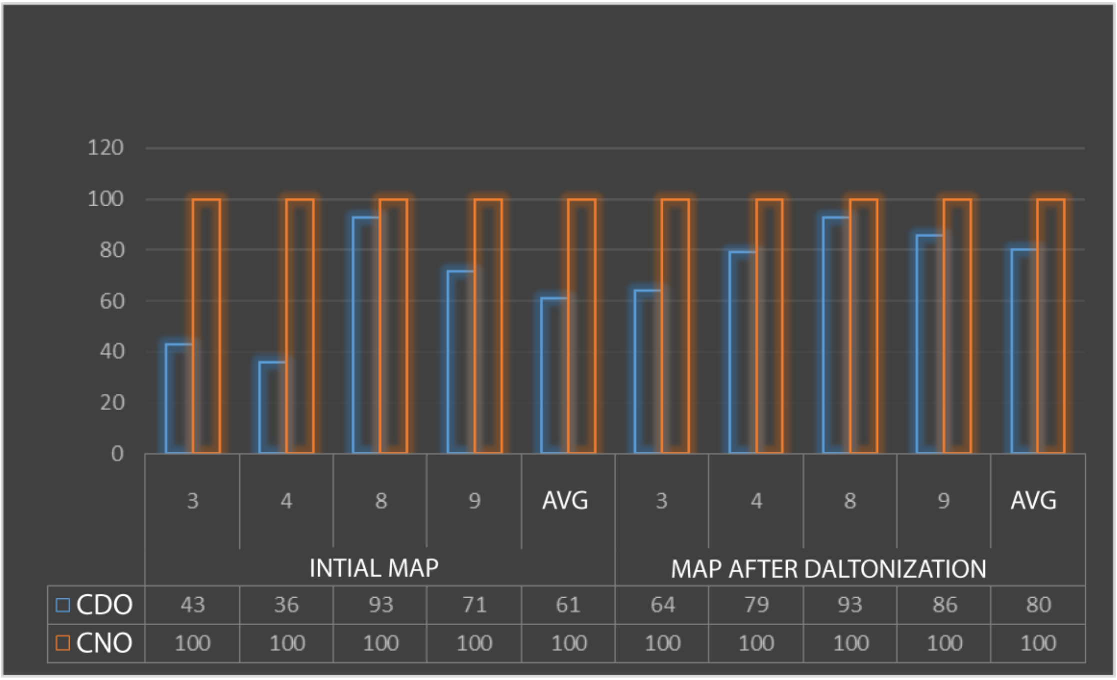
Graphic 1 presents results of test accuracy while Graphic 2 presents average times for transportation lines and summary for map versions. From Graphic 1 can be noticed that daltonization resulted for the test group (CDOs) with the growth of the task-solving successfulness rate from 61% to 80%.
A Chi-square test for independence (with Yates Continuity Correction) indicated significant accuracy rate difference, with a significance level of $p<0.05$, between test group (CDO) and reference group (CNO) in the following cases:

<u>I The initial map</u>

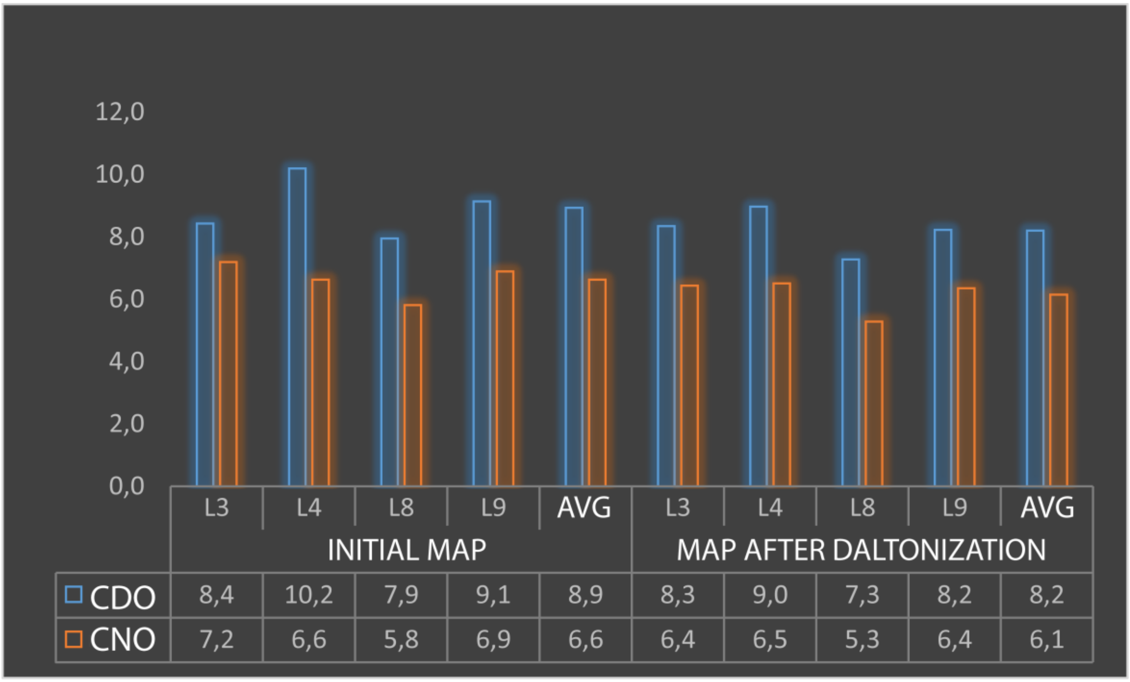
Line 3: c2(1, N=30)=9.717, $p<0.01$, fi=0.645 (large effect)
Line 4: c2(1, N=30)=11.792, $p<0.01$, fi=0.7 (large effect)
Line 9: c2(1, N=30)=3.092, p=0.037 (with Fisher’s correction), fi=0.419 (medium effect)

II The map after daltonization

Line 3: c2(1, N=30)=4.527, p=0.014 (with Fisher's correction), fi=0. 479 (medium effect)
In other words, the successfulness rate is significantly grown in the test group in the case of Line 4: c2(1,N=28)=3.646, p=0.05, fi=0.433 (medium effect).



Graphic 1: The accuracy rate in solving eye-tracking tasks- tracing correct transportation line (3, 4, 8, 9) according to target colour patch in the metro map before and after daltonization
(CDO – colour defective observers (test group), CNO –colour normal observer (reference group))



Graphic 2: The average times for successfully solved eye-tracking tasks- tracking correct transportation line (3, 4, 8, 9) according to target colour patch in the metro map before and after daltonization
(CDO – colour defective observers (test group), CNO –colour normal observer (reference group))

Besides higher accuracy percentage, daltonization reduced the average time of successfully solved tasks from 8.93s to 8.21s for the test group. The faster reaction is the most noticeable in the case of Line 4 (from 10.2s to 8.97s).
The reference group with normal colour vision observers had no problems in solving tasks before or after the daltonization (see Graphic 1). However, Graphic 2 reveals the daltonization was effective even for the reference group since average time for solving tasks are lower in the case of all four lines.

4. DISCUSSION

If the focus of the experiment is to measure task accuracy, then interval for solving visual task should be limited and predefined. In the case of focusing on the response time, the duration of the solving task should be unlimited or until the observer solves the task successfully, and the supervisor of the experiment should control when to switch to the next task.
The following advantages of the suggested eye-tracking evaluation method were determined:

- tasks mimic the real-life scenario - tracking the transportation line on the public map;
- the methodology can also be used for testing how image processing influences the image context by defining "track-object" tasks in natural scene images;
- the feedback from subjects are positive – solving tasks is more interesting compared to paired samples comparison or Likert scale ranking;
- the setup of experiment has very small time consumption and equipment investments;
- the method can be used for effectiveness evaluation of just one specific daltonization method for CDOs (enhanced test images vs. original) or effectiveness comparison of two/more daltonization methods;
- the data can be easily aggregated in order to obtain average heat maps with the longest and the most frequent fixations.

On the other hand, several limitations of the methodology were revealed:

- potential difficulties in tracking eye movement can arrive when participant wears certain kinds of corrective glasses;
- test stimulus should be carefully prepared so that areas of interest (AOIs) for detecting the gaze can be clearly distinguished. If the completion of the task is not attached to a certain area of interest on the test image then response times and accuracy rates cannot be automatically obtained by the eye-tracking software analysis;
- although every software for eye-tracking data interpretation has integrated options for statistical analysis like the average time viewing the certain area of interest (AOI), the number of revisits to the AOI, the percentage of subjects who viewed the AOI etc., it can be necessary to check the task fulfilling data and response times manually.

5. CONCLUSIONS

The daltonization represents a complex and still unsolved problem of optimising perceptual image quality for the visually impaired observers. Compared to the behavioural method of Liedtke et al. (2013), eye-tracking data can detect what exactly caused the delay in the response and/or misled them in finding information at all - qualitative data besides quantitative. The conducted experiment gives valuable insight into CDOs' perspective and reveals the potential of the eye-tracking evaluation to become the standard procedure for checking the availability of the universal design of public visual information.
Besides that, the same methodology can be used for evaluation of the enhancement effectiveness in terms of preserving image naturalness by using object-finding tasks and images with real-life natural scenes instead of infographics or maps.

6. ACKNOWLEDGMENTS

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Digital media optimization

ARTIFICIAL NEURAL NETWORKS AS A TOOL FOR SPECTRAL REFLECTANCE ESTIMATION OF RGB COLOR PATCHES

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Abstract: *A three-component color representation of a digital image, such as RGB, is far less accurate than a multi-component spectral representation with several tens of spectral readouts. However, spectral acquisition is at the moment still not very convenient and accessible so often an RGB image is obtained with a conventional RGB camera and then the corresponding spectral estimation or reconstruction is performed via one of the available mathematical procedures, such as using polynomials or the Wiener estimation method. Although as demonstrated by metamerism, colorimetric RGB data cannot be unambiguously transformed back to the corresponding spectral reflectance data, these methods work in practice quite well. One of the possible solutions that also proved to be successful are artificial neural networks (ANNs). Although ANNs as function estimators are mostly used for modelling the systems that map higher dimension input data to lower dimension outputs, they can also be applied to solve few-inputs-to-many-outputs problems, such as the one that we investigated in our study.*
In our research, we measured the ColorChecker DC Gretag Macbeth test chart containing 240 color patches. We made 36 spectral measurements – from 380 to 730 nm in 10 nm steps – of the color patches with the i1Pro spectrophotometer and acquired RGB values with the digital SLR camera Nikon D3X. The 3-to-N mapping was accomplished using two-layer feed-forward neural networks with sigmoid hidden and linear output layer neurons, where N = 36, 18, 12, 9, 6 and 4. In other words, we wanted to examine how a progressively smaller set of known outputs – spectral measurements – affects the network performance. The networks were trained with Levenberg–Marquardt backpropagation algorithm. Presented and discussed are the results obtained, such as the mean squared error between the measured and the predicted values for each of the model, where several of parameters varied, such as the hidden layer neurons number – from 3 to 48.

Key words: artificial neural networks, reflectance estimation, color test chart

1. INTRODUCTION

A few decades ago, creating an actual computer that would be based on the model of the neural network, or better to say, connected units or nodes being able to self-organize and thus learn, was an almost unsolvable task. With the rise of modern digital computing such attempts were largely inhibited by the lack of efficient learning algorithms. The ideas of artificial learning developed from 1960s with Henry J. Kelley's control theory context (Kelley, 1960) through the next decade until in 1973 backpropagation was used by Stuart Dreyfus to adjust parameters of controllers according to error gradients (Dreyfus, 1973). Paul Werbos in his PhD Thesis (Werbos, 1974) recognized the applicability of backpropagation principle to artificial neural networks (ANN) and applied Linnainmaa's AD method (Linnainmaa, 1970) into the modern concept of the ANN. The enthusiasm of ANN applications subsided at the end of the the last century largely because of the ANN's slow learning process with then available "slow" digital computers.
In the last decade with the ever increasing power of digital computers, the ANN gained momentum again and their implementation has expanded to numerous fields of science and technology, especially in expert systems in medicine, in robotics, machine and vehicle control, voice and visual pattern recognition, function approximation and many more. As ANNs are based on the simplified brain learning principle, they can be applied to machine learning and solve a broad spectrum of problems, which are otherwise difficult to accomplish and solve using classic approach of algorithm-based programming.
In color science, researchers have also implemented ANNs. Dong and Ming proposed a system for the segmentation of color images based on neural networks. Their segmentation system comprises both unsupervised and supervised segmentation (Dong et al., 2005). Phung, Chai and Bouzerdoum developed a new image classification technique that utilizes neural networks to classify skin and non-skin pixels in color images. The aim is to develop a universal and robust model of the human skin color that caters for all human races. Experimental results show consistent accuracy up to 90% in skin color detection (Phung et al., 2001). Tominaga described a method for color-notation conversion between the Munsell and CIE color

systems by means of neural networks. A multilayer feedforward network was regarded as a nonlinear transformer, which was trained to learn a mapping between the two color spaces (Tominaga, 1993). Abet and Marcu used ANN for RGB to CMYK color conversion (Abet et al., 1994). Fdhal et al. compared transformations in digital color imaging from RGB to CIELAB between conventional ICC profiles and a newly developed ANN model (Fdhal, 2009). Mansouri, Marzani and Gouton (Mansouri et al., 2005) described the spectral reflectance curves reconstruction using neural networks. Reflectances were obtained by the multispectral system with 10 interference filters.

The goal of our study was to implement ANNs with a multilayer perceptron (MLP) architecture in order to model color transformation from digital camera RGB to spectral values. Supervised learning is used to achieve desired function approximation. MLP consists of the input layer, one or more hidden layers and the output layer (Figure 1). Nodes in all layers, except in the input layer, are neurons with a non-linear activation function. Connection weights between neurons in MLP are adjusted during backpropagation learning process, which, using gradient descent, minimizes MLP output error. Backpropagation means that the weights of the output layer neurons have to be adjusted first to allow correction of connection weights to propagate backward through the inner layers of MLP.

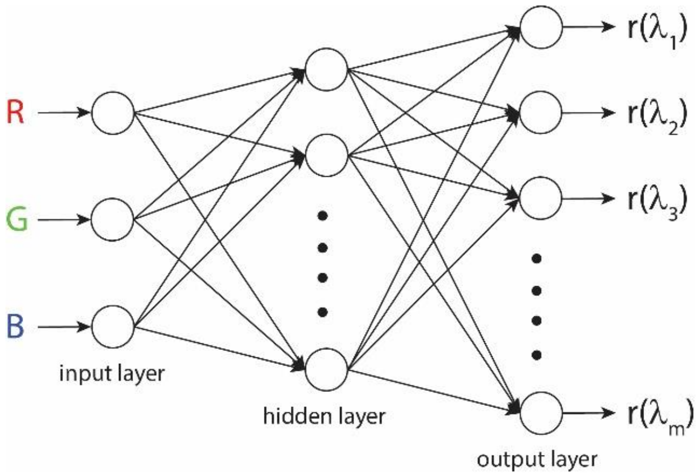

Figure 1: MLP with a single hidden layer, three input neurons and a varying number of hidden layer and output layer neurons

Many questions arise when using models like MLP-based ANNs to reconstruct higher dimensional spectral data from lower dimensional colorimetric values: "How big a learning set should be to get precise and consistent results under constant measuring conditions?"; "Is it possible to generate some satisfactory results from a small learning set like ColorChecker DC color samples?"; "How does the number of neurons in the hidden layer influence the I/O characteristics of the ANN?", "How does the dimension of the output vector influence the learning capability of the ANN?" and "Are there some colors in the available ColorChecker patch set that will be better or worse reconstructed from RGB to spectrum?" These are the questions we wanted to address in our study.

2. METHODS

Our aim was to create several ANN models that map the digital camera's RGB three-dimensional value space into the multi-dimensional spectral data under stable, but not fully defined RGB color capturing conditions, by means of the MLP data fitting ability. Because of the speed and based on the findings from our previous study (Lazar et al., 2013), we adopted a two layer MLP with a hidden layer sigmoid activation function and a linear activation function for output neurons, that can fit multi-dimensional mapping problems, when using enough neurons in the hidden layer and appropriate number of output neurons for a chosen spectral subset, and being fed by consistent learning data set. The network was trained with Levenberg–Marquardt backpropagation algorithm. Learning data sets consisted of input RGB values and output subset of spectral values. Number of input layer neurons was constant (3 – for R, G and B digital camera readouts), whereas number of output layer neurons varied depending of the size of the spectral components subset (4, 6, 9, 12, 18 and the full set of 36 spectral components). The number of hidden layer neurons also varied from 3, 6, 9, … to 48.

As an experimental test chart we used Gretag Macbeth ColorChecker DC test chart with 240 patches. Input RGB values were captured with the digital SLR Nikon D3X camera with 35 mm sensor. The average RGB values of the central 10% square area of each patch were calculated. Output data were 36 spectral readouts – from 380 to 730 nm in 10 nm steps – of every color patch, measured with the i1Pro spectrophotometer.

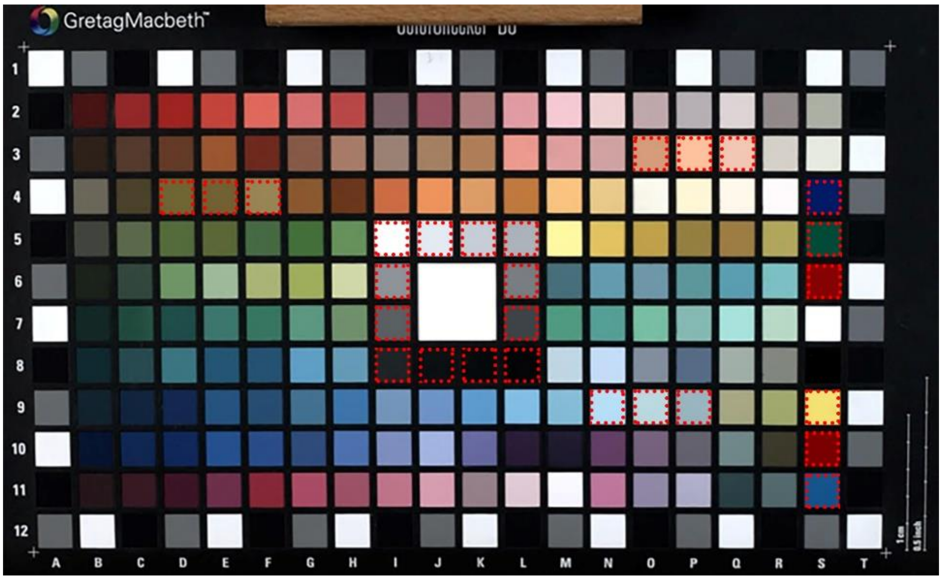

Figure 2: GretagMacbeth ColorChecker DC

3. RESULTS

For each combination of the number of hidden layer neurons (HLN) and the size of the spectral components subset (SCS) an ANN was modelled 11 times. Average, median and minimum mean squared error (MSE) was calculated for every number of HLN and SCS (Figure 3). An example of results for 18 spectral components is shown in Table 1.

Table 1: Average, median and min MSE and median times for all 11 ANN models with 18 outputs and varying number of hidden layer neurons

		median	median	median	average	median	min
Hidden layer num. of neurons	Num. of output spectral components	sum(tr.time) for all iterations	mean(tr.time) for all iterations	number of epochs	MSE (test Performance)	MSE (test Performance)	MSE (test Performance)
3	18	16.671	0.50124	30	0.0031117	0.0032783	0.0018985
6	18	20.44	0.64526	33	0.0014944	0.0013509	0.00094885
9	18	16.607	0.698	22	0.0013989	0.0013533	0.0010393
12	18	17.838	0.81082	21	0.0012137	0.0010783	0.00065967
15	18	33.525	1.1973	22	0.0012849	0.0012646	0.00049094
18	18	27.326	1.4382	18	0.0014127	0.0012048	0.0007786
21	18	47.151	1.9646	23	0.0013081	0.0012838	0.00065639
24	18	37.707	1.9846	18	0.00141	0.0013668	0.0010756
27	18	39.162	2.1757	17	0.0015132	0.0014958	0.00071774
30	18	39.572	2.4007	15	0.0013509	0.0014897	0.00062697
33	18	63.774	3.3565	18	0.0015	0.0012063	0.0007959
36	18	61.273	3.6043	16	0.0014008	0.0014728	0.00080512
39	18	46.627	3.3305	13	0.0017326	0.0014432	0.00071127
42	18	59.694	3.9796	14	0.0015443	0.0016069	0.00086289
45	18	50.581	3.8908	12	0.0013864	0.0013944	0.00062362
48	18	63.284	4.5203	13	0.0018161	0.001577	0.00095289

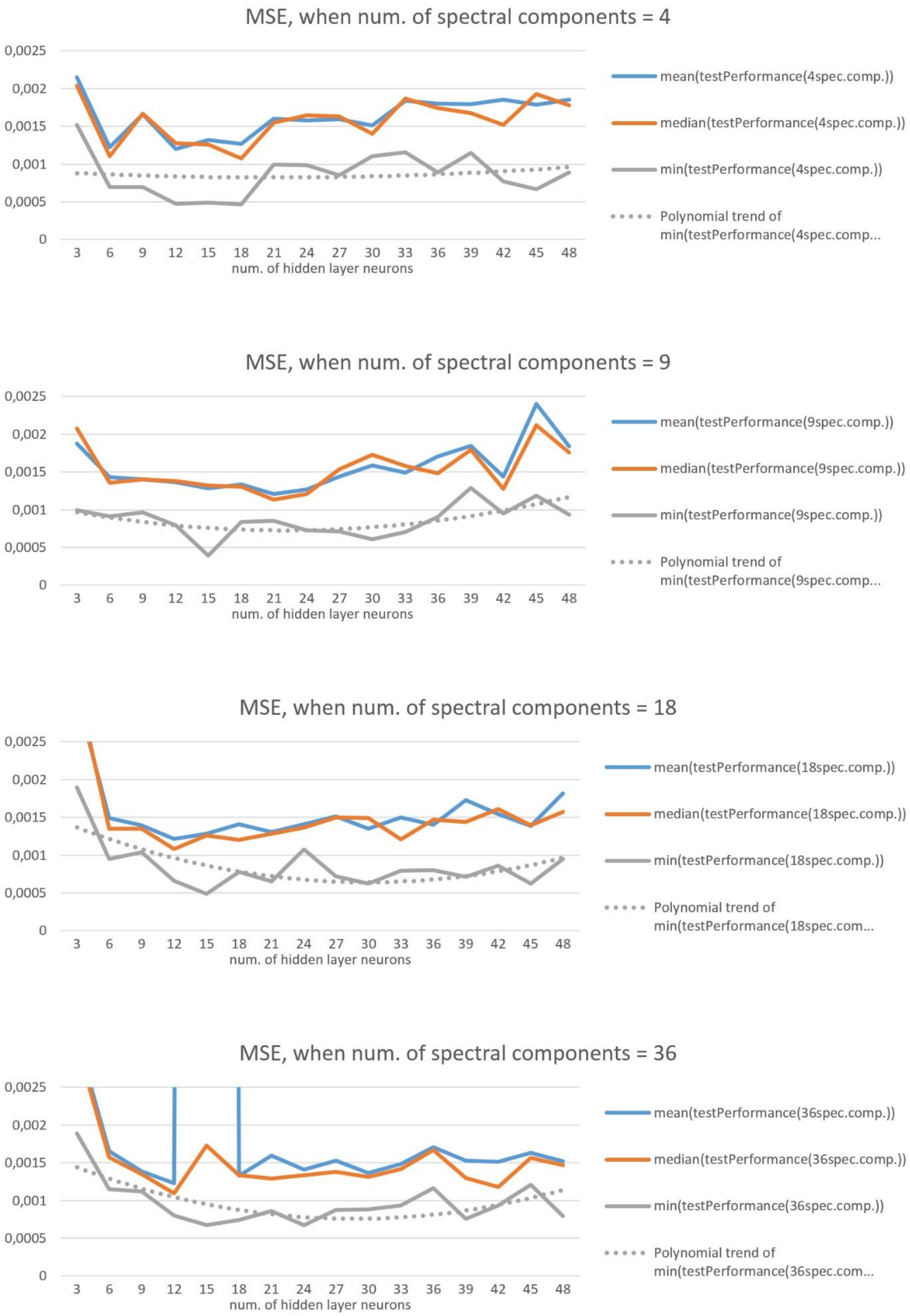

Figure 3: Average, median and minimum MSE with polynomial trend of minimum MSE, for ANNs with 4, 9, 18 and 36 outputs.

Median of number of epochs (repeated calculations for modelling a single ANN), median of single epoch calculation time and median of total calculation time for modelling an ANN for every number of HLN and SCS were recorded, as shown in Figure 4.

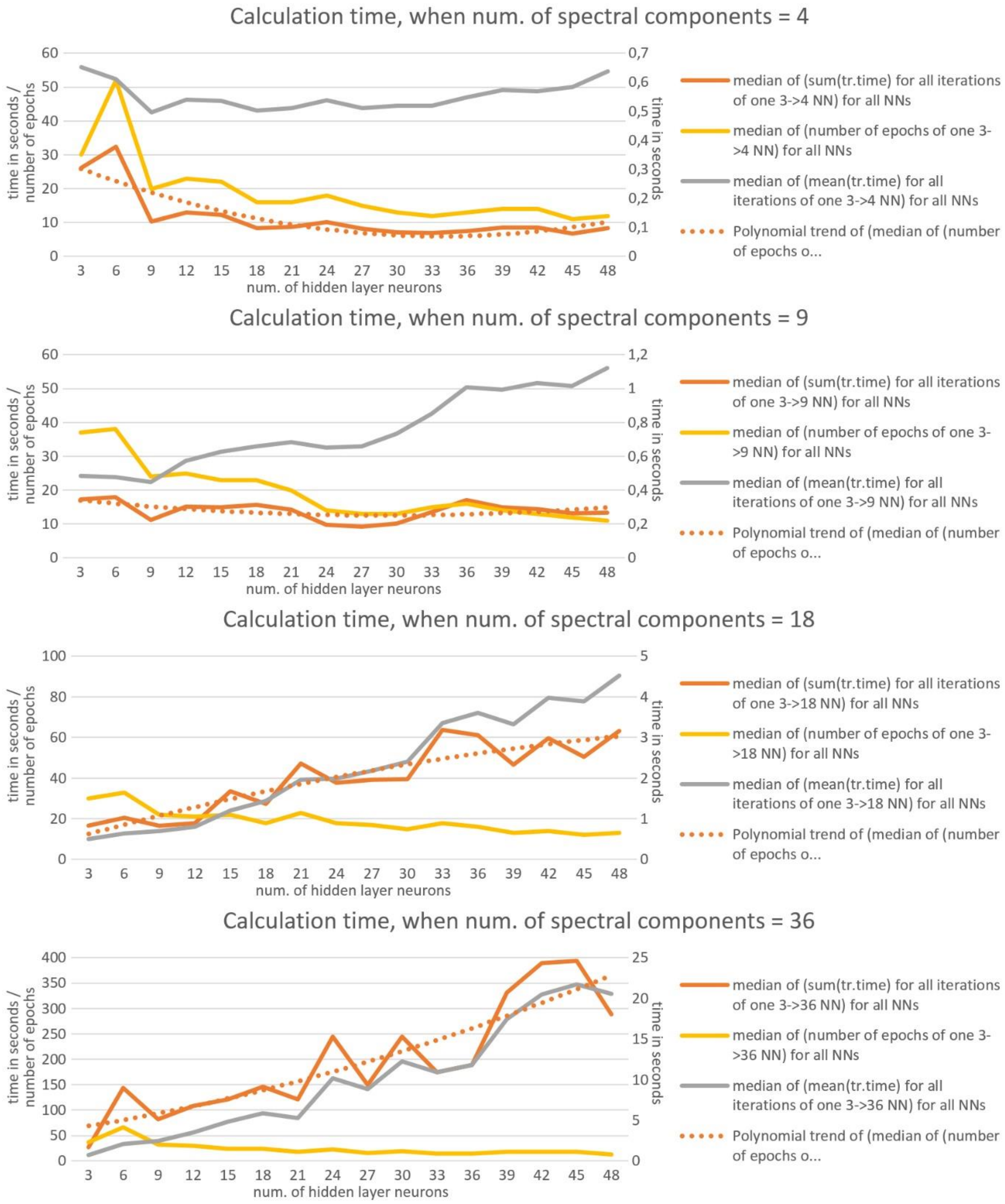

Figure 4: Median of number of epochs, median of single epoch time and median of total calculation time for modelling ANNs with 4, 9, 18 and 36 outputs.

The best ANN model was picked for every SCS, thus resulting in 6 best ANNs (ANN3-4, ANN3-6, ANN3-9, …, ANN3-36). With these six best ANNs the spectral components were reconstructed from RGB, as shown in Figure 5. MSE values for some neutral, pastel, RGB and CMY patches, marked in Figure 2 with red dots, are displayed in Figure 6.

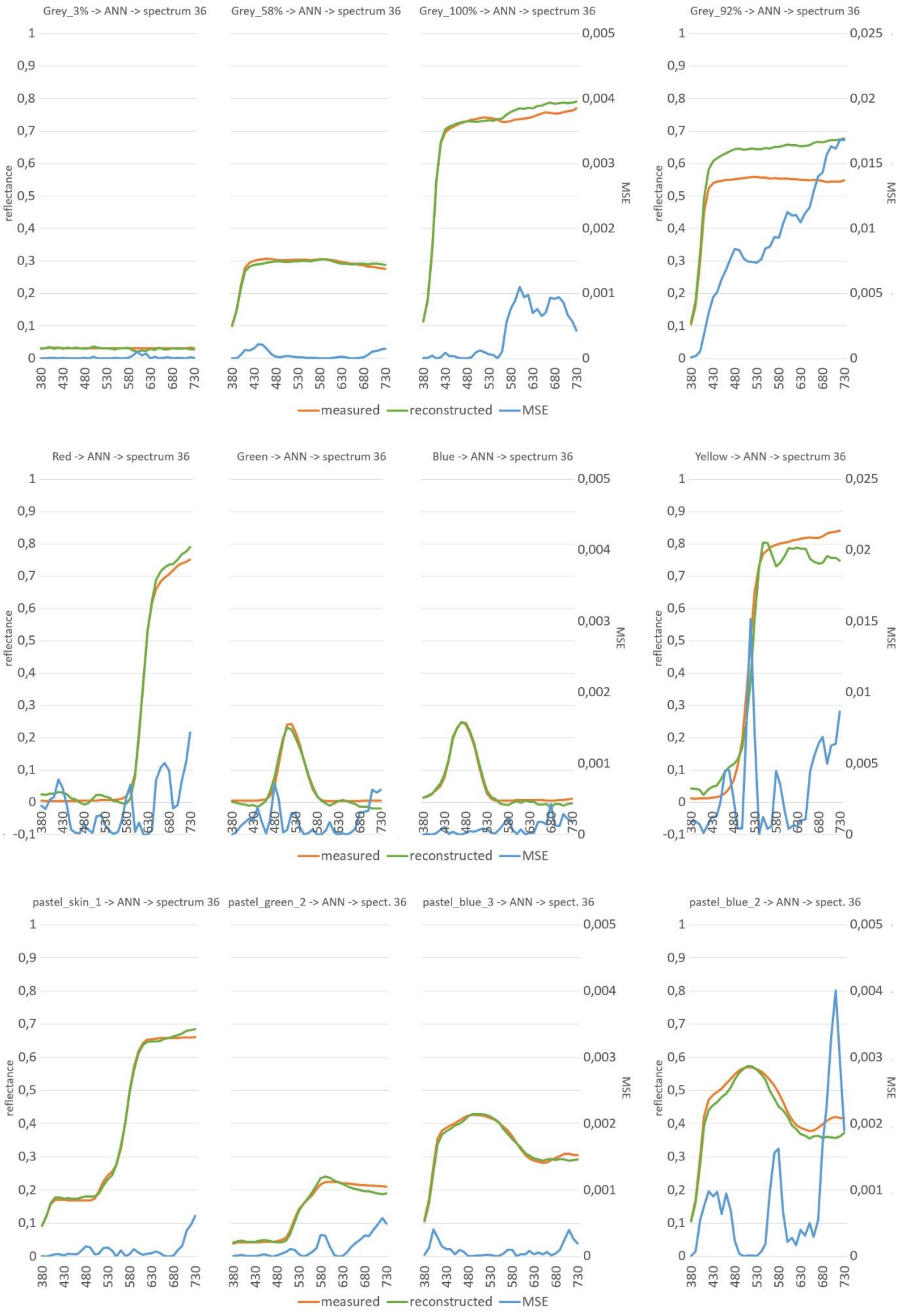

Figure 5: Measured (= original) and reconstructed spectra and their MSE, of several neutral, RGB, yellow and pastel colors

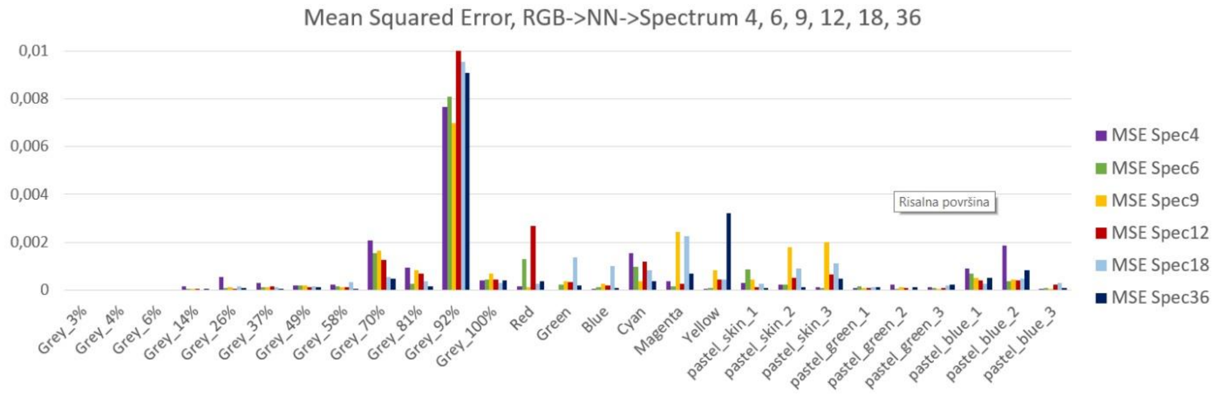

Figure 6: MSE of reconstructed spectra for some neutral, pastel, RGB and CMY patches

4. DISCUSSION

Our main goal was to create the ANN models that would be able to reconstruct higher dimensional vectors of spectral components from three dimensional camera RGB data and test their performance. Even though our learning data set was relatively small with just 240 patches and even less different colors, because of some repetition, we managed to train 3-to-many ANN to satisfactorily reconstruct most of the higher dimensional spectra. To study the influence of the output vector size, we tried to reconstruct spectral components vectors that included every 9th, 6th, 4th, 3rd, 2nd and even output vector with all 36 spectral readouts. Average, median and minimum MSE was calculated from 11 repetitions of ANN modelling for every spectral components subset (4, 6, 9, 12, 18 and 36) and every hidden layer size (3, 6, 9, …, 48). As it can be seen from Figure 3, there is no drastic difference in MSE when increasing the size of SCS. Polynomial trend of minimum MSE shows slight increase from just under 0.001 when reconstructing 4 spectral components to around 0.0015 with 36 components. Curvature of polynomial trend indicates (see its minimum) the best choice of the number of neurons – for example between 15 and 27 for SCS = 4 and between 24 and 33 neurons for SCS = 36.
For ANN applications, learning times are crucial factor. We studied the influence of the number of HLN and of SCS size to the number of epochs, to a single epoch time and to the total ANN modelling time. Number of epochs is the number of learning repetitions to model a single ANN and total ANN modelling time is time spent to model a single ANN. Observed time values vary significantly with every ANN modelling, thus we focused on median times of 11 repetitions of ANN modelling, because extreme time values influence averages more than medians. An interesting trend was discovered with increasing SCS size. For small SCS size of 4 ANN spectral outputs, learning time decreased with the increasing number of HLN from 25 seconds with 3 HLN to 10 seconds with 48 HLN, whereas for a complete spectral components set, learning time almost linearly increased from 75 seconds with 3 HLN to 350 seconds with 48 HLN. Turning point, when learning time was almost equal for each number of HLN is with SCS size of 9.
For every SCS we kept the ANN model with the lowest MSE. Results for such "best " ANN 3→36 model, which are depicted in Figure 5, show in most cases satisfactory matching of reconstructed spectra to the original, measured values, with MSE well under 0,001. Fitting spectral curves for some of the patches, such as light grey (grey_92%) and yellow is a bit worse. Because some patches show high MSE of reconstructed spectra with all six "best found" ANNs, especially in the case of grey_92%, poorer reconstruction could be attributed to a smaller subset of these shades/colors in the learning set.

5. CONCLUSIONS

Results from applying ANNs for reconstructing partial or even full spectrum from camera RGB values, described in the article, are promising, especially if we take into account that the learning set was small and the color space was not fully covered. In the future work, larger learning set will be investigated using more complex network architectures.

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ANALYSIS OF DIFFERENT THRESHOLD ALGORITHMS FOR DEFINITION OF SPECULAR AREAS OF RELIEF, INTERLACED STRUCTURES

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Abstract: *Our contribution presents a preliminary report of the research for definition of the workflow for optimal virtual representation of a relief object with the use of maps. In the research different thresholding algorithms for definition of specularity of the real interlaced structure (cloth, a part of the Slovene national costume from the Gorenjska region) were tested and analysed. Six global and six local thresholding algorithms were studied. The results were analysed regarding the functionality that specular map is presenting in cloth's visualisation. In the results the application of selected algorithms is visually (distribution of specular areas) and numerically (count, surface area and average size of specular areas) presented and discussed. Selected thresholded images were finally used in the workflow for preparation of specular maps and visualisations of virtual cloths.*

Key words: thresholding algorithms, specular map, interlaced structure, cloth, visualisation

1. INTRODUCTION

In general, reflection of light on the surface of interlaced structures depends on two correlating attributes: texture and lustre. The more distinct texture has as a consequence less lustre and vice versa. Lustre defines the selective specular light reflectance. The perception of material reflection depends on viewing conditions (viewing angle) and also on the angle and the properties of illumination. Depending on the portion and distribution of reflected light, it can be specular and diffuse. In general, reflection can be defined as:

- specular reflection: the rays are reflected in the same angle as incident light. In this case the appearance depends on the angle of observation.
- partly specular/diffuse reflection: the portion of rays are specularly reflected, while the remaining portion of rays is diffusely reflected. The correlation between the portions determines the specularity and/or diffuseness of the surface.
- diffuse reflectance: the equal portions of light rays are reflected in all directions. The appearance is independent of the angle of observation.

The development of the appearance model of an interlaced structure's relief (such as cloth) presents a challenge for researchers and developers. This is due to the complex light interactions of fine surface structure, anisotropic light scattering and the effect of self-shading, which are formed by fine microstructures on micro level and on the level of the whole object surface. Author Schröder (Schröder, 2012) with his colleagues performed a research with the analysis of three main types of cloth's appearance models: surface-based models, volumetric models and explicit models. Surface- based models calculate the interactions of light/material with Bi-directional Reflectance Distribution Function (BRDF) and BRDF-based lighting techniques. Besides, Bidirectional Texture function is implemented in computation of final appearance. These models give very accurate visualisations, however some issues remain unsolved. Volumetric models use volumetric data for representation of object's appearance. Data are usually acquired with CT and processed on voxel and sub-voxel level. The explicit models do not include many approximations and simulate exact light interaction for surface points. The appearance models can be qualified considering: translucency, light diffusion, rendering in real time, scalability, viewing distance, silhouette, etc. Cloth visualisation in architecture, fashion, automotive and entertainment industries often requires less complex models that include many simplifications (by means of mathematical simplifications or simple workflows for fast production) for presentation of optical phenomena. Within these methods the techniques of texture mapping on geometric models are frequently performed. In these workflows the final appearance of the relief structure depend on the contribution of reflectance models (shading algorithms) and the sum of maps. When the cloth objects are visualised, these maps are:

- Diffuse map that presents diffusely reflected light rays and consequently the color information of the structure.
- Specular map that presents the relation between diffuse and specular reflection. The map is grayscale, and the pixel intensity means that the brighter the pixel the higher portion of specular reflection.
- Relief maps (bump, normal, displacement) and maps presenting porosity (translucency).

In many researches, the specularity is discussed from the point of view of developing the optimal algorithm and mathematical abstractions for prediction and simulation of cloth appearance. Authors Irawan and Marschner (Irawan, 2012) presented a procedural model, while authors Sadeghi with coauthors (Sadeghi, 2013) studied the possibilities of implementation of the empirical shading model based on measurements of profiles generated with the reflection of light from different yarns. Sadeghi's experiments implemented a visual analytical model BRDF for cloth rendering including numerous BRDF measurement of different fabrics and yarn patterns. Author Iwasaki (Iwasaki, 2014) with the group of researchers developed an interactive rendering and a microcylinder for calculation of light reflectance.

Image processing and analysis are firmly established methods for definition and evaluation of optical and relief phenomena of real fabric and cloths. Besides the porosity, the image analysis is used also for the definition of lustre of interlaced structures. The pioneers in this researching area were certainly Anton with his colleagues (Anton, 1978), which method included the computer aided processing and analysis of image negatives. The lustre of the structures was numerically evaluated. Researcher Hadjianfar with his colleagues developed (Hadjianfar, 2010) a method for lustre measurements and evaluation, which results were comparable to human observation and perception of this phenomenon.

Image analysis was also implemented in the Jong-Jun's study (Jong-Jun, 2002). Here, cotton, silk and velvet fabrics were analysed and surface's pattern histograms were processed. 3D representations were furtherly used for analysis of optical phenomena and the results were applied in the modelling of 3D virtual structures. Thresholding is a method that includes an optimal threshold algorithm for a pixel-level image processing that performs a conversion of a grayscale image to bi-level output image. The aim of threshold is the representation of the area of interest (object).

Author Devi (Devi, 2006) explains that efficient thresholding algorithms should preserve logical and semantic content and can be divided in two types: Global (a single threshold is used for all the pixels of the image) and local or adaptive (image is divided in local areas, which are defined with different threshold values). In their survey authors Sezgin and Sankur (Sezgin, 2004) categorize thresholding methods (in the context of nondestructive testing applications and for document images) in six main groups: Histogram Shape-Based Thresholding Methods, Clustering-Based Thresholding Methods, Entropy-Based Thresholding Methods, Thresholding Based on Attribute Similarity, Spatial Thresholding Methods and Locally Adaptive Thresholding.

1.1 The aim of the research

The aim of the research was the study of selected global and local thresholding algorithms used in the open source image analysis application ImageJ and to define an optimal solution for generation of a specular map. The analysis of the influence of the structure relief was performed with different illumination settings during acquisition. The focus was the numerical analysis of specular areas (surface areas, count, average size) that were defined with different thresholding algorithms and with the analysis of visualisations after rendering in 3D virtual environment.

2. METHODS

The selected interlaced structure (backside of "rokavci", a part of the national costume from the Gorenjska region) has many significant signs of non-uniformity and structural heterogeneity (Naglič, 2015). Fabric was photographed with the camera Nikon (105 mm) at seven different light combinations. Samples were numbered from 1 to 7. Illuminations (samples) from 1 to 3 included diffuse lights, while illuminations (samples) from 4 to 7 included direct light and one or two diffuse lights. The samples were numbered: 1. right and left diffuse light; 2. right diffuse light; 3. left diffuse light; 4. right diffuse and direct light; 5. left diffuse and direct light; 6. right and left diffuse and direct light and sample 7. direct light. The parameters of the analysed interlaced woven structure were: 100% cotton fabric, plain weave, warp density = 20 threads/cm, weft density = 15 threads/cm, Z yarn twist in warp and weft threads. The image acquisition was performed in a photo studio at the Department of Textiles, Graphic Arts and Design (Faculty of Natural

Sciences and Engineering). The light characteristics were: power 1000 W, type IFF Q 1250, manufacturer OSRAM. Diffuse illumination was obtained using the light diffuser Softbox. The samples of dimensions 1500 × 1500 px were extracted from the same (middle) parts of the original .raw images and converted into the lossless format .tif. Image histograms of the samples from 1 to 7 were equalised.

Threshold algorithms were tested in ImageJ, where the montages of all built-in algorithms was prepared and carefully analysed regarding the visual observation of specular areas of the real cloth. The application of many algorithms resulted in detection of too large areas of specular parts, while a few of them resulted also in the calculation error. Two types of thresholding algorithms were analysed, global (6 algorithms) and local (6 algorithms), and presented in Table 1. Methods were chosen regarding their differences in segmented phase (surface covered by specular areas, distribution of specular regions). Selected global thresholding algorithms were: Mean, Min. Error, Otsu, Percentile, Triangle and Yen and local thresholding algorithms were: Bernsen, Mean, Median, MidGrey, Niblack and Sauvola (ImageJ, 2016). The algorithms were, consequently implemented in the workflow for preparation of visualisation of interlacing structures.

Image analysis was used for numerical evaluation of thresholded images (specular areas). Parameters as Count, Surface area (%) and Average size of specular surfaces (px) were calculated and analysed. Besides, thresholded images were visually analysed considering distribution and organisation of thresholded specular areas.

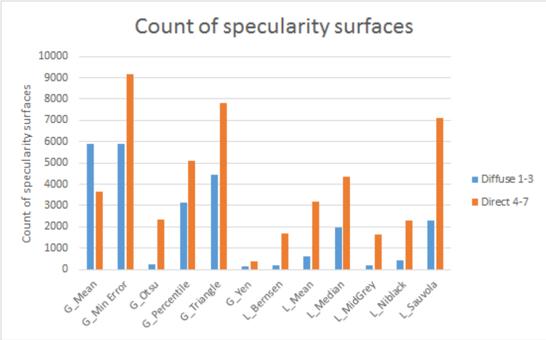
Final visualisations were prepared in the 3D computer program Blender. 3 image maps were used for the final visualisation: the diffuse map (photograph), the normal map (generated with the computer program CrazyBump) and the specular map (a part of the photograph that was extracted with thresholded image used as a mask). The type of the used lamp was “Sun” with the strength 0.4 and the position x = 0, y = 0, z = 10. The renderings were done using Blender render engine Cycles Render.

3. RESULTS

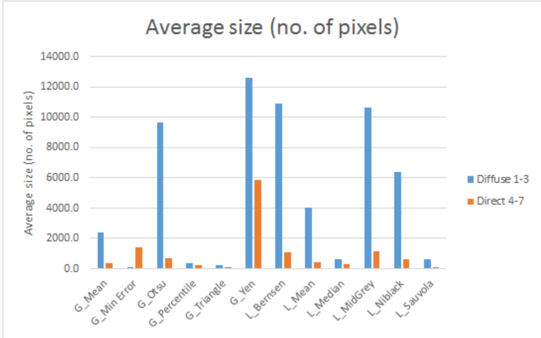
In Table 1 the results of the number of specular surfaces (Count), average size (Ave. size, num. of pixel), and area covered by specular areas (Area, %) for global and local thresholding algorithms and two types of illumination (Diffuse - samples 1-3, Direct - samples 4-7) are presented. In Figs. 1a to 1c graphical comparisons of the number of specular surfaces average size and area covered by specular areas for global and local thresholding algorithms and two types of illumination are shown. In Figs. 2a and 2b thresholding images of diffuse (sample 1) and direct (sample 4 and 7) illuminated samples after processing with global and local thresholding algorithms are presented. In Fig. 3 visualisation of samples 1, 4, and 7 (with details), specular maps of which were defined with four different algorithms for histogram thresholding (global: Otsu and Mean, local: Bernsen, Sauvola) are shown.

Table 1: Results of image analysis of samples for global and local thresholding techniques and two types of illumination (Diffuse - samples 1-3, Direct - samples 4-7); number of specular surfaces (Count), average size (Ave. size, num. Of pixel), and area covered by specular areas (Area, %).

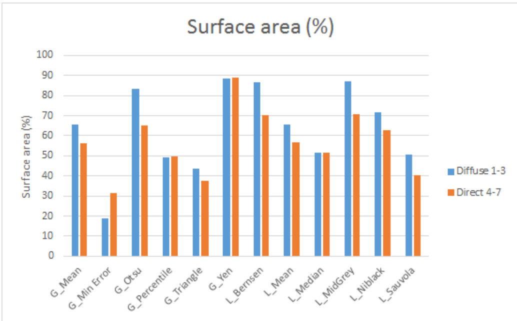
Illum.	**Global**	**Count**	**Ave.size (px)**	**Area (%)**	**Local**	**Count**	**Ave.size (px)**	**Area (%)**
Diffuse Samp. 1-3	**Mean**	5904	2402.4	65.8	**Bernsen**	195	10910.1	86.8
	Min Error	5904	86.5	18.9	**Mean**	630	4030.8	65.4
	Otsu	217	9686.2	83.3	**Median**	1947	606.3	51.6
	Percentile	3150	364.3	49.4	**MidGrey**	199	10672.9	86.9
	Triangle	4457	248.0	43.7	**Niblack**	404	6405.2	71.7
	Yen	164	12581.6	88.7	**Sauvola**	2313	624.1	50.6
	average	*2457*	*4228.2*	*58.3*	***average***	*948*	*5541.6*	*68.8*
Direct Samp. 4-7	**Mean**	3652	358.8	56.2	**Bernsen**	1692	1063.8	70.3
	Min Error	9184	1408.4	31.3	**Mean**	3201	410.5	56.5
	Otsu	2358	663.9	64.9	**Median**	4365	271.8	51.4
	Percentile	5107	224.5	49.7	**MidGrey**	1642	1116.4	70.7
	Triangle	7794	110.1	37.5	**Niblack**	2286	645.3	62.9
	Yen	361	5861.5	88.9	**Sauvola**	7104	131.7	40.1
	average	*4743*	*1216.0*	*54.8*	***average***	*3382*	*606.6*	*58.6*



a.)



b.)



c.)

Figure 1: a.) Number of specular surfaces (Count), b.) Average size (Ave. size, num. of pixel) and c.) Area covered by specular areas (Area, %) for global (G) and local (L) thresholding techniques and two types of illumination (Diffuse - samples 1-3, Direct - samples 4-7).

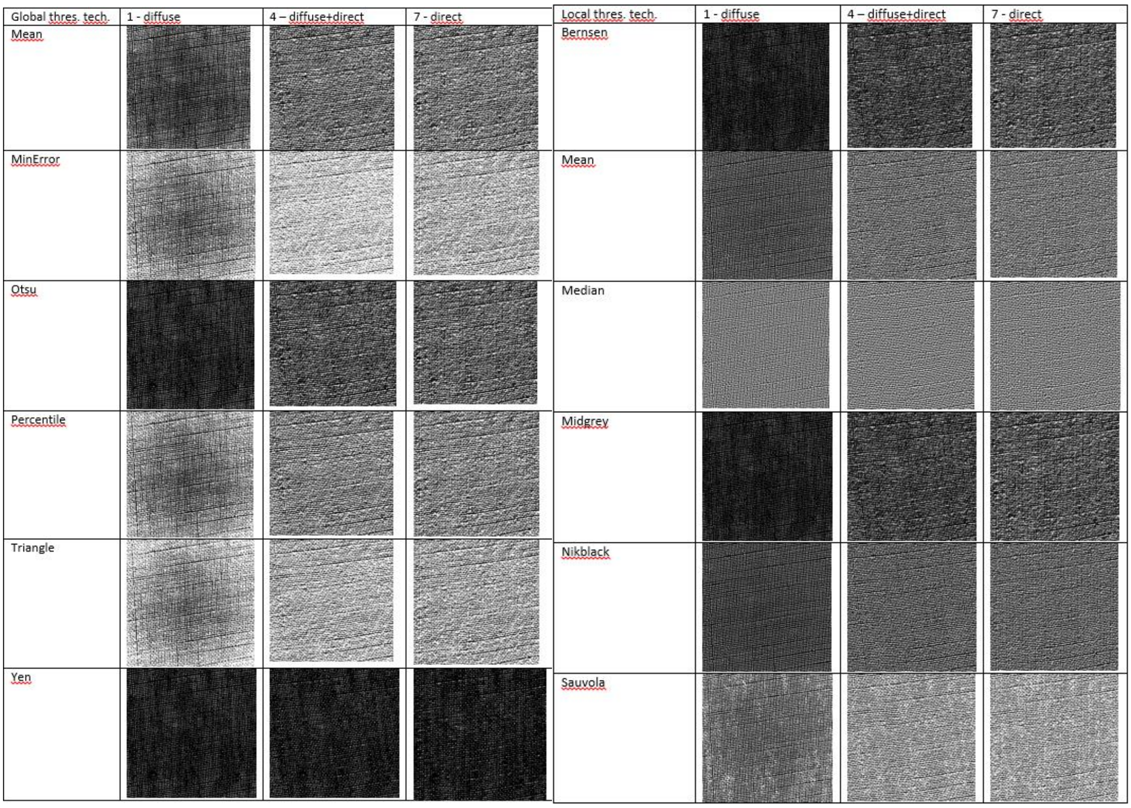


Figure 2: Thresholding images of diffuse (sample 1) and direct (sample 4 and 7) illuminated samples after processing with a.) global and b.) local thresholding algorithms.

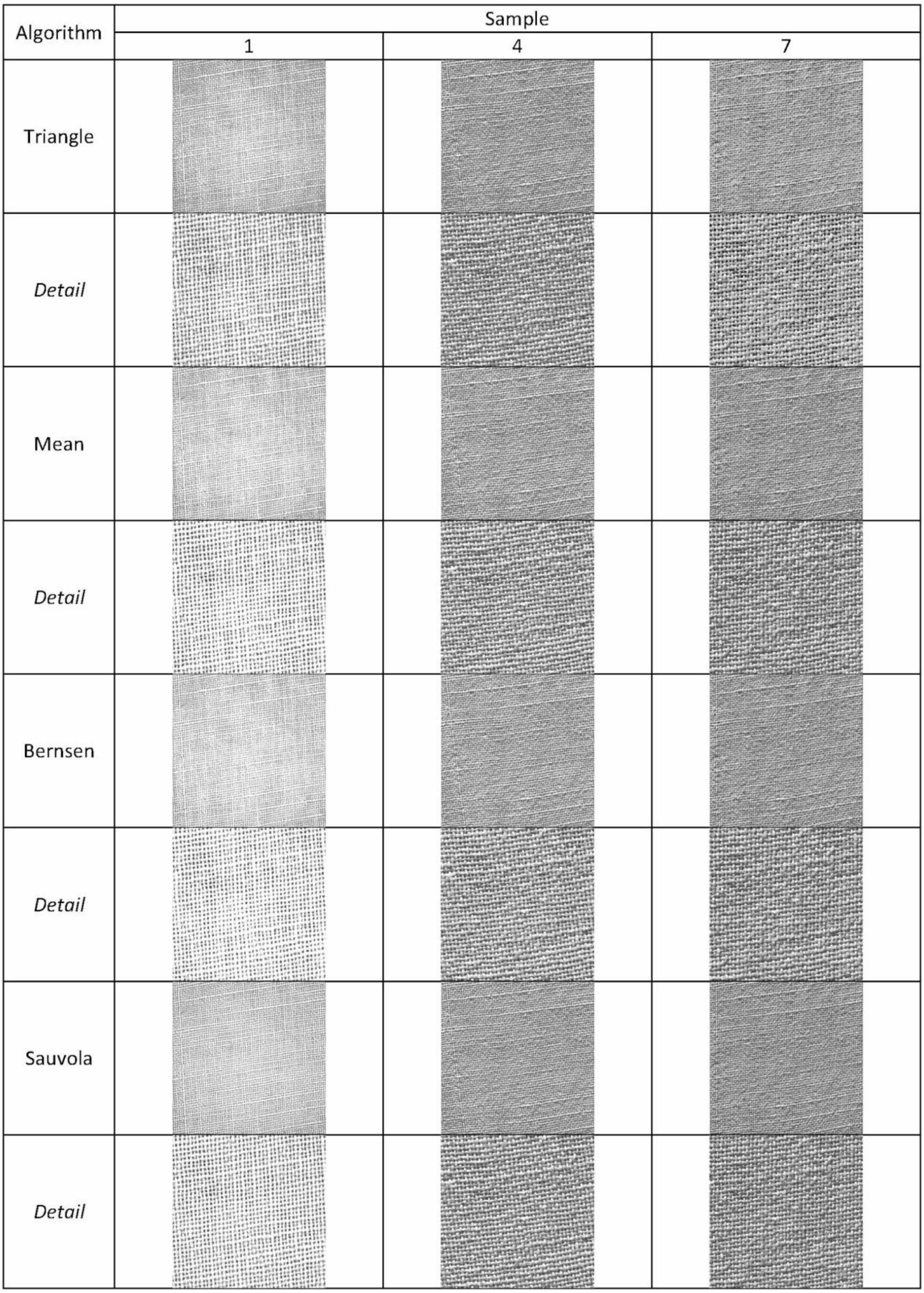


Figure 3: Visualisation of samples 1, 4, and 7 (with details), specular maps of which were defined with four different algorithms for histogram thresholding (global: Otsu and Mean, local: Bernsen, Sauvola).

4. DISCUSSION

In general the local thresholding techniques result in lower values of count of specular surface (Fig. 1a). This results can be confirmed so for diffuse type of illumination (samples 1-3) as for direct (samples 4-7). The deviances between global and local thresholding techniques are higher in case of diffuse illumination, where average number of specular surfaces for global thresholding techniques is 2457 and for local 948. Within the group presenting direct illumination (samples 4-7) the difference is smaller, the number of specular area for global techniques is 4743 and for local 3382. Thresholding techniques that result in the highest number of specular areas are Mean, MinError and Triangle in the global group of thresholding techniques and Median and Sauvola in the local group. In our opinion, the results of the count of specular areas are only the initial indicator of adequateness of thresholding algorithm and only with the consideration of other parameters the successful analysis is possible.

Fig. 1b presents that average size of specular areas (with the unit: no. of pixels) varies significantly for different (global, local) thresholding algorithms when images were acquired with diffuse illumination (samples 1-3), however these values are higher for local thresholding methods. Global thresholding techniques as Min.Error, Percentile and Triangle and local thresholding techniques Median and Sauvola result in average sizes of specular surfaces from 86,5 (Min.Error, global) to 624.1 pixels (Sauvola, local), while for other algorithms the average size of specular areas are higher than 4000. Local thresholding algorithms result for samples 1-3 (diffuse illumination) in average higher values of size of specular areas (5541.6) as global techniques (4228.2). On the contrary, samples with direct illumination (samples 4 -7) results in higher values of average size, when they are processed with global algorithms (average values 1216.0 pixels) and lower values when they are processed with local algorithms (average value 606.6 pixels). Here especially global algorithm Yen is resulting in extremely high average value of surface area, i.e. 5861.5, what could point out the inadequateness of this algorithm. Namely, in interlaced structures it should be considered that specular areas are in fact smaller lifted areas, that optically pronounce the relief morphology of the structure and not very large surfaces spreading over the direction of the interlaced structure. With this consideration and taking into account the results of average size of specular areas, direct illumination is more appropriate for definition of specular areas, however the crucial parameter for a complete analysis is also an examination of distribution of specular areas (Figs. 2a and 2b).

The results of surface area, i.e. area that is covered by all specular surfaces is in our opinion the less significant parameter for the analysis. This can be seen also in Fig. 1c, where there are small deviances between the results for global and local thresholding algorithms. Local techniques result in higher values of surface areas than global techniques and the surfaces of the samples illuminated with diffuse lights are covered with large amount of specular areas than samples illuminated with direct lights. Considering the numerical results (Table 1, Fig. 1c) this means that the average surface that is covered by totally and partly specular areas is 58.3% for global techniques and diffuse illumination, 68.8. for local techniques and diffuse illumination, 54.8% for global algorithms and direct illumination and 58.8% for local algorithms and direct illumination. In our opinion this is due to the characteristic of diffuse illumination that enable higher portions of surface light scattering and consequently higher values of partly specular areas are detected. In samples illuminated with direct illumination there is a higher portion of total specular reflectance (on the level of fibre, yarn and fabric) and lower portion of partly specular reflectance.

In our experiments, it was found out that besides image analysis of thresholding images, visual evaluation and comparison with original images are crucial for understanding and reproducing of the specular phenomena. Figs. 2a and 2b present the distribution and organisation of specular and partly specular areas after thresholding with global and local algorithms during diffuse illumination (sample 1), during the combination of diffuse and direct illumination (sample 4) and during direct illumination (sample 7). There are very obvious differences in processing of specularity between global and local thresholding algorithms. In general, local algorithms due to their mathematical principle result in more uniform distribution of specular areas while global techniques detect more surface irregularities and unevenness. After the images are processed with global algorithms there is also more horizontal orientation of specular areas visible on the surface, but especially for samples illuminated with direct light (sample 4 and 7). We assume that the orientation of specular surfaces could be a consequence of a correlation of illumination settings and direction of relief phenomena on cloth's surface (pronounced relief effects in the direction of horizontal yarns). Interesting phenomena result also for sample 1 (illuminated with diffuse lights) so after thresholding with global as after processing with local algorithms. Here, horizontal direction in organization of specular surfaces is not so pronounced, however these thresholding images shown a centrical distribution of specular surfaces after processing with global techniques and the reduction of the visibility of distribution

and orientation of specular surfaces after processing with local algorithms. These trends in disposition of specular surfaces are obvious also in Fig. 3, where the 3D visualisations in large scale and in detail are shown. Certainly, the deviations in visualisations of different samples are more exposed in dependence of a type of illumination as of a type of thresholding algorithm. Our experiments discovered also unexpected smaller visual deviations (image intensity and contrast) between the 3D visualisation created with thresholding images, which image analysis results were very different (see Bernsen and Sauvola local algorithm in Fig. 3). We presume that the cause for this could be found in rendering settings, what is going to be confirmed in our further researches.
When considering only specular reflectance, the most optimal global thresholding algorithms could be Min.Error and Triangle. Besides these algorithms, also Percentile and Mean should be taken into consideration, when a wider aspect of specularity (specular and partly specular/diffuse reflectance) would be observed and visualised. In our research it was discovered that Sauvola and Mean local thresholding algorithms are the most adequate, due to the preservation of irregularities of interlaced structures and optimal numerical results of image analysis. Besides, algorithm Median should also be taken into consideration in further researches.

5. CONCLUSIONS

In 3D computer graphic pipeline, texture and map editing is usually performed with a set of tools that do not enable the analytical approach of the texture preparation. On the other hand, advanced appearance models can analytically and numerically accurately represent an interlaced structures at micro level including all details. These structures are in the terms of geometrical and image data very complex. In our research the study of global and local thresholding algorithms used in open source image analysis application ImageJ was performed. The focus was on definition and generation of a specular map. The structure characteristics were analysed with different illumination settings during acquisition, which, due to interactions between the illumination settings and cloth's relief, enable different specular and partly specular phenomena. Besides also an image processing on a very large sample surface (where it is possible to see the uneven structures and time-dependent deformation) was crucial.
The results of the research present the differences in processing the specular areas when global and local methods are applied. Namely, there are evident deviances in count and average size of specular surfaces after the acquired images are processed with global and local thresholding algorithms. However, in our opinion the the most interesting observation were the variations in organisation of traced specular areas after the implementation of different global and local thresholding algorithms. The latter in fact influence significantly on visual perception of the interlaced surface. The research revealed also some unexpected results, i.e. the phenomena of specularity manifested less obviously in the 3D visualisations as in thresholding images. Besides, after our research there remain some unsolved issues. Image processing and segmentation of separate parts of specular areas (i.e. totally and partly specular surfaces), which do differently contribute on final reflectance is still in the research phase. In this sense the further researches should cover the image analysis of organisation of specular areas and the development of specialised thresholding method for uneven interlaced structures.

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COMPARISON OF DISPLAY COLOURS OF A PROFILED COMPUTER SCREEN AND DIGITAL PROJECTOR

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Abstract: *Calibrating, profiling and certification of computer screens is scientifically very well treated. However, it is the digital projection that is not thoroughly covered. Certified computer screen is 100 percent capable of depicting the color space of Adobe RGB (1998) or eciRGB. High-quality computer screen colors can be reproduced with the precision of dE * ab <1.5. In our previous studies we observed to what extent could this be achieved with a digital projector. Research was conducted with regard to describing profiling and related problems, but the projector performance conditions and set up adjustment functions were not stated. In this study we examined the difference between the colorimetric accuracy of two profiled screens: Eizo 242 (LCD computer display) and Hitachi (CRT computer display) and two digital projectors NEC NP210 and JVC DLA-RS 15 with selected modules. The sRGB module was used for NEC NP210 projector while the projector JVC DLA-RS-15 uses module Natural HB. For successful implementation of the research it was necessary to determine the parameters for performing calibration and profiling of all devices and to choose a way to determine the colorimetric accuracy thus comparing the results using the formula for calculating color differences. The results show that according to the ISO 12646: 2010 standard digital projection can not compete with high-quality CRT or LCD computer displays.*

Keywords: display, digital projection, colorimetric accuracy

1. INTRODUCTION

While calibration, profiling and certification of computer screens have been scientifically well-researched (ISO, 2008); (ISO, 2009); (Kunihiko, 2007); (Kunihiko, 2008); (Kunihiko, 2009), only little has been published on digital projection. Certified computer screen is capable of using the full 100% of the Adobe RGB colour space (1998) or eciRGB (ECI, n.d.).A high-quality computer screen is able to reproduce colours with the precision of dE*ab < 1.5 (Ugra, n.d.). The existing researches do not provide information to what extent it is possible to reach that by using a digital projector. In general, the researches relate to description of profiling and possible problems connected to it (Cooper, 2016); (Cooper, 2015), , however, the settings of the digital projector and the conditions it operated in, are not evident. For an impeccable colour display, profiling of the projector is absolutely necessary every time the nature of the light in the room or the type of screen or projection screen changes (Cooper, 2016). Projectors are profiled in dark (low light) rooms in order to create colour profiles with different settings of the colour temperatures of the white point (usually 5000 K, 6500 K and natural white in given conditions), whereas in real conditions of the presentation, the most appropriate colour profile is visually chosen (Matt, 2003). As stated by the same source, the distance between the optic sensor, the projector and the screen plays no role, yet these relationships are clearly defined by others.

Various researches refer to geometrical calibration (i.e. manual configuration of the contrast, brightness, reciprocal colour temperature) of digital projectors (Park, 2010); (Ashdown, n.d.), whereas colorimetric evaluation with regard to testing of digital projectors is only summarized by source (Park, 2010). According to the ISF (Turk, n.d.) certification specification, the most precise display of six colours so far has been reached by using the digital projector JVC DLA-RS25, namely, with the colour difference of 1-3 with default settings and the colour difference of 0,5 with a designed profile (in all six reproduced colours). The source does not reveal details on test methods, methods of measurements, colour difference calculations; the only information give is that the calibrator ISF (Turk, n.d.) is certified. According to experience and certain sources (Matt, 2003), it is possible to improve colour display by calibrating and profiling of the digital projector with visual evaluation, while other sources (Turk, n.d.) list excellent results that, most likely, hold true only for the six basic colours. However, there is no source that would deal with objective colorimetric evaluation of the digital projection, based on the display of real colours at different observing conditions.

2. METHODS

In order to perform the experimental part as part of this research we had various types of equipment at our disposal. We needed digital projectors and projector screens, a spectrophotometer and profiling software, computer screens and other necessary equipment (studio lighting, plumb line, level, tape measure, air-conditioning appliance, thermometer, etc.) that enabled performance under controlled and repeatable conditions. The first projector we used for the experimental part was a low-priced NEC NP210 classroom digital projector, the simplest of models from the series of NEC's projectors, based on the DLP technology. Natural display resolution of the projector is XGA (1024 x 768 pixels) and includes six projection modules: High Bright, Presentation, Video, Movie, Graphic, and sRGB. The second projector we used was JVC DLA-RS15, which belongs to the category of home theatre projectors (Turk, n.d.) and is based on the liquid crystal silicon LCoS technology. Display resolution of the projector is high, maximum 1920 x 1200 pixels, if such resolution is supported by computer. The projector has six modules for watching movies (Cinema 1, Cinema 2, Cinema 3, Natural module, Stage, and Dynamic).
Calibration and profiling (of the computer and/or the projection screen) were performed by using the two already established applications: i1Match 3.6 application in combination to the i1Pro spectrophotometer, and basICColor display 4.1.22 application in combination to the i1Pro spectrophotometer. The computer screens (CRT and LCD) were certified by an UDACT application, which is unfortunately not (yet) appropriate for digital projection certification. The i1Match 3.6 application (dialog box of the application is displayed in Figure 1) enables profiling (characterization) of the projector only, whereas in other cases, the experiments had shown that by geometric calibration, i.e. manual setting of the contrast, brightness, and if possible, also of the reciprocal colour temperature, the results are more likely to worsen than to improve. We limited ourselves to projector profiling at set parameters only, which means that the created colour profile carried out all the necessary corrections more or less efficiently by using the LUT lookup table the graphics card of the computer, which supported the projection. Prior to profiling, we always eliminated all profiles from the computer's operating system and rebooted the computer, and after the finished profiling, the created profile was manually made default as a system profile, and then once again, we rebooted the computer before the projection and measurements of the colour charts.

Figure 1: Dialog window of the i1Match 3.6 application

2.1 Colorimetric accuracy

Colorimetric accuracy of the digital projection and the computer screen were evaluated by the aid of colour chart Color Checker Classic (Figure 2). Standardised (reference) colour values of the individual fields are measured and colour differences (dE*ab) between reference values and the ones that are actually measured are calculated. The desired dE*ab is 5 on average (Mx), and the maximum (Max) should not exceed 10. The measuring fields are projected to the middle of the projection screen.
The measurements were made in studio conditions. We adjusted the NEC NP210 projector, so that the projection covered 1.71 m^2, while the digital projector JVC DLA-PR15 was attached to the ceiling of the studio, so that projection covered 3.43 m^2. The NEC NP210 digital projector had been installed in the studio at least 8 hours before the measurements took place, and both projectors were warmed up at least half an hour prior to individual measurements by projecting a white colour chart DPT-W315 on the projection screen.

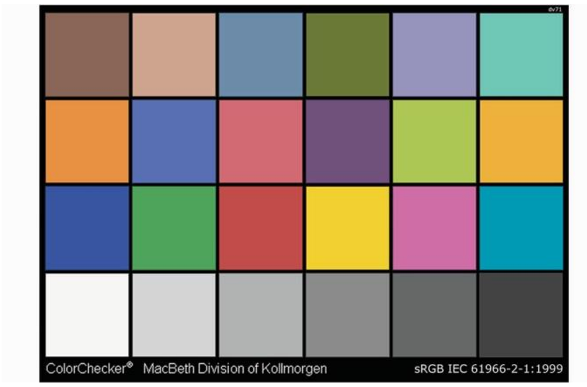

Figure 2: Colour chart Color Checker Classic.

After 45 minutes of heating the projector, the measurements of the unprofiled projection were performed in adequate modules. Calibration and profiling of the digital projector were using two well-established applications i1Match 3.6 in basICColor display 4.1.22 in combination with the spectrophotometer i1Pro. In all cases the desired values that fit the reproduction of the standardized colour space sRGB were set, whereas the white point luminance was defined by 100 cd/m^2 instead of the standard 80 cd/m^2. Higher value of luminance was chosen because the projected reproductions are observed from much greater distance than computer screens, which sRGB colour space is adapted to. The colorimetric accuracy of the digital projection was evaluated by using the 24 fields of the Color Checker Classic colour chart. One after another, colour charts were projected to the screen and standardized colour values X, Y, Z of the central field were measured on each of them. Colour differences dE*ab between the displayed and reference values were calculated.
Although the ISO 12646:2008 standard regulates the reference values of the colorimetric accuracy of averagely dE*ab 5 and of maximum dE*ab 10, we wanted to find out how well the display on (high quality) CRT and LCD screens suits them, and draw comparison with digital projection. With the available measuring equipment, we first calibrated (basICColor display 4.1.22+i1Pro) the Hitachi 21inch CRT Monitor to the desired values according to sRGB standards, that is, the white point reciprocal colour temperature of 6500 K and the gradation or gamma sRGB respectively. We performed the same measurements on LCD Eizo 242 Monitor, yet we changed the desired screen luminance (Lv) of 90 cd/m^2 and reached it. The quality of the profile in question was additionally tested by the UDACT programme, which confirmed that the screen was capable of displaying all colour spaces for screen preview, because it had been certified. One by one, colour charts were projected to the screen and standardized colour values X, Y, Z of the central field were measured on each of them. Colour differences dE*ab between the displayed and reference values were calculated.

3. RESULTS

Table 1 shows the measurement results of the colorimetric accuracy of the computer screen and digital projector. From the results obtained we can make out that both computer screens meet requirements of the standard at the direct display of the Color Checker colour chart by using Microsoft Power Point and sRGB system profile. On average even the NEC NP210 projector with default sRGB Module and without profile in the studio conditions would do. The JVC DLA-RS15 projector produced by far the worst results, as all colour differences exceed 10. The projection with sRGB Module and NEC NP210 digital projector shows larger colour differences that are visible especially in saturated colours, such as yellow, red, green, magenta and blue. To sum up, digital projection displaying the sRGB standardized colour space is not comparable to the high quality CRT or LCD computer screen.

*Table 1: The colorimetric accuracy of the computer screen and digital projector, measured by i1Pro; yellow colour marks the dE*ab values, lower than 5.*

Color Checker Classic	*Module sRGB NEC NP 210*	*Module Natural HB JVC DLA-RS15*	*Computer screen EIZO*	*Computer screen Hitachi*
	without profile	*basICCcolor display 4.1.22 + i1Pro*	BasiCC_sRGB/ UDACT	BasICC_sRGB
Patch 1 (Dark skin)	5,60	12,07	6,05	4,53
Patch 2 (Light skin)	4,83	17,15	3,62	3,31
Patch 3 (Blue Sky)	3,03	13,17	2,95	4,38
Patch 4 (Olive Green)	1,69	11,66	4,35	5,01
Patch 5 (Violet)	4,03	14,54	2,42	*3,35*
Patch 6 (Bluish Green)	6,86	18,56	2,53	5,16
Patch 7 (Orange)	8,48	17,05	4,73	2,69
Patch 8 (Purplish Blue)	3,45	14,88	4,15	4,47
Patch 9 (Moderate Red)	9,55	15,25	3,70	2,79
Patch 10 (Purple)	6,58	10,42	3,84	3,96
Patch 11 (Yelow Green)	4,24	19,08	4,71	5,94
Patch 12 (Orange Yellow)	6,94	19,71	5,3	4,10
Patch 13 (Blue)	3,09	14,05	4,5	5,08
Patch 14 (Green)	8,93	14,53	4,29	6,30
Patch 15 (Red)	10,49	12,25	4,34	2,67
Patch 16 (Yelow)	6,37	26,37	5,75	5,14
Patch 17 (Magenta)	10,47	16,31	2,71	3,72
Patch 18 (Cyan)	11,87	11,84	2,51	3,78
Patch 19 (White)	3,51	25,88	3,66	4,33
Patch 20 (Neutral 8)	3,33	22,18	2,98	3,87
Patch 21 (Neutral 6,5)	2,20	16,75	2,63	3,38
Patch 22 (Neutral 5)	2,54	12,87	3,01	4,00
Patch 23 (Neutral 3,5)	3,42	10,55	4,36	4,47
Patch 24 (Black)	5,59	11,32	8,22	7,16
All colours				
Mx[1] dE*ab	**5,57**	**15,73**	**4,05**	**4,34**
Max[2] dE*ab	**11,87**	**26,37**	**8,22**	**7,16**
Tones only				
Mx[1] dE*ab	3,43	16,44	4,14	4,61
Max[2] dE*ab	5,59	25,88	8,22	7,16

[1] *Mx - average value, dE*ab = 5.*
[2] *Max - maximum value, dE*ab =10.*

4. CONCLUSIONS

Digital projection using the analysed projectors (and supposedly all other projectors) is not comparable to the projection using high quality CRT or LCD computer screens, not in any other module and not by the SIST ISO 12646:2010 standard. Exactly the choice of the suitable default module, either for direct projection or colour management, is the chief issue. The results have shown that colorimetric accuracy evaluation by using digitalized Color Checker Classic colour chart is the only that produces useful results; especially, if the chromatic colours display with a focus on skin tones and achromatic colours with a focus on grey balance and chromaticity respectively are separately examined.

However, considering the fact that semi-professional and professional projectors are very expensive, the perspective lies in colour management by machine calibration and profiling –as with better screens – and not in the wide array of (inadequate) projection modules and/or settings that can be experimented with without getting good results. And yet, any other colour management of digital projection can be efficient and reasonable only if it ensures similar quality or colour differences in the form of colour display on certified screens according to the SIST ISO 12646:2010 standard.

Following the example of UDACT, a reliable equipment is necessary for digital projection certification. Good channel balance and a very large colour range of the chromatic basic colours do not by itself necessarily guarantee a high quality display of colour in RGB colour spaces, sRGB in our case. It is crucial to reach the white point screen luminance (Lv) that defines the colour space. It is not sensible to profile (colour manage) digital projections for personal, office or average school use – it is best to use a likeable projection module and correct it on the basis of the visual assessment of the Color Checker Classic colour chart and other test images, taking into consideration the projector characteristics. When it comes to studio projection that, regarding the expenses, allows the purchase of an adequate (expensive) measuring equipment, it is worth to make an effort and improve it step by step. One has to understand that it is a long-term process, as the same projector displays colours differently in different conditions and the results cannot be transferred.

In order for the digital projection to be equal to the display of colours on certified computer screens, an adequate standard (ISO) is required, which will deal with digital projection exclusively, a reliable instrument with an appropriate software support for credible measuring and profiling, an application for a fast, irreproachable choice of the projection module and reliable digital projection certification, professional digital projectors without the possibility of choosing a number of projection modules and settings, yet with an efficient machine calibration chosen according to the desired display.

Digital projection colour management is still in its infancy, as at the current state of the digital projection and colour management, the latter does not offer any substantial advantages. To this purpose, software and measuring instruments will have to be strongly improved.

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Tools for media optimization

FUNDAMENTAL FACE ELEMENTS AND FACE IMAGE RECOGNITION

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Abstract: *Images, as one of the main elements of web content (beside text, animations, audio and video) are highly informative. One common type of images is face images. It is mainly used for personal presentations (companies, universities, associations, etc.). There is a question how users see face images and how they remember it. One of most useful approach to address this issue is to use eye tracking system. Our research was implemented with Tobii eyetracker X-120 and consist two tests. In the first experiment, we analysed how users see face images when they are displayed short time. The procedure of test was controlled. Face images were presents for 4 seconds which was followed by a blank screen for one seconds. One second "pause" was implemented to "neutralize" the eye position before the next face image. First we investigated which are the main face elements. After confirming previous researches, we focused on the time distribution of these main three face elements: eyes, nose and mouth. We also investigated the duration of fixations for each face element. Second experiment was implemented to find out how time elapsed between the observation test and recognition test influence recognition performance. Observation test was the same as in experiment 1 (controlled), while recognition test was user-free (controlled by participants). Our assumption that the longer time from observation to recognition will result in worse recognition performance was confirmed by the observation of two sets of face images presented sequentially. Recognition performance of the second set higher than of the first set. Since our participants were both, men and women, we also investigated the recognition performance for each sex respectively. And on top of that, we also looked at same-sex and cross-sex recognition.*

Key words: Face image, eye tracking, face elements, face recognition, fixation time

1. INTRODUCTION

Web content has five most important elements of information: text, images, animations, video and sound (1). Many web designers underestimate the power of images and often try to explain certain things with description. In many cases, it turns out that it is easier to use image, which can then be further explained with little text. Therefor using images means clearer and understandable presentation. Bottom line user experience is better.

One common type of images that often appear on websites are face images, most often at the presentation of companies, associations, organizations, universities and research institutions. Presentation persons with attached image is much more relevant and looks more "serious" than just text description.

Important aspect in process of face image preparation is how well users remember face. Face image can be prepared in difference face expression (emotions) or face can be presented from different angle (front or perspective) (2).

We analyzed how users look at face images and what are the most important face elements. Previous researches (3) clearly shows that eyes, mouth and nose are most important face elements, which attracts most attention from viewers.

We also tried to find out the correlation between participant's exposure to face image presentation, recognition and remembering, therefore does time from face image presentation to face image recognition influence on capability of remembering. Basic idea lies in BBC test of face recognition (4). We presented face images in two separate groups one after another and later presented all faces from both groups and saw how many faces was recognized correctly. Assumption was that recognition from first test would be worst that from the second test due to the longer time passed from presentation to recognition.

Aside this main recognition test we also did research of same-sex and cross-sex recognition. In other words, how well we remember face of same sex comparing to the face of opposite sex (5).

2. METHODS

2.1 Participants

We had 20 participants, 6 male and 14 female. They were all our students and had normal vision. They received little bonus in study process for their participation.
For the test of face element analysis, we set the limit of 80% recording accuracy, which means that we have eliminated participants who have less than 80% of the recorded samples by eyetracking system (6). 14 participants passed that criteria (5 male and 9 female) and their observation and recognition was taken for analysis.

2.2 Stimuli

Stimuli for our experiments was 30 face images taken from internet. In further preparation they were cropped to the dimensions of 600 x 600 and we ensure that the faces in the images were the same size and have face elements of our interest (eyes, nose, mouth) in the same position. We equally include faces by their age (young, middle age, elderly) and by race (white, black, yellow). These face images were divided into three groups.

2.3 Apparatus

Out tests were done with stand-alone eyetracking system Tobii X-120. This system was connected to the computer and separate 24'' screen with resolution 1440 × 900 (demand from Tobii Studio software). Best results can be obtained at distance of 60 cm from participant to the screen (eyetracking system) (6). Testing set is shown at Fig. 1.

Figure 1: Testing setup

Analysis were done in Tobii Studio 3.4.4 software. The defaults setting for definition of fixation was 100 ms for 30 pixel area. That means if eyes stayed in the area 30 pixel for at least 100 ms it was concerned as one fixation (7).
Data for the analysis of main three face elements was obtained by using Area Of Interest (AOI). In the memory test, we simply manually recorded the responses of users at the recognition test.

2.4 Procedure

Procedure of the test was common for both experiments and is shown in Fig. 2.

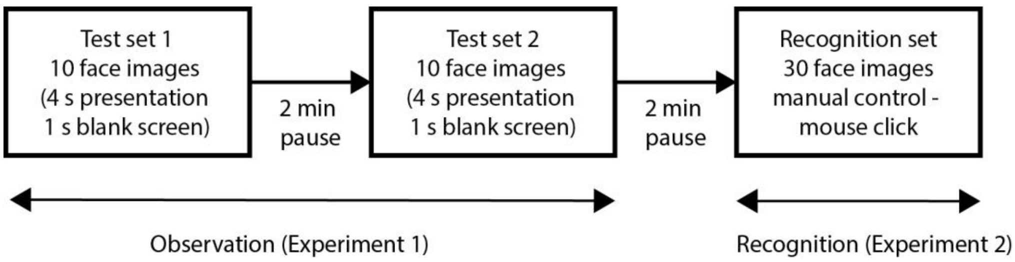

Figure 2: Test procedure

Observing part of test procedure was used in Experiment 1, whereas recognition part was used in Experiment 2. Participants were shown two sets of 10 face images. The process has been automated. After presenting the instruction face images were displayed for four seconds each with one second of pause with dark screen. The purpose of the pause was to neutralize eye position. This was to ensure that last position of fixation to the previous face image had no influence on the first fixation of the new face image.

We had two minutes break between each set of 10 images and two minutes break between second set of face images and recognition test. These pause was used to investigate how time influent degradation of memory capabilities.

Each participant controlled recognition test manually. The test included 30 face images (10 from each two previous tests and 10 new face images) and for each displayed face image (presented after mouse click) participants decided they had seen it, either in first set, second set, or they did not see it before. The results were recorded manually.

2.5 Experiment 1

In the first experiment, we were interested in main three face elements and their observation time from participants. We also analyzed fixation time for each face element.

Displayed time of face images was quite short (four second), which leads to the assumption that the total time of the observation of these three face elements would be very large. In this short displayed time participants rarely moved their gaze to any other face element. That would have happened when displayed time would be longer. As mentioned before we set AOI at area of eyes, mouth and nose as they are shown in Fig. 3.

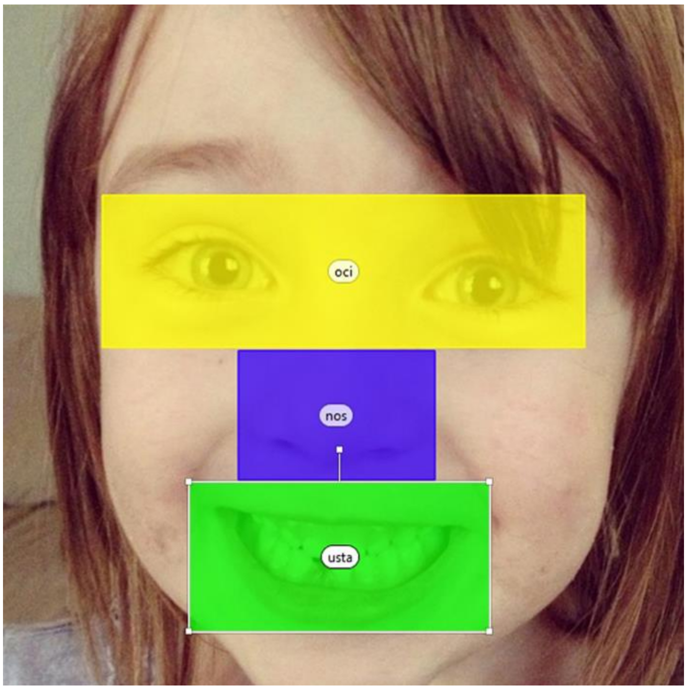

Figure 3: Area Of Interest (AOI)

2.6 Experiment 2

The focus in experiment 2 was how capability of memorizing faces drops with time. We measured correct recognition of faces in set one and set two. Those two sets were presented with time pause of two minutes, so we predicted that correct recognition of face images is set two would be better that in set one. We also measured "presence" and "absence" recognition. We defined those two terms as participant correctly recognize that face image was presented in either two sets or participants correctly answered that face image was not present in the previous two sets.
In addition, we did gender test. We analyzed same-sex and cross-sex recognition (woman recognizing man face images and vice versa).

3. RESULTS

3.1 Experiment 1

Table 1 shows the proportion of time of observation of each of main three face elements and their total time.

Table 1: Portion of time observing main three face elements

Portion of observation time	Set 1	Set 2	Both groups
% of time observing eyes	50,7%	50,9%	50,8 %
% of time observing nose	14,8%	12,6%	13,7 %
% of time observing mouth	16,1%	19,5%	17,8 %
Total % observing main three face elements	81,6 %	83 %	82,3 %

Table 2 shows the average fixations time for each main three face elements. Time is as statistical data obtained from with software Tobii Studio 3.4.4 from the number of fixations and total time spent on each face element.

Table 2: Fixation time for different face elements

Average fixation time	Set 1	Set 2
Average fixation time on eyes (ms)	243	261
Average fixation time on nose (ms)	246	237
Average fixation time on mouth (ms)	246	275
Average fixation time for all three (ms)	245	258

3.2 Experiment 2

Table 3 shows the performance of face recognition for both groups. 10 face images in each set were shown to 14 participants. Therefore, the maximum number of correctly identified face images were 140. "Presence" recognition had max. 280 correctly recognized face images and "absence" recognition had 140 face images.

Table 3: Recognition performance

Face image tests	Correct recognition (N)	Correct recognition (%)
Set 1	105	75%
Set 2	111	79%
"presence" recognition (20 face images)	259	93%
"absence" recognition (10 face images)	128	91%

Results of same-sex and cross-sex are shown in Table 4. Male participants were 5 and male face images were 15 (half of 30), so possible correct recognition was 75. For 9 female participants that number was 135. There is also cumulative correct recognition for male and female participants (gender recognition).

Table 4: Same-sex and cross-sex recognition

Gender combination	Correct (N)	All (N)	Correct recognition (%)	Correct recognition (%)
male-male	61	75	81,3%	76,6 %
male-female	54	75	72,0%	
female-male	113	135	83,7%	84,1%
female-female	114	135	84,4%	

4. DISCUSSION

4.1 Experiment 1

Table 1 shows us that eyes are, by far, the most attractive element in face images and consequently attract the most attention. Participants spent just a little more than half (50,8 %) of the total observation time looking at eyes. Time that participants spent on mouth (17,8 %) and nose (13,7 %) are little in favor of mouth. All results are very similar to results in previous research (8). When we looked manually at gaze plot we saw that many participants had a short fixation on nose. This fixation occurred when participants moved their gaze from eyes area to mouth area and was not intentional (due to the reason that it was only one fixation). Participants then moved their gaze to the nose area after looking at mouth area. This order (eyes, mouth, nose) was for majority of participants.

There is no significant difference between two sets in the proportions of individual face elements, but we can see that for both sets of face images all three face elements together have been observed for more than 80% of the total observation time and only confirm the assumption of these three elements that most attract attention. The rest is observation other facial features (forehead, cheeks, ears, chin) or the participants gaze left the area of face image (looked at dark part of the screen where face image is not shown).

In Table 2, we can see the average fixations time of main face elements for both sets. In the first set results for all three face elements are almost identical, the second set has fixation time difference for these face elements a little bigger.

Average fixation time in second set is a little longer than in first one (258 ms vs. 245 ms). The difference is not big but it shows to participant's tiredness so gaze is not as active as before. Further research with more sets of images and with more face images in each set should be done to confirm that assumption.

4.2 Experiment 2

Recognition results in Table 3 shows the influence of short-term memory. Recognition performance in set 2 was better than in set 1. Reason was in time from presentation to recognition, which was shorter at set 2.

"Presence" recognition test just measured the percentage of image faces that participants correctly recognized, regardless whether they sad correct set of particular face image. Result of 93 % is a little better than 91 % of "absence" recognition. Therefor, "positive" memory (we remember that we saw certain thing) is a little better than "negative" memory (we are sure that we have not seen certain thing).

Results in same-sex and cross-sex (Table 4) confirm previous researches that in general woman (84,1 %) has better performance in face recognition than man (76,6 %) (5). Previous researches showed that man better recognize female faces or at least equally male and female faces (5). In contrary in our case it is just the opposite; male participants much better recognized male face images than female and the difference is relative high (81,3 % vs. 72 %). For women participants, there is almost no difference in recognition success for male or female face images.

5. CONCLUSIONS

Our research and results confirmed that when we have short presentation time of face images, participants look only main three face element (eyes, mouth and nose), and only for longer presentation time the majority of participants will also see other parts of face. Fixation time results for second set of face images was a little longer, which indicate that tiredness have resulted in longer fixation. This would be even more evident at longer tests (ours were about one minute each) and if we would have more tests one after another. As for the gender recognition, we proved hat woman have better memory capabilities for faces (8).

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TESTING LEGIBILITY ON LCD SCREEN WITH EYE TRACKER

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Abstract: *Printed newspapers and other news media have largely migrated to the internet, so that thousands of newspapers and news websites are published online today. The Independent, for example, is to become the first national newspaper title to move to a digital-only future. This is the reason why we daily read an increasing amount of news via screens of various devices, where the typeface and size play an important role. The research included 48 participants who were divided into 8 groups of 6 participants. Groups were shown 8 different texts with approximately the same number of words that have been previously selected in the preliminary measurement. Among different groups, the display sequence was varied using the Latin square design. Each group received the texts in a different order. Texts were styled with the CSS style sheet and displayed as a HTML document. Two typefaces designed for screen rendering (Georgia and Verdana) in sizes 12, 14, 16 and 18 px have been analysed by eye-tracking technology (Tobii X120). We tracked each participant's reading time and number of fixations. Legibility and the reading process can be studied by tracking eye movement. For both typefaces the reading speed increased with increasing font size. Regardless of the font size, the texts set in Verdana were read faster. For LCD displays, the Verdana typeface proved faster to read. Verdana has no variations in stroke width, while Georgia does. At the same time Verdana has a slightly larger x-height and wider characters, which increases its legibility in reading from screens.*

Keywords: LCD screen, reading, reading online, eye movements, fixation duration

1. INTRODUCTION

Digital technology has dramatically transformed the newspaper and media industry in the last decade. Globally, consumers spend an average of almost 2.2 hours per day on their mobile phones (97 minutes) and tablets (37 minutes), which together accounts for 37 percent of media time, ahead of television (81 minutes), the desktop (70 minutes), radio (44 minutes), and print (33 minutes), according to the InMobi mobile media consumption report (Azizuddin et al., 2014). In a study conducted by the Reuters Institute (Levy et al., 2016), 51% of the participants surveyed said that they use social media as a source of news on a weekly basis. Around one in ten participants (12%) said that this is their main source of news. Among the social media, Facebook is by far the most important source of news. In addition, more than a quarter of 18–24 year-olds (28 %) said that social media are their main source of news, social media thus overtaking television (24 %) for the first time. There has been a sharp increase in the use of smartphones for following the news, a minimal increase in the use of tablets, while the use of the personal computer has been on the decline. Eight out of ten smartphone users check their device within fifteen minutes of waking up, most of them still in bed (Milosevic et al., 2015). We thus read increasing amounts of text via the screen. The aim of our study was to establish how the process of reading and information processing from the LCD screen is affected by two different typefaces in two different type sizes.

1.1 Reading

Both the process of reading and text legibility can be studied using eye-tracking. Reading is a complicated perceptual process, which involves decoding the symbols for reading comprehension. We understand reading comprehension as the process of reading, processing and understanding the material (Pečjak, 1993). Legibility reflects the ease with which this process is carried out. For this to happen, the text must be visible and recognizable, but these two characteristics are affected by the typographic choice, which involves the typeface and the spacing between the letters, words and lines of the text (Reynolds, 1988). From the point of view of the physiology of the eye movement, reading is a sequence of horizontal non-continuous saccadic movements with individual fixations. (Lopez-Aranda et al., 2009).

1.2 Saccades

Saccades are extremely quick eye movements, with which we change the direction of our gaze in a moment and align the image of the object of interest with the macula of retina. When reading, saccades move over groups of letters. Saccades are the most common type of eye movement; their speed can exceed 500°/s (Hochberg, 1978) and an individual saccade may last from approx. 25 to 75 ms (Rayner, 1984). Saccadic eye movements vary according to the letter size; lengths from 4.8 to 5.7, from 5.4 to 5.7 and from 7 to 8 letters have been reported in different studies (Rayner et al., 2010), 8.5 letters (Peterson et al., 2010), 7.8 letters for the Consolas and 8.4 letters for the Georgia typeface (Rayner et al., 2010), 5.9 for the Georgia and 5.6 letters for the Verdana typeface (Franken et al., 2015). In Peterson and Jordan study focusing on increased word spacing, saccade lengths of 8.5 characters were reported for single word spacing, while saccade lengths of 6.9 characters were reported for increased letter spacing and single words spacing for the Courier typeface (Peterson et al., 2010).

1.3 Fixations

Fixations are short pauses on individual words or groups of words which enable the brain to process the information. They last between 200 and 250 ms (Mackworth, 1972, Rayner et al., 2001, Feng, 2009), 250 ms (Olzak et al., 1986) or between 200 and 300 ms (Rayner, 2009). A studyes examining reading the Consolas and Georgia typefaces reported an average duration of fixations of 220 ms for the Consolas typeface for reading from the screen 235 ms for the Georgia typeface (Rayner et al., 2010), and from 286 ms for the Verdana typeface to 328 ms for the Georgia typeface (Franken et al., 2015). Based on the data on fixations (the lengths and the locations) and saccades (the number per time unit, the length), as well as the reading speed, we can draw conclusions about the reading process and the legibility of the text.

2. METHODS

2.1 Preliminary measurements

Prior to the main study, in which the reading speed of two typefaces at various sizes has been examined, we conducted a set of preliminary measurements in which the texts suitable for the main study were selected. In these preliminary evaluations 50 participants took part, 25 of whom were female and 25 male, aged 17 to 46, with an average of 24.4 years (*SD* = 7.37). All participants had normal or corrected-to-normal vision. The study was performed in accordance with the latest declaration of Helsinki. The measurements were performed in a quiet room with walls painted in neutral matte gray, according to the ISO 3664 standard. We used 50 different texts in Slovene language (the mother tongue of all participants). For sentences to remain semantically complete, the texts contained different numbers of words, ranging between 104 and 155 (*SD* = 8.92), and similar number of lines (*M* = 8.69, *SD* = 0.48). To avoid the bias on readers' pre-existing knowledge of a certain subject-matter that might have influenced the reading speed, simple literary texts of similar content were used. The participants were divided into 5 groups of 10 people. Each group read the texts in a different sequence. In this manner we eliminated the factor of fatigue and lack of concentration that might have affected the final part of the reading. The texts in Verdana typeface at 12 pt (16 px) were displayed on a 24-inch LCD screen with a resolution of 1900 × 1200 pixels (pixel size 0.27 mm) at a 60 Hz refresh rate in dark characters on light backgrounds. The tested individuals were positioned 60 (± 1) cm from the screen according to the recommendations of the ISO 9241 standard (2012). The texts were set in a CSS style sheet and displayed as a HTML document. In this way we have ensured a precise display of the texts in the chosen size. The texts were displayed in the middle of the screen. Consecutive texts were invoked by successive mouse clicks.

2.2 Main measurements

In the main study we used the texts chosen in the preliminary measurements. The texts were displayed as HTML documents in the Georgia and Verdana typefaces at 12, 14, 16, and 18 px (Table 1) with leading of 130%. The texts were displayed in dark characters on light backgrounds (text color #000000, background color #FFFFFF). Only the main screen, where the texts were displayed, was active in display. In this way we ensured the chosen text size on the main screen (Table 2).

Table 1: Font sizes in px, pt, em and %

	Georgia and Verdana font size			
px	12	14	16	18
pt	9	11	12	14
em	0.75	0.875	1	1.125
%	75	87.5	100	112.5

Table 2: The sizes of x-height for the Georgia and Verdana typefaces displayed on the screen

Georgia and Verdana font size on Screen					
Selected font size in pixles		12	14	16	18
Georgia	x (px)	7	7	8	9
	x (mm)	1.89	1.89	0.21	0.23
	x (°)	0,18	0.18	100	112.50
Verdana	x (px)	7	8	9	10
	x (mm)	1.89	2.16	2.43	2.70
	x (°)	0.18	0.21	0.23	0.26

Line length was adapted to the typeface and size so that the same number of characters or words was displayed in each case. There were 48 participants, 24 were male and 24 female, aged 18 to 47, with an average of 23.74 years (±7.53); all participants had normal or corrected-to-normal vision. The participants were divided into 8 groups of 6 participants. The participants within a single group read the texts in the same sequence for both typefaces and in all font sizes. We used the so-called Latin square design to vary the display sequence in order to prevent the possible fatigue effect with texts displayed towards the end of the experiment.

2.3 Apparatus

To track the eye movement we used the Tobii X120 eye tracking device and the Tobii Studio 3.1.3 software. The eye tracker tracks the movement of the eye by following the reflection of the image from the cornea. This reflection is generated when the infrared illuminators at the front side of the eye tracker create patterns of light reflecting from the cornea. Eye tracker contains an infrared-sensitive camera that tracks the individual’s eye movements and fixations. Prior to the measurement, each individual adapted to the lighting conditions of the room for 5 minutes and then underwent a 9-point screen-based calibration. We measured the total reading time of each text by each individual. The texts were ranked according to the average reading speed. We selected 8 texts from the middle of the ranking list (with ranks 22 to 29) to be used in the main study.

3. RESULTS

In presenting the results we have focused on the *reading time, reading speed, saccade length, number of fixation and fixation duration.*

3.1 Reading

The reading time in seconds decreased with the increase of font size (Figure 1). For both typefaces, the readers needed 27.75 seconds for 500 letter characters at 12 px and 26.17 seconds at 18 px. On average, the Verdana typeface was read faster (26.55 s) than the Georgia typeface regardless of the type size (27.35 s). When predicting reading time, there were statistically significant main effects for typeface ($F(1.47) = 11.836$, $p < 0.001$, partial $\eta^2 = 0.14$, $1–\beta = 0.759$) and type size ($F(2.240, 105.286) = 7.369$, $p < 0.001$, partial $\eta^2 = 0.13$, $1–\beta = 0.951$)). The average reading time was longer for Georgia ($M = 27.36$, $SD = 0.76$) than for Verdana ($M = 26.55$, SD = 0.83). The average reading time also decreased with increasing type sizes. The interaction between the typeface and the type size was not statistically significant ($F(1, 41) = 0.323$, $p = 0.808$, partial $\eta^2 = 0.01$, $1–\beta = 0.112$).

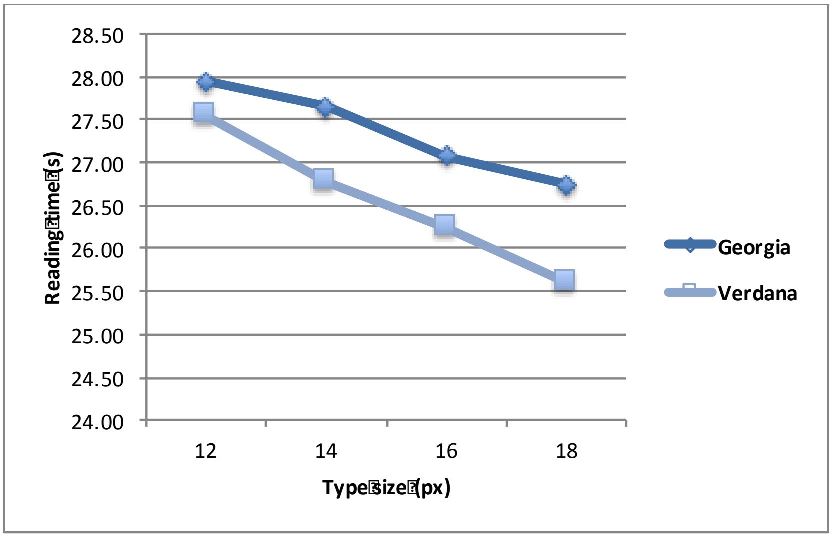

Figure 1: The reading time for individual typeface and size in seconds

Figure 2 shows the number of characters read per second. We can see that the number of characters increases with increasing the type size. For both typefaces, the average number of characters read at 12 px was 18.89, while the average number of characters at 18 px was 20.21. More characters were read on average for all type sizes in the Verdana typeface (19.92) than in the Georgia typeface (19.17). For both typefaces and all type sizes, the average number of letter characters read was 19.54. When predicting reading speed (character in seconds), there were statistically significant main effects for typeface ($F(1.47) = 7.388$, $p < 0.01$, partial $\eta^2 = 0.20$, $1–\beta = 0.921$) and type size ($F(3, 45) = 9.723$, $p < 0.001$, partial $\eta^2 = 0.39$, $1–\beta = 0.996$)). The average reading speed was longer for Verdana ($M = 19.92$, $SD = 0.61$) than for Georgia ($M = 19.17$, $SD = 0.61$). The average reading speed also increased with increasing type sizes. The interaction between the typeface and the type size was not statistically significant ($F(1, 45) = 0.653$, $p = 0.585$, partial $\eta^2 = 0.04$, $1–\beta = 0.176$).

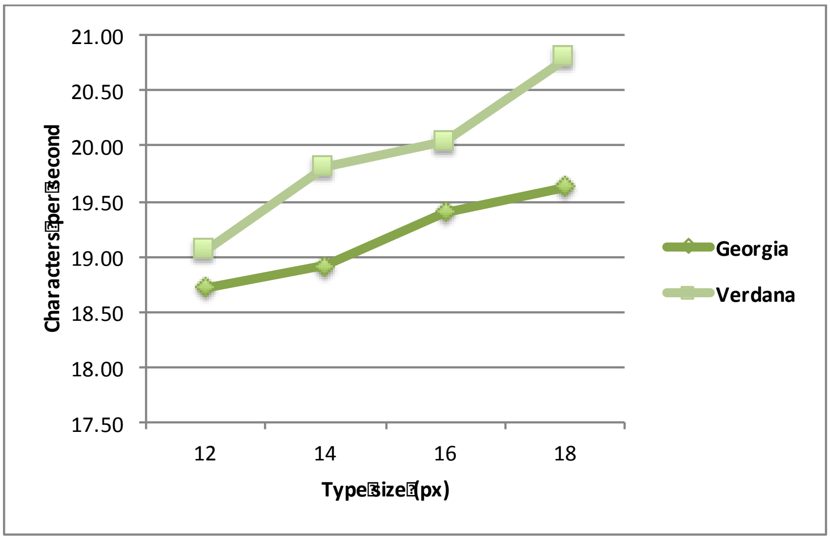

Figure 2: The reading speed for individual typeface and size (characters per second)

3.2 Saccade length

Figure 3 shows the saccade length for both typefaces. The number of characters per saccade decreased with the font size. For both typefaces, the saccade length was 8.10 characters at 12 px and 6.13 characters at 18 px. For the Georgia typeface, the average saccade length was 7.46 characters and for the Verdana typeface the average saccade length was 6.60 characters. When predicting saccade length there was a statistically significant interaction between the typeface and the type size, $F(2.586, 121.540) = 7.056$, $p <$

0.001, partial $\eta^2 = 0.13$, $1-\beta = 0.965$. The length of saccades decreased with increasing type size (Figure 3), $F(1.737, 81.623) = 120.660$, $p < 0.001$, $MSE = 130.176$, partial $\eta^2 = 0.72$, $1-\beta = 1.000$. The average length of saccade in characters was longer for Georgia ($M = 7.46$, $SD = 0.13$) than for Verdana ($M = 6.60$, $SD = 0.12$), $F(1.47) = 72.18$, $p < 0.001$, $MSE = 71.605$, partial $\eta^2 = 0.61$, $1-\beta = 1.000$. The possible reason for this difference is that Georgia has narrower characters shape than Verdana and thus more characters can be acquired and processed within a single fixation.

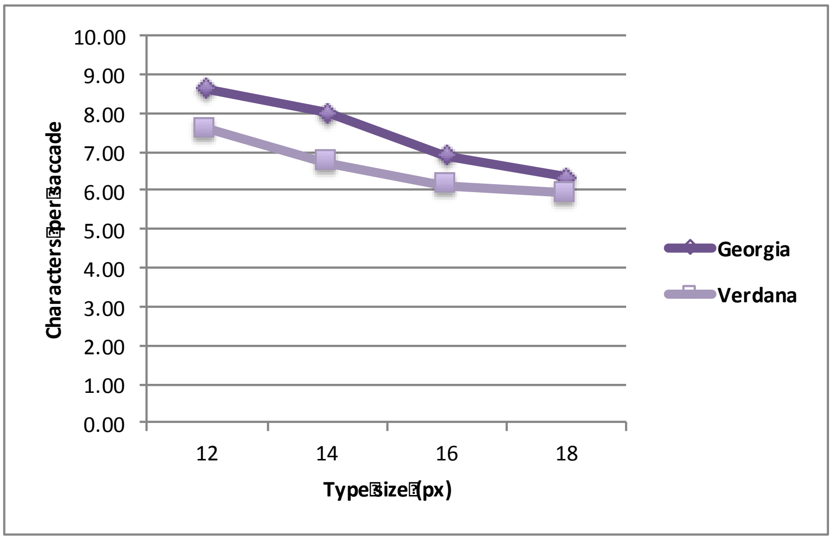

Figure 3: The saccade length for individual typeface and size (characters per saccade)

3.3 Fixations

Figure 4 shows the number of fixations for both typefaces. The number of fixations increased with increasing the font size. For both typefaces, the average number of fixations was 64 at 12 px and 84 at 18 px. For all font sizes, the number of fixations was greater for the Verdana typeface (80) than for the Georgia typeface (70). When predicting number of fixations, there were statistically significant main effects for typeface ($F(1.47) = 79.619$, $p < 0.001$, partial $\eta^2 = 0.63$, $1-\beta = 1.000$) and type size ($F(2.004, 94.188) = 111.204$, $p < 0.001$, partial $\eta^2 = 0.70$, $1-\beta = 1.000$)). The average number of fixations was higher for Verdana ($M = 79.07$, $SD = 1.28$) than for Georgia ($M = 70.64$, $SD = 1.181$). The average number of fixations also increased with increasing type sizes. The interaction between the typeface and the font size was not statistically significant ($F(3, 41) = 1.956$, $p = 0.123$, partial $\eta^2 = 0.04$, $1-\beta = 0.496$).

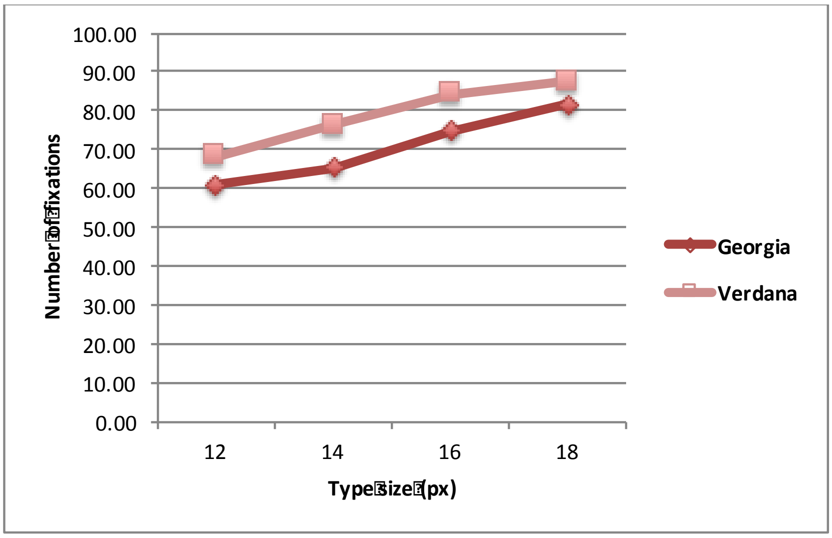

Figure 4. The number of fixations for individual typeface and size

Figure 5 shows the duration of fixation for both typefaces at all the sizes tested. For both typefaces, the average duration of an individual fixation was 442 ms at 12 px and 311 ms at 18 px. For all font sizes, the duration of fixations was 400 ms for the Georgia typeface, and somewhat shorter, 340 ms, for the Verdana typeface. While predicting fixation duration (measured in milliseconds) there was a statistically significant interaction between the typeface and the type size, $F(2.430, 114.221) = 5.784$, $p < 0.001$, $MSE = 12221.793$, partial $\eta^2 = 0.11$, $1–\beta = 0.906$. The difference between the two typefaces was relatively large for small type sizes, but it decreased with the increase in type size (Figure 5). The average fixation duration decreased with increasing type size, $F(1.566, 73.587) = 114.658$, $p < 0.001$, $MSE = 626848.817$, partial $\eta^2 = 0.71$, $1–\beta = 1.000$. The average fixation duration was longer for Georgia ($M = 400.59$, $SD = 13.64$) than for Verdana ($M = 340.69$, $SD = 9.31$), $F(1.47) = 94.028$, $p < 0.001$, $MSE = 344460.940$, partial $\eta^2 = 0.67$, $1–\beta = 1.000$.

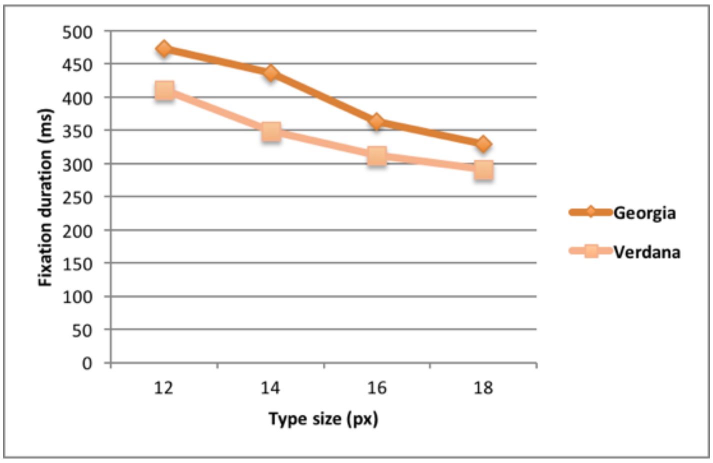

Figure 5. The fixation duration for individual typeface and size (fixation time in milliseconds)

4. DISCUSSION

The results of our study show that the reading speed and consequently the legibility of the text shown on LCD screen depends on the typeface and type size. We expected the Verdana typeface to be read more slowly because of the wider typeface design which results in longer words and lines. However, the lines in the Verdana typeface were read faster than in the Georgia typeface. The faster reading speed of the Verdana typeface is probably partly due to its increased x-high which contributes to a better recognition, and results in faster processing. Similar results were obtained in Ferrari study (Ferrari et al., 2008), where seven different typefaces, including Georgia and Verdana, were measured at 12 type size and leading at 17 pt. The Verdana typeface was read the fastest of all the typefaces. Furthermore, the results of our study are in line with Beymer et al. (2008) analysis of reading, which was based on Helvetica and Georgia at 10, 12 and 14 px. Their findings also reveal that the reading speed increases with increasing the font size. The reading speed also increased due to the faster processing of individual fixations. Similarly, the results of a study focusing on Georgia and Verdana at 16, 17, 19, 20, 21, 24, 26 and 32 px showed that Verdana was read the fastest and that the reading speed increased with increasing the font size (Franken et al., 2015). The study carried out by Bernard et al. (2003) was based on four serif typefaces (Century Schoolbook, Courier New, Georgia New, Times New Roman) and four linear typefaces (Arial, Comic Sans, Tahoma, Verdana). All the typefaces were displayed at 10, 12 and 14 px on a 17-inch CRT screen. No eye-tracker was used in the study. The results revealed that the Verdana typeface was read faster than the Georgia typeface at all font sizes. Both typefaces were read the fastest at 12 px and the slowest at 10 px, while medium speed was used at 14 px. A study comparing reading from different types of screens (Siegenthaler et al., 2012) established that the average reading speed was 18.31 characters per second, which is comparable to our results (19.54). We also expected that the choice of a bigger type size and consequently longer lines would slow the reading process because of a greater number of fixations. The number of fixations increased with increasing the type size, but the duration of fixations was considerably shorter, and as a consequence, the reading time was shorter as well, in spite of the greater number of fixations. Choosing a bigger type size results in better recognition and leads to a faster processing and, ultimately, a greater reading speed. The length of the lines and the longer eye movement patterns thus has no impact on the reading speed at the sizes measured.

5. CONCLUSIONS

The results of our study showed that increasing the type size on an LCD screen leads to a faster reading speed in spite of the greater number of fixations. This means that larger type sizes contribute to a faster recognition and faster processing. By comparing the Georgia and Verdana typefaces, we established that the latter was read faster. The thickness of character strokes does not vary in Verdana as it does in Georgia, but Verdana has a slightly higher x-high and wider characters with wider character spacing, which contributes to its legibility. And it is the legibility in particular that contributes to the faster information processing when reading from a screen. To retrieve and process the information that we read on LCD screen on a daily basis as fast as possible, choosing the right typeface and type size is essential. When reading from LCD screen it is also crucial to set the right type size to read as comfortably as possible. It is recommendable to use typefaces that are easy-to-read and suitable sizes above all in situations where there is a time limit for information capture, e.g., various types of displays and user interfaces.

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Original scientific paper

TESTING MAGAZINE DESIGN WITH EYE-TRACKING TECHNOLOGY

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Abstract: *The eye-tracking technology has widely spread in the last decade. The results showing how people observe and comprehend the presented content help us understand the market and properly adjust products to consumers. Furthermore, the ecological validity plays an important part when discovering the market. On-screen verification on how a certain magazine design affects consumers results in lower costs and more importantly, in smaller environmental pollution. If appropriate experiments are undertaken in advance, the final product can be more carefully designed. For this reason, we researched the Slovenian tabloid magazine design. Four different, most popular, magazines were selected in the experiment conducted with the eye-tracking device TOBII X120. The testing was divided into eight parts and included the cover page, a short and long text, the change of page order, an advertisement, a positive and negative colour combination, linear and serif typefaces, the position of the advertisement, and the layout order (changing the order of pictures in combination with the text). Apart from the results presented in the form of heat-maps, Q/A were also a part of the experiment. A question with multiple answers followed each presented scene. The participants were able to choose one out of four answers. In the research, the time limitation was set in each part of the experiment. The participants had to focus on each presented scene while the questions were closely connected to the presented content. The presentation times were short and we were able to obtain results that show how layout, typeface use, position of titles and/or text, colour combination etc. draw attention and affect the recall of presented content. Since the eye-tracking device was used for measuring, a strong connection between the answers and eye movements can be observed. It is noticeable that a higher number of fixations in many cases results in more accurate answers; however, this is not the rule.*

Keywords: advertisement, design, eye-tracking, magazine

1. INTRODUCTION

The majority (i.e. 80%) of all information is obtained through visual perception. When the light from a specific object reaches the retina in the eye, it triggers neural responses that are converted into pulses and travel to different parts of the brain, where they form a visual experience and identify objects. The neurophysiological principle of data breakdowns runs from the retina to the cortex. In the parallel subsystems of vision, different parts of the image information are processed, e.g. shape, movement, colour and depth. The psychological principle of data processing is a visible synthesis. In the synthesis, brains connect individual characteristics of an image into a comprehensive picture. Even the words we see or read are the stimuli that are processed by the primary visual cortex. This is a part of the network for the identification in the brain, where most of the visual information arrives (Carrasco et al., 2004; Legge & Bigelow, 2011; Rudnicky & Kolers, 1984).

When designing a magazine, all elements should be treated equally as an appropriate connection among them will results in better perception, effectiveness and quality of communication. With the help of designing principles, relations, compliances and contrasts, an attractive product can be achieved. A successful graphic design is assessed by how quickly and easily a piece of information gets to the reader (Bringhurst, 2004; Pastoor, 1990; Reynolds, 1988).

Photos and pictures have been in use for different reasons. In the case of magazines and newspapers, pictures perform a supporting role since they are a part of the design, making the content more attractive. With a good design, typefaces and pictures can form a perfect combination for comfortable reading; the picture captures the reader while the text communicates the essential information. Most multilateral publications with a great amount of text consist of at least a couple of pictures which are included at the beginning of or within a text (Baetens, 2008; Leckner, 2012).

The fusion of the text, pictures, colour combinations and layout elements was checked with the help of an eye-tracking device TOBII X120. The device allows testing of different stimuli while watching TV or other screens, projection screen, a physical object or scene. Tobii X120 allows binocular tracking, which means that it follows the view of both eyes at the same time and automatically determines the left eye from the right one, irrespective of the position of the head or squinting. This allows for greater deviation during the testing, while the device works perfectly despite a short loss of connection between the device and one or another eye (Josephson, 2003; *Tobii*, 2016).

2. METHODS

The measurements took place in the room specially prepared for eye-tracking measurements. The colour of the walls was neutral grey (RAL 7037). The ISO 3664 standard determines that the surrounding area should be in neutral colour with the maximum reflectivity of 60% (*ISO* 3664:*2009*; White, 1996).
30 participants were involved in the testing, namely 22 female and 8 male. They were divided into two groups, each taking up different tests. Each group comprised of 11 female and 4 male participants. They were divided into the following age groups: 18–20, 21–23, 24–26, 27–29 and over 29 years old. 60% fitted into the age group between 21 and 23 years. Since the testing was broad-based, the participants were students, employees and other randomly selected people. Most participants had normal vision but some used prescription glasses or lenses.
The testing was divided into two parts; hence, the accustomisation of participants was not possible. Each participant performed tests with the elements differently distributed on a page. The testing involved the Slovenian magazines *Nova*, *Suzy*, *Zvezde* and *Lea*, which were published in the same week. After each test, a question about the displayed content followed. The questions served as a control of participants, whether they were focused and attentive in each experiment. The main goal was to see if there are any differences in fixation times in the area of interests (AOI) if we change colours (positive with inverse or vice versa). Furthermore, we were interested in the typeface selection. In two articles of different line length, the typeface style was changed and a comparison of reading time was made. Another observation connected to typefaces was the change from upper to lower case and vice versa. Of our interest were also the advertisements included in the magazines, how well they can be observed if the position is changed and if they are presented in different time intervals.

2.1 Covers

The first comparison was used to determine if different colours and colour combinations affect perception. 15 participants were observing cover pages in the original (positive) design while other 15 participants observed the same cover pages in an inverse colour combination of popular tabloid magazines. In both groups, the presenting interval was 15 s. Our interest was in the time required for the first fixation, in the average and total number of fixations and the average number of all fixations. Moreover, we wanted to find out where the first fixation would take place, which the first three and the last two most common fixations would be and in which part of the cover page they would take place.

2.2 Reading

We took the introductory text from the magazine *Zvezde*, which was written in lower case letters. The text involved 360 letters with spaces, extending in 9.5 lines. On average, each line consisted of 37.9 letters. The changed introductory text consisted of 10 lines with 36 letters per line and was aligned to the left. We focused on the reading speed, namely which of the two texts would be read faster (the original or the modified one).
A similar procedure was with the magazine *Suzy*. The difference was that in this case, the introductory text was in upper case letters. The text consisted of 278 letters with spaces and was set in 3.5 lines. The changed text had the same number of letters with spaces but was set in 2.5 lines and was written in lower case letters. The text was justified. We wanted to know which introductory text would be read faster.
The type style was changed in the article taken from the magazine *Zvezde*. The original article was set in a serif typeface but we changed it into a linear typeface. The typeface size and style remained the same. Our question was which of the two articles would be read faster. Both consisted of 643 letters with spaces. When the serif typeface was used, the text was extending in 19.5 lines, i.e. 32.2 letters with spaces per line on average. When the linear typeface was used, the number of lines decreased to 18.25, whereas the number of letters with spaces per line increased to 33.8.
Furthermore, the type style was changed in the article from the magazine *Lea*. The original article was set in the linear typeface with extra bold but narrowed letters (Figure 5a). The type style was changed to regular and consisted serifs (Figure 5b). The typeface size remained the same. The article consisted of 734

letters with spaces which gave 56.5 letters with spaces per line. We wanted to know which group of participants would read the text more quickly and by how much.

2.3 Advertisements

Two pages taken from the magazine *Lea* were presented to participants. One page contained a full-page advertisement while the other contained articles. The advertisement was for the first group on the left page of the spread sheet and for the second group on the right page of the spread sheet. The time limitation for observing pages in either arrangement was 2 s. AOI was set only on the page where the advertisement was placed. The first question was whether the participant recalled where the advertisement was positioned. The second question was if participants' attention would be higher for the advertisement or the articles. The verification refers in this case to the details of the advertisement in the magazine *Nova*. The procedure was the same as in the previous example, the only difference being in the time interval which was set to 10 s. Our concern was if the left or right page of the spread sheet is more appropriate for advertisements or articles. Based on the set AOI, the number of fixations and time from the beginning of the experiment to the first fixation, we wanted to establish where a more suitable place for an advertisement is and where other content should be placed (i.e. articles, pictures etc).

2.4 Interview

A longer interview was taken from the magazine *Suzy*. The spread sheet was composed of an interview on one and a picture on the other page. Our interest was in the visibility of the headline of the interview. Which page (left or right) would help the headline to be more noticeable. The presenting time was 2 s and after that, the question followed where the headline was placed. The page with an interview was taken from the magazine *Nova*. The participants of group 2 were observing a double page spread sheet with the headline on the left side. The participants of group 1 were observing the same double page spread sheet interview; the difference was in the text/picture position. The headline was in this case on the right side of the spread sheet. The observing time was set to 10 s and after that, the question followed about the number of pictures.

3. RESULTS AND DISCUSSION

The results of individual observed variables will be analysed and commented upon in the same order as in the testing.

3.1 Covers

The magazine *Nova* (Figure 1) uses in addition to black and white colour also yellow and red colour. After the change into an inverse colour combination, red became light blue (turquoise) and yellow changed into dark blue. More than 66% of participants fixated their eyes on the picture of a man (i.e. Bine Volčič) which is positioned on the left middle side of the magazine cover page (Figure 1a). 40% of all participants fixated their eyes on the logo *Nova* and 60% on the logo together with the article above it. The penultimate fixation for less than a quarter of participants was the left upper corner of the cover page, for another quarter the right middle spot of the cover page and for the rest two quarters, the bottom centre of the cover page.
In the first half of the second, the most attention was in the left upper position of the cover page where the logo and a picture of a man (i.e. Bine Volčič) was placed, followed by the right bottom spot of the cover page where the biggest or main headline is. When controlling the inverse colour combination, the first fixation for more than 70% of participants was on the left middle spot, where the picture, and name and surname Bine Volčič is placed (Figure 1b). The second fixation for 60% of participants was on the picture in the middle of the cover page (Melanija Trump). 93% of all fixations (1st, 2nd, 3rd) was on the picture in the centre of the cover page (Melanija Trump). The last fixation with most of the participants was on the main or the largest headline. The last fixation for the majority of participants was on the bottom third of the cover page. The logo was not in great interest of the participants.

a) b)

Figure 1: Cover of magazine Nova in original (a) and inverse colour combination (b)

The main colours in the magazine *Suzy* (Figure 2) are black, white, yellow, magenta and cyan. When changed into inverse colour combinations, yellow became dark blue, magenta became green and cyan changed into orange. The first fixation of more than 50% of participants was on the logo or close to it (Figure 2a). The second and third most common fixations were in the centre of the cover page where the word »ekskluzivno« (Eng. *exclusively*) is placed and little to the right of it where the picture of a woman (i.e. Tanja Ribič) is. The last fixation was in most cases in the left upper spot of the cover page. The results of the inverse cover page (Figure 2b) show that the first fixation for more than 50% of participants was on the logo or in its proximity. Apart from the logo, the most common fixation spot was on the largest headline and the biggest picture (woman positioned slightly right from centre). The three most common fixations on the cover page were in the centre. The last fixations were in the upper left corner of the cover page.

a) b)

Figure 2: Cover of magazine Suzy in original (a) and inverse colour combination (b)

The magazine *Zvezde* (Figure 3) uses black, white, purple and yellow colour. When converted into inverse colours, yellow became dark blue and purple became green. In 65%, the first three fixations were on the biggest picture, i.e. the hugging couple (middle of the cover page) and on the biggest headline, which is in the centre bottom position of the page (Figure 3a). 50% of participants fixated their eyes on the picture of a man (i.e. Peter Prevc) which is on the left, slightly upper side of the cover page. The first fixation was in 66.7% in the centre of the cover page. The last fixation of a half of participants was in the bottom of the cover page.

At the inverse colour combination, the first three fixations for 80% of participants were on the largest picture (hugging couple) in the centre, on the logo and on a man (i.e. Peter Prevc) on the left side of the cover page (Figure 3b). The most common fixation was on the logo. The last fixation was in most cases captured in the bottom of the cover page.

a) b)

Figure 3: Cover of magazine Zvezde in original (a) and inverse colour combination (b)

The black, white, purple-blue, red and yellow colours are the main colours of the magazine *Lea* (Figure 4). The variation in an inverse combination gave the following changes: purple-blue into ochre-green, red into green and yellow into blue. The most frequently fixated part in the first three fixations was the face of the woman in the centre of the cover page (Figure 4a), followed by the title below the face (65%) and the third most commonly fixated object was the picture below the headline *Lea*. All three first fixations were in the upper half of the cover page. The most common penultimate fixations were in the bottom third and left side of the cover page. The last fixations were mainly focused on the news, which were placed to the left side of the cover page (80% of participants).
The first three fixations for more than 70% of participants were the same in inverse as in positive colour combination, i.e. on the woman in the upper centre of the cover page (Figure 4b). 60% of participants fixated on the logo. All first fixations were in the upper two thirds of the cover page. 80% of the last fixations were in the bottom half of the cover page.

a) b)

Figure 4: Cover of magazine Lea in original (a) and inverse colour combination (b)

Table 1 shows that the highest number of fixations was at the magazine *Nova*, regardless of the positive (675) or inverse (630) colour combination. The smallest fixation number in both versions was at the magazine *Zvezde* (550 fixations in positive and 607 fixations in inverse colour combination). The highest average fixation duration was in the positive (original) colour combination at the magazine *Zvezde* (0.30 s). In other cases, the fixation duration was the same (0.28 s). The magazines *Lea* (0.34 s) and *Suzy* (0.26 s) recorded the highest average fixation duration.

Table 1: Comparison of results for all magazines in positive and inverse colour combination for group 1 and group 2

Magazine	*Nova*		*Suzy*		*Lea*		*Zvezde*	
Version	Orig.	Inv.	Orig.	Inv.	Orig.	Inv.	Orig.	Inv.
Number of all fixations	675	630	606	617	602	629	550	607
Average number of fixations	45.00	42.00	40.40	41.13	40.13	41.93	36.67	40.47
Average duration of all fixations [s]	0.28	0.30	0.28	0.26	0.28	0.34	0.30	0.33

3.2 Reading

Table 2 contains the data based on which it is clear that the participants from group 1, who were reading the text in upper case letters needed more time (15.13 s) compared to group 2, where the text was set in lower case letters (14.67 s). While the text in lower case letters was shorter compared to the one in upper case letters for a half of a line, we decided to make the calculation which was based on one letter and one word. The letters and words from one line were taken into account. Accordingly, we calculated that the participants needed to read a separate letter in upper case style by 2.43% more time as for lower case style and that the time needed to read a word in upper compared to lower case style was by 1.63% longer. The average number of letters per line was in the lower case style by 4.34% higher than in the upper case style.

Table 2: Reading time comparison for introductory text for group 1 (upper case) and 2 (lower case) in magazine Zvezde

Readers	Introductory text in upper case letters	Introductory text in lower case letters
	Reading time of group 1 [s]	Reading time of group 2 [s]
1	16.87	15.91
2	14.71	18.82
3	14.25	10.19
4	17.56	18.18
5	21.20	19.03
6	15.28	15.29
7	15.48	11.21
8	14.16	14.35
9	12.90	16.76
10	16.37	10.83
11	15.80	11.27
12	10.97	13.57
13	11.16	15.30
Average	15.13	14.67

The average reading time of the introductory text is presented in Table 3. The participants of group 1 who were reading the text in lower case letters needed 11.03 s. Group 2, who read the text in upper case letters, needed 12.35 s. The reading was faster by 1.32% when the text was presented in lower case letters. Since the line length between the lower and upper case letters was not the same, we decided to make a calculation which is based on one letter and one word. The participants needed by 6.98% more time to read each upper case letter compared to lower case letters and consequently by 3.10% more time to read a word in upper compared to lower case letters. The average number of letters per line was in the case of lower case letters by 24.89% higher.

Table 3: Reading time comparison for introductory text for group 1 (upper case) and 2 (lower case) in magazine Suzy

Readers	**Introductory text in lower case letters**	**Introductory text in upper case letters**
	Reading time of group 1 [s]	**Reading time of group 2 [s]**
1	12.92	11.55
2	11.10	15.90
3	9.51	13.05
4	12.62	13.59
5	9.73	11.42
6	10.04	11.80
7	13.19	12.06
8	12.31	12.21
9	10.25	11.56
10	9.92	12.22
11	9.72	10.52
Average	11.03	12.35

The article where the linear typeface was used was read in the average time of 26.79 s, while the article with the serif typeface in 26.72 s (Table 4). The difference is small (0.07 s or 0.26%). If the average reading time of group 1 is divided with the number of lines, the data show that the participants read one line in the average time of 1.47 s. At group 2, the time was 1.37 s per line. The difference in the average reading time is small, i.e. 0.10 s. If the reading time of one line of group 1 is multiplied with the number of lines of group 2, the result shows that group 1 would have read the same amount of text as group 2 in 28.67 s. This means that the same amount of text would have been read more slowly by 1.95 s (6.81%).

Table 4: Reading time comparison for article in linear (group 1) and serif (group 2) typeface in magazine Zvezde

Readers	Article in linear typeface	Article in serif typeface
	Reading time of group 1 [s]	Reading time of group 2 [s]
1	37.58	23.24
2	26.95	25.95
3	21.45	30.86
4	31.21	28.28
5	24.85	24.24
6	22.64	25.73
7	24.89	21.57
8	23.88	33.55
9	19.57	29.90
10	31.40	26.53
11	26.10	26.40
12	33.98	26.20
13	23.83	24.95
Average	26.79	26.72

The participants of group 1, who were reading the article in the serif typeface (Table 5, Figure 5b) needed on average 23.75 s. The participants of group 2, who were reading the article in the linear typeface (Figure 5a) needed on average 26.14 s. The difference is 2.39 s or 9.14%. The text in the serif typeface was read faster compared to the one in the linear typeface.


Simpatična ameriška igralka, ki je zaslovela z vlogo v priljubljeni seriji Razočarane gospodinje Eva Longoria, je prejšnji teden doživela prav posebno izkušnjo. Med obiskom Mehike, v kateri se je udeležila številnih dogodkov in prireditev, je s svojo ekipo namreč obtičala v dvigalu hotela. Kot je povedala na svojem družabnem omrežju Snapchat, so bili v dvigalu ujeti približno 30 minut, vendar pa je ta čas, zaradi njene bojazni pred zaprtimi prostori, mineval zelo počasi. "Po tem, ko smo v dvigalu pritisnili prav na vse gumbe, kar smo jih našli, smo opazili obvestilo, na katerem je pisalo, da v primeru ustavljenega dvigala ne smeš pritiskati gumbov. No, kot da bi pomagalo," je še povedala Eva, ki v Mehiki preživi veliko časa.

a)

Simpatična ameriška igralka, ki je zaslovela z vlogo v priljubljeni seriji Razočarane gospodinje Eva Longoria, je prejšnji teden doživela prav posebno izkušnjo. Med obiskom Mehike, v kateri se je udeležila številnih dogodkov in prireditev, je s svojo ekipo namreč obtičala v dvigalu hotela. Kot je povedala na svojem družabnem omrežju Snapchat, so bili v dvigalu ujeti približno 30 minut, vendar pa je ta čas, zaradi njene bojazni pred zaprtimi prostori, mineval zelo počasi. "Po tem, ko smo v dvigalu pritisnili prav na vse gumbe, kar smo jih našli, smo opazili obvestilo, na katerem je pisalo, da v primeru ustavljenega dvigala ne smeš pritiskati gumbov. No, kot da bi pomagalo," je še povedala Eva, ki v Mehiki preživi veliko časa.

b)

Figure 5: Article in magazine Lea in original (a) and amended typeface (b)

Table 5: Reading time comparison for article in serif (group 1) and linear (group 2) typeface in magazine Lea

Readers	Article in serif typeface	Article in linear typeface
	Reading time of group 1 [s]	Reading time of group 2 [s]
1	14.83	15.66
2	34.37	33.68
3	25.49	19.42
4	20.12	31.83
5	25.86	30.90
6	26.78	27.00
7	23.77	30.18
8	25.03	18.94
9	21.91	31.83
10	21.72	28.33
11	22.44	28.34
12	28.09	24.14
13	15.74	22.16
14	27.55	27.21
15	22.54	22.42
Average	23.75	26.14

3.3 Advertisements

When AOI was part of the test, we can see (Table 6) that 13 participants of group 1 and less than a half of participants from group 2 fixated their eyes on the set area. The average number of preliminary fixations was smaller in group 1 (on average 0.5 or 62.65%). The time to the first fixation on the advertisement was in group 1 (0.21 s) by more than a half shorter compared to group 2 (0.44 s) where the advertisement was positioned on the right side of the spread sheet. The total number of fixations in AOI was higher for group 1 (67) compared to group 2 (12). The average number of all fixations for group 1 was higher compared to group 2.

Table 6: Comparison of fixations for group 1 and 2 where the whole advertisement was included in AOI for 2 s

AOI: whole page including advertisement	Group 1	Group 2
Advertisement position	left	right
Number of persons from total number of testees (15) who stopped in AOI	13	6
Preliminary fixations (total)	5	5
Preliminary fixations (average)	0.31	0.83
Time to first fixation [s]	0.21	0.44
Number of all fixations (total)	67	12
Number of all fixations (average)	5.43	2.00

Heat maps (Figure 6) present that more fixations were made on the advertisement when it was positioned on the left side of the spread sheet.

Figure 6: Heat maps of fixations for group 1 (left) and group 2 (right) in 2 s interval

Table 7 shows that group 2 (advertisement was on the left side of the spread sheet) needed on average 0.40 s to the first fixation in AOI while group 1 (advertisement was on the right side of the spread sheet) needed on average 2.33 s to the first fixation in AOI. The difference is 1.93 s, which represents 82.80% more time to the first fixation in AOI between the groups.
Attention to the advertisement on the left side of the spread sheet was higher considering the number of fixations. For the left side, the number was 16.27 and for the right side 13.80. There were by 2.47 fewer fixations for the right side, i.e. 15.18%.

Table 7: Comparison of fixations for group 1 and 2 where whole advertisement was included in AOI for 10 s

AOI: whole page including advertisement	Group 1	Group 2
Advertisement position	right	left
Preliminary fixations (total)	35	6
Preliminary fixations (average)	2.33	0.40
Time to first fixation [s]	0.72	0.32
Number of all fixations (total)	207	244
Number of all fixations (average)	13.80	16.27

We changed the position of the advertisement for both groups. Table 8 shows that group 1 made fewer fixations on the advertisement when it was positioned on the right side of the spread sheet while the number of fixations for group 2 was higher for the advertisement on the left side of the spread sheet. Group 1 made 110 fixations before AOI, while group 2 made 55 fixations. On average, the participants of group 1 made by 3.02 more preliminary fixations, which represents 19.22%. The time to the first fixation in AOI was in group 1 by 0.71 s longer compared to group 2. Group 2, which was observing the advertisement on the left side of the spread sheet needed on average by 16.27% more fixations than group 1.

Table 8: Comparison of fixations for group 1 and 2 where whole advertisement was included in AOI for 10 s

AOI: area of nail polish	Group 1	Group 2
Advertisement position	left	right
Number of persons from total number of testees (15) who stopped in AOI	7	12
Preliminary fixations (total)	110	165
Preliminary fixations (average)	15.71	12.69
Time to first fixation [s]	4.49	3.78
Number of all fixations (total)	22	45
Number of all fixations (average)	3.14	3.75

A comparison of heat maps for the advertisement on the left and right side of the spread sheet (Figure 7) points out to differences. The difference is even more evident when comparing the heat maps in the area of detail, which was the subject of interest. More attention was given to the advertisement by group 2 when it was placed to the left side of the spread sheet. Moreover, more attention was noticed in the part the advertisement for a nail polish.

Figure 7: Heat maps of fixations for group 2 (left) and 1 (right) where advertisement was included in AOI for 10 s

3.4 Interview

In this part of the research, we tested how well the participants noticed the interview headline. Table 9 shows that the participants of group 1 (headline was on the right side) made 8 out of 15 first fixations on it. At group 2 (headline was on the left side), 7 out of 15 participants made the first fixation on the headline. There were by 31.38% fewer fixations made by group 2 compared to group 1. The time to the first fixation in AOI was by 0.2 s shorter for group 2 compared to group 1 (i.e. 4.55%). The average number of all fixations in the area of headline (group 2) was 5.29 or by 38.56% more compared to group 1, where the number of fixations was 3.25.

Table 9: Comparison of fixations for group 1 and 2 where headline was included in AOI for 2 s

AOI: headline	Group 1	Group 2
Headline position	left	right
Number of persons from total number of testees (15) who stopped in AOI	8	7
Preliminary fixations (total)	15	9
Preliminary fixations (average)	1.88	1.29
Time to first fixation [s]	0.44	0.42
Number of all fixations (total)	26	37
Number of all fixations (average)	3.25	5.29

The data in Table 10 show that the average number of preliminary fixations for group 2 is 2.45. Group 1 had by 0.85 fewer average preliminary fixations, which represents 34.69%. The time to the first fixation at group 1 was 0.48 s and 0.76 s at group 2. The difference between the groups is by 0.28 s and means that the participants of group 1 needed by 36.84% less time for the first fixation compared to group 2. The average number of all fixations in AOI was by 11.63% lower compared to group 1.

Table 10: Comparison of fixations for group 1 and 2 where full-page picture was included in AOI for 2 s

AOI: full-page picture	Group 1	Group 2
Picture position	right	left
Number of persons from total number of testees (15) who stopped in AOI	15	11
Preliminary fixations (total)	24	27
Preliminary fixations (average)	1.9	2.45
Time to first fixation [s]	0.48	0.76
Number of all fixations (total)	71	46
Number of all fixations (average)	4.73	4.18

A comparison of heat maps between groups (Figure 8) shows that there was a greater interest on the full-page picture when it was positioned on the left side of the spread sheet.

Figure 8: Heat maps of fixations for group 2 (left) and 1 (right) at magazine Suzy

Table 11 shows that group 2 (headline was positioned on the left side of the spread sheet) did not make any preliminary fixations. On average, the participants of group 1 made 1.8 fixations before AOI (in the case of group 1, headline was positioned on the right side of the spread sheet). The time to the first fixation in

AOI for group 1 was by 0.48 s shorter compared to group 2, i.e. 85.71%. The participants of group 2 made 9 fixations more compared to group 1, which amounts to 2.98% fewer fixations when comparing the groups.

Table 11: Comparison of fixations for group 1 and 2 where full-page advertisement was included in AOI for 10 s

AOI: whole page including headline	Group 1	Group 2
Headline position	right	left
Preliminary fixations (total)	27	0
Preliminary fixations (average)	1.8	0
Time to first fixation [s]	0.56	0.08
Number of all fixations (total)	293	302
Number of all fixations (average)	19.53	20.13

The difference between the fixations for both groups when the headline was included in AOI was only in one fixation (2.58% fewer preliminary fixations for group 2 compared to group 1). The time to the first fixation was by 0.07 s longer for group 1 compared to group 2 (i.e. 10.45%). The participants of group 1 made a total of 33 fewer fixations, i.e. on average 2.20. This means that there were by 23.23% of all fixations more at group 2.

Table 12: Comparison of fixations for group 1 and 2 where headline was included in AOI for 10 s

AOI: headline	Group 1	Group 2
Headline position	right	left
Preliminary fixations (total)	35	34
Preliminary fixations (average)	2.33	2.27
Time to first fixation [s]	0.67	0.6
Number of all fixations (total)	109	142
Number of all fixations (average)	7.27	9.47

Based on the visual results obtained by the heat maps (Figure 9), it is noticeable that the number of fixations was higher at group 2. The reason for a smaller number of fixations at group 1 could be the inconsistency of spaced elements.

Figure 9: Heat maps of fixations for group 1 (left) and 2 (right) at magazine Nova

4. CONCLUSIONS

4.1 Covers

The magazines *Zvezde* and *Suzy* contain fewer pictures compared to the magazines *Nova* and *Lea*. It is therefore understandable that in the case of *Zvezde* and *Suzy*, more attention was on headlines and in *Nova* and *Lea*, on pictures. Shorter viewing patterns were observed only in the magazine *Lea*, i.e. the direction in which the testees followed the news on the sidelines. The magazine *Nova* had on general the highest number of fixations in both versions (positive and inverse), while the number of fixations at the magazine

Zvezde was the smallest. At three out of four magazines, the total number of fixations was higher in the inverse colour combination. The average number of fixations was higher at three out of four cover pages in the inverse colour combination. When comparing the logos, most participants made one of the first three fixations on the logo of the magazine *Suzy*, which could be due to the fact that this logo was the only one placed at a certain angle (all other logos were horizontally aligned).

4.2 Reading

When the introductory text was longer and placed in upper case letters (*Suzy*), we established that the reading time was by a tenth shorter as when the same text was presented in lower case letters. The introductory text with shorter lines (*Zvezde*) was read faster by only 3% when presented in lower compared to upper case letters. When the line lengths were shorter, the differences between upper and lower case letters were small. In the case of longer lines, the difference between lower and upper case letters increased. The reason could be found in the fact that in a shorter line, the eye has more time to refresh itself with an eye blink.
In the case of an original article (*Lea*) in the linear typeface where the used typeface is less readable and legible and the reading is impeded, we confirmed that the serif typeface turns out better. It would be interesting to find out what the difference is between a serif and a linear typeface when some other (more legible) linear typeface were in use. When comparing the linear and serif typeface at the magazine *Zvezde*, the results show that if a typeface style is changed, the serif typeface still remains advantageous (by little).

4.3 Advertisements

In the case of the advertisement which was present for 10 s, we noticed that the participants paid more attention to it when it was placed to the left side of the spread sheet. The advertisement consisted of one large picture advertising makeup and one small picture which was placed in the left corner of the page, and consisted of a woman's face and part of the body. When the content was on the right side of the spread sheet, more attention was drawn to the smaller picture which was closer to the middle of the spread sheet. This could be due to the brain function, since each time, the eyes were searching for an eye contact (irrespective if there is a live person or merely a picture of a person). The distribution would probably be different if a longer time interval for observation would be included; however, the fact remains that faces attract our attention faster and more intensely. At the advertisement, which was observed for 10 s, the results show that it attracted more attention when it was placed on the left side of the spread sheet. It would be reasonable to place more advertisements onto the left side of the spread sheet as our attention is higher in this part and the purpose of an advertisement is to be noticed. Nevertheless, noticing and recalling cannot be equated. In our example, the question was about the number of nail polishers. The participants recalled that there was a commercial for a nail polisher. Regarding the number of different nail polishers, more correct answers were obtained in the group that observed the advertisement on the right side of the spread sheet. Since the difference is just in one participant, that might be a coincidence. Similar results were obtained also in the case when the participants were asked about the position of the advertisement. When the advertisement was placed on the right side of the spread sheet, the participants gave more attention to the left side of the spread sheet. The reason could be found in the way we read (from the left to the right).

4.4 Interview

When checking the interview, which was presented for 10 s, the results show that more fixations were on the headline when it was placed to the left side of the spread sheet. Another finding was that there was less focus on the pictures if the headline and the pictures were presented in the right side of the spread sheet. The reason for this could be in the inconsistency of the layout (change of layout we are used to). During the experiment, one interview was observed for just 2 s. In this case, one page was occupied with a full-page picture. As in the previous case, we found out that more fixations were on the headline and pictures which were placed on the left side of the spread sheet. In both cases (10 or 2 s), we noticed that the participants needed an almost equal amount of time to make the first fixation on the headline. This could be due to the fact that almost every time, we first read the headline and only then decide if we are going to continue reading the article; if the content is not of our interest, we skip the reading.

We confirmed the predictions that the serif typeface is going to be slightly better accepted by the participants and that lower case letters are read faster. Another interesting observation was that the time to the first fixation in the case of headlines was equal regardless of its position (left or right side of the spread sheet). When the time was limited, the advertisement which was placed on the left side of the spread sheet drew more attention.

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IMPROVEMENT OF METHOD FOR USER EXPERIENCE EVALUATION

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Abstract: *If we want to have a positive user experience with some kind of product (media, devices...) basic human needs and emotions, should be satisfied. Nowadays, we are familiar with human basic needs, and there are different user experience evaluation methods. One of the these methods is the Valence method. The method consists of two phases, exploration phase and retrospective interview phase. In an exploration phase, the user, by pressing the green (for positive) or red (for negative) button, gives us information how he feels at that exact moment during the interaction with the product. In the second retrospective interview phase, each valence is discussed in order of finding a reason for this emotional state caused by the interaction with the product. Since the user is indirectly interrupted using buttons in the first phase the best thing would be to find another solution. Concretely the aim of this research was to find out, if we can replace the buttons with the FaceReader Noldus software for the automatic detection of facial expressions.*

Key words: User experience, Human basic needs and emotions, Valence method, FaceReader Noldus software

1. INTRODUCTION

The user experience is based on the subjective factors of the customer, which specifically refers to his personal experience and emotional reaction. Each designer's goal is to achieve positive user experience when interacting with their products. Aspects of the design of the product can be classified into the following:

1) presentation (eg, shape, form, color ...)
2) interactivity (eg, control and navigation interface)
3) functionality (eg, search, storage)
4) content (eg, text, video, photos, illustrations.).

For designer to optimize product design for the best user experience, it is important to understand which aspects of design can cause a positive or negative experience, and why. Today there are various methods by which would be possible to evaluate the effect of the product on the user, and one of them is a method of Valence. Through its two stages, research and retrospective interview, leads to detailed information about the user's experience when interacting with the product. The user, in relation to the current experience during interactions, pressed green (referring to positive emotion) or red (refers to negative emotion) button. In the next stage with the help of valence mark and interviews we learned how satisfied the user's basic needs during the interaction.
Since the use of valence in the first phase of Valence methods indirectly disturbs the user when interacting, through this research is trying to replace the use of the buttons with FaceReader Noldus program for automatic recognition of human facial expression and emotion (Noldus FaceReader, 2010); (Noldus Observer XT, 2010). In this case, to enable their smooth interaction with the product, in particular, in this case, the media. The study was conducted in three phases:

1. recording of respondents camera during video playback positive and negative content,
2. video processing of materials in FaceReader program,
3. processing of facial expression of respondents by people in order to test the credibility of FaceReader program in the method in which it is to be implemented.

Before the start of the research, it was necessary to explore the basics of human emotions and facial expressions caused by exactly certain emotions. It was necessary to educate respondents and make the best of facial expressions with which they personally identify emotional states during the interaction with the information media.

2. VALENCE METHOD

The Valence method is based on Marc Hassenzahl model (Hassenzahl, 2010) for user experience. He distinguished three types of goals: be-goals, do-goals, motor-goals. Be-goals are closely related to personal human motives, for example, when a user is bored and there is a need for stimulation. At the same time when the motive is obvious, do-goals are achieved and become an instrument for fulfilling motives, eg. If prompted, the user can open favorite pages to check whether certain new features are available. The engine-goals are necessary to accomplish do-goals, eg. A user opens a browser to get to his favorite portal. Be-goals can be identified with basic human needs. They are answers to questions about the reasons behind someone's behavior. There are a number of researchers who have made their theory of man's basic needs. Among them is Sheldon with his list: confidence, autonomy, competence, connection, satisfaction, physical fitness, personal understanding, safety, the influence and the need for luxury.

People have needs that are caused by experience. If the design of the product meets personal needs, the user will experience a positive user experience, and if not, the user will have a negative experience. This statement confirms the means-ends Guttman theory (Gutman, 1982), noting that aspects of the design of a product as a result may have a connection to the user's basic values. The user is at all times ready to report the quality of his feelings when interacting with the product (refer to the positive or negative sense). What is more difficult is to express is the meaning of these feelings and which basic needs caused them. Guided by this theory, Gutman and Reynolds have developed a so-called laddering technique. The basis of this technique is constantly asking the question of why the product in a precise part of the interaction caused a positive or negative sense as long as the level of personal needs to be met. Valence method has been developed to record the user's experience when interacting with a product in that way that no single detail would be missed and to obtain information about the basic and "hidden" reasons on the side of the psychological point of view (Burmester et al., 2010).

In the research phase, the user receives instructions to investigate the product in any way he wants. He needs to pay attention to his feelings during the interaction. The goal is to record a positive or negative emotions regardless of their intensity. It keeps track of them by using the positive sense (plus sign green in color) or the button for a negative sense (red minus sign). Pressing the button is recorded as valence mark also with recorded time through video material. The research phase should last for quite a short memory as not to diminish the retrospective phase.

Through the phase of retrospective interviews it is necessary to examine two aspects separately for each valent label:

1) What aspects of product design caused a certain valent label
2) What are the related personal needs.

The user viewing video material on which he pressure marks in exactly specified time. The instructions are to watch the video and comment on what is in that moment felt. The job of examiners is to investigate which aspects of product design caused such a sensation, with the first of all necessary to identify all related aspects. For example, users can comment on the positive valence label "This picture here is also beautiful, I love it." At this point the design elements have been identified, and the next step is to determine the design aspects of these elements. The examiner for example may ask "What is so nice in this picture" whereby the user can respond, "Well this is a picture of the turbulent river". At that moment exactly certain aspect of the image defined. Then, the examiner determines the meaning and the user's basic needs using laddering technique. The basic question of this technique would be, "Why are these features positive or negative?" Or, in this context, "Why is the restless river for you positive? This question "Why?" Is repeated until the basic needs (according to Sheldon) is not related to the valence label that has been identified. As soon as the examiner defines a label, rewinds the video to the next video, and the procedure is repeated.

The outcome of retrospective interview phase is video material that is synchronized with valent markings. From the video material the verbal protocol is made. For each valence label characteristics were defined: the number of respondents, the order of markers, time, positive or negative mark, the aspects of product design, what they mean for users, defining the user's basic needs. In the next step, the terminology used for the aspect of product design and basic needs are harmonized through the obtained data. This allows sorting and filtering. For example, the top ten aspects of the design of a product can be isolated, and it can be assumed that they have the greatest impact on the user experience. When the product design optimizes, meaning valence code shows how users experience aspect of design. For each user the number of positive and negative mark is separated. The result is divided by the sum of all the marks. The result serves as an indicator of between -1 (bad experience) and +1 (good experience) for the overall user experience when interacting with the product.

3. FACEREADER NOLDUS PROGRAM

FaceReader is a program for the analysis of facial expressions, reveals emotional facial expressions. It can recognize six basic emotions: joy, sadness, anger, disgust, fear, surprise and neutral state. It can also detect the condition of the person, for example: Is it left or right eye opened or closed, in which the position are the mouth, whether brows lowered, raised or neutral, as well as the direction of movement of the head. Before analysis program can detect the gender of the person, age, nationality, amount of hair on the face, whether respondent has glasses or not (usually correctly detected these variants), or examiner them can manually adjust. FaceReader can be used in various research fields: psychology - testing react to certain stimulations, eg, cognitive research, education - watching facial expressions of students can help in the development of new educational tools, the interaction of people and computers - facial expressions can provide precious information about the user experience, user testing - emotional expressions may point to the simplicity of use and efficiency of the user interface, market research - How do people react to design new commercials and user behavior - how users react to the presentation of the sensory panel.
FaceReader program can analyze the facial expressions of videos, pictures and live by webcam. In the case that there are a lot of material and long episodes of events, it is possible to directly jump to a part that is to be analyzed. Facial expressions are represented as graphs or as continuous signals. The examiner can decide how to view the results. The biggest challenge during the analysis of facial expression, is the way to solve the changes of pose, orientation and the lighting on the face. The solution used by this program is that it classifies persons through three stages:

1. Face detection - The position of the face in the image is found with the help of Viola Jones cascade classifier algorithm, which was developed for face detection.

2. Modeling faces - In this step, the synthesized virtual model of the face where there is five hundred key points of the face and the texture of the face in the area of these points. The method is based on Active Appearance Model (AAM), uses a database of notes and pictures showing the main sources of variation found in the picture.

3. Classification of faces - actual classification of facial expressions is done using pre-programmed neural networks. As training material was used more than ten thousand hand-marked image. The network is trained to be able to classify the six fundamental and universal expression described by Ekman: happiness, sadness, anger, surprise, fear, disgust and neutral state.

FaceReader is able to recognize the facial expression with a probability of 90%. For some emotions likelihood is higher, for other less as is shown in Figure 1.

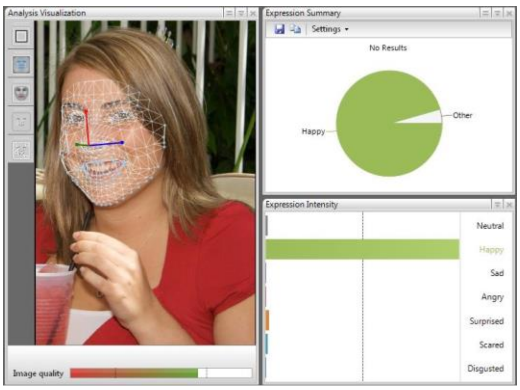

Figure 1: FaceReader modeling faces

4. EXPERIMENT

The study of the expression of the face is in the interests of different research, and can be linked to other aspects of behavior, such as emotional experience, psychological excitement, and communication. FaceReader is one of several publicly available resources for the automatic detection of the expression of a person who also possesses advanced function analysis and reports. Although the program has considerable accuracy in recognizing facial expressions, it is necessary to investigate its credibility in relation to human observation and assessment of the same facial expressions.
Between the offered choices (pictures or video) about stimulating material that would cause certain facial expressions, the video was selected. Four short sets of videos were used, among which were placed images. The following sequence was selected: video with extremely negative content, neutral image, video with extremely positive content, neutral image, then a negative video, a neutral image and at the end another positive video.
The negative part of the stimulus material is supposed to lead to negative emotions such as sadness, disgust, fear, while the positive part was responsible for the feeling of joy, surprise and the happiness. The neutral image between each set of video, represents a zone that prevents copying of emotions and leave enough time between the return to the neutral state. The study included seven participants who watched a stimulating video, and simultaneously FaceReader program analysis live in real time (figure 2). Respondents to the end did not know that this is a study of emotions or facial expressions. Their task was to view video concentrated for 10 minutes, and were alerted to the negative video content, and could at any moment stop the research. Since they had no information on the reasons for the research, they were able to relax and watch the video smoothly. Participants were between 19 and 27 years old.

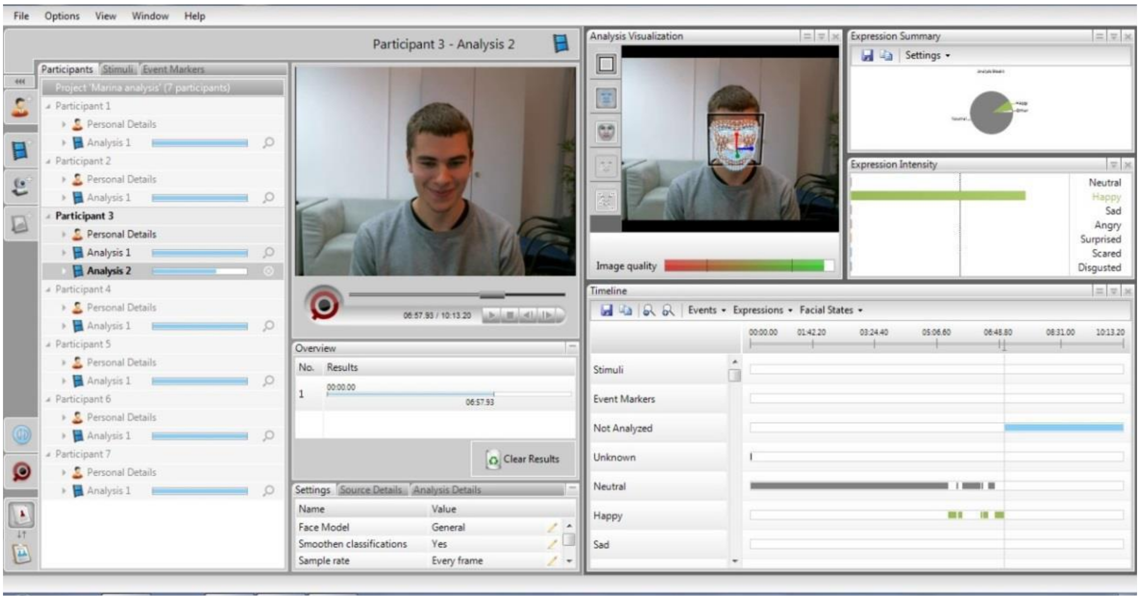

Figure 2: FaceReader analyze

It was necessary to make an analysis of the same video (facial expressions and emotions of seven participants as they watched video) by the people, and was previously analyzed by the FaceReader. The information were to compare and see the correlation, but since FaceReader, a program for automated recognition of facial expressions, works according to the codes given by Ekman, it was necessary to prepare materials that will educate and assist respondents in the next phase of research to make an analysis. After intensive study of facial expressions and certain training, the manual for detection of facial expressions was written.
In 1972, American psychologist Paul Ekman came to the conclusion of the six basic emotions and appropriate facial expressions that are universal and present in all human cultures, such as: fear, anger, joy, sadness, surprise and disgust (Ekman, 1970). After a while, Ekman expanded his list of basic emotions to some more: contempt, shame, excitement, pleasure, pride and fun. According to Ekman, facial expressions are a form of nonverbal communication. These are the movements and positions of the muscles that move in relation to certain emotional states (Ekman, 1993).

There are micro expressions that last less than a second and could show the right emotional state. Micro expressions are universal. Whether you are in Zagreb, New York or India - when you are angry, your face shows the same expression. Ekman claims that it is relatively easy to learn to read each micro expression. Reading micro-expression through a twenty five part of second quickly brings the status of experts. In figures 3 and 4 are shown expression for fear and joy.

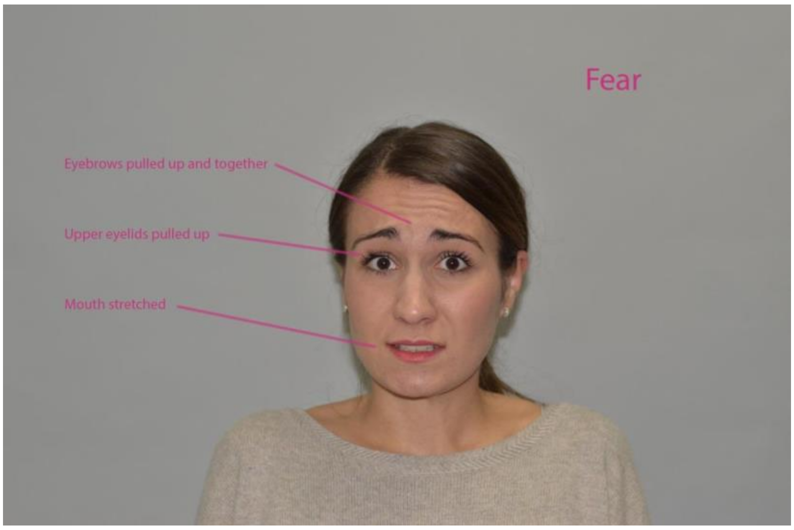

Figure 3: Expression for emotion of joy

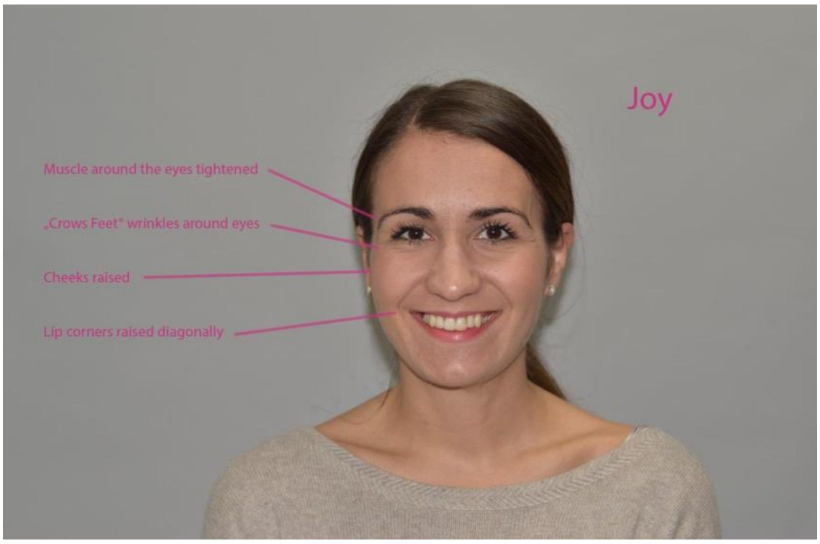

Figure 4: Expression for emotion of joy

In addition to the manual in printed form, educational material for easier recognition of facial expression, was available in the video. Through this form, participants who took part in the next phase of research have received proper training and were able to perform an analysis of facial expressions. After a thorough analysis, it was necessary to compare their data, and then compare them with FaceReader analysis.

5. RESULTS

Since different people analyze the video, it was necessary to take into account that not all react at the same time, so it is allowed a certain time deviation, and if the same emotions (by different subjects) observed within +/- 3 minutes, the result is valid. The facial expressions that overlap with two or more subjects who performed the analysis have been accepted. These results were compared with the FaceReader analysis (figure 5).

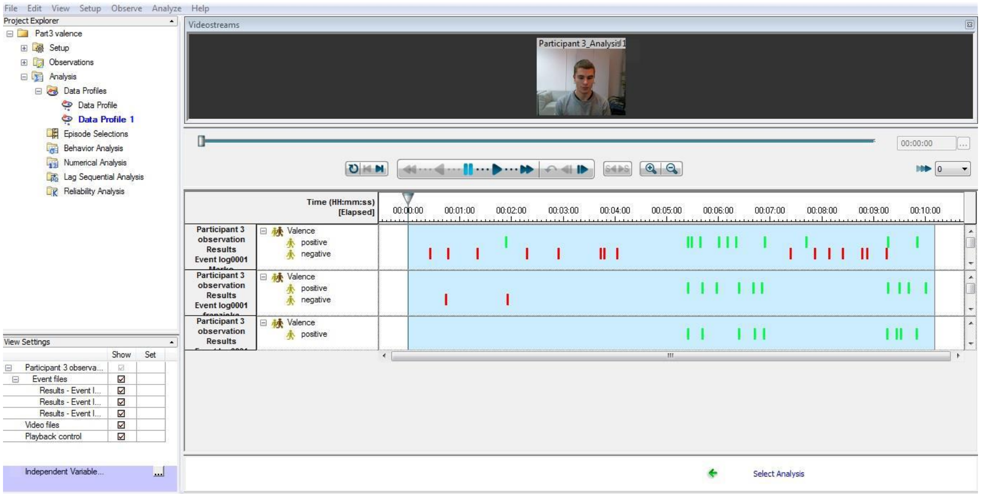

Figure 5: The visual representation of the analysis in The Observer XT

In table 1 is shown the correspondence with FaceReader for one examinee.

Table 1: Correspondence with FaceReaderom, respondent 1

Time	valence	2 correspondence	3 correspondence	FaceReader correspondence
00:05	positive		+	☺
00:52	positive	+		☹
01:39	negative		+	☺
02:17	negative	+		☹
03:00	negative		+	☹
03:22	negative	+		☺
05:07	positive		+	☺
05:11	positive	+		☹
05:27	positive	+		☹
05:35	positive	+		☹
06:25	positive		+	☹
07:28	negative	+		☹
07:47	negative	+		☺
09:34	positive		+	☺
10:04	positive		+	☺

If we take the total percentages of correspondence with all participants with FaceReader, leads to the result that 57% of human facial expression analysis does not overlap with the results of the analysis FaceReadera, a 43% overlap (Figure 6). Unfortunately, such a result is not satisfactory and does not support the integration FaceReader Noldus program in Valence method.

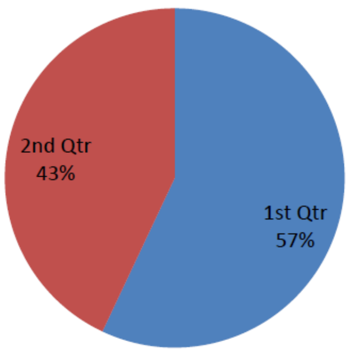

Figure 6: Correspondence of human analysis with FaceReader analysis

6. CONCLUSIONS

Nowadays, a lot of attention is paid to the study of user experience using different methods. Specifically in this work was research Valence method. The main objective was the improvement of the above-mentioned method, whereby as the result would be that user smoothly interact with the product. As a means for the achievement of this goal to an end, the package Noldus program was used, specifically using the FaceReader program for automatic recognition of facial expressions. Carefully designed and conducted research at the University of Information Psychology in Stuttgart, was carried out with the latest technology as well as the mentorship of leading scientists of the area. One of the main issues was the matching analysis carried out by the program, with the results of human analysis. Unfortunately, although the investigation to the end was uncertain, the results did not support integration FaceReader program in Valence method. With a percentage of 57% discrepancy between these two analyzes, ultimately leads into question the accuracy and validity of the program. But since this is the fifth version of FaceReader program, where each following is better than the previous one, does not need to pursue further investigations if future versions become available. If the program has led to a high level of credibility, not only Valence method will approve, but could be integrated into the Human - Computer Interaction where it had the greatest benefit people with disabilities.

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REVIEW OF TOOLS AND APPLICATIONS FOR COLOUR SCHEMES GENERATION

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Abstract: *One of the biggest challenges for both novice and professional designers, when initialising a new design process, is how to select appropriate colours for a project. Generally, designer's goal is to generate perceptually harmonious colours combination or colour scheme, i.e. set of colours that produce a pleasing effect when seen together. Today, an enormous amount of tools are available for generating colour schemes. So-called colour scheme composers or generators are built for different platforms and have different functionality and supported features. Due to a large number of colour schemes generators, the purpose of this study was to provide a systematic and comprehensive review of current and publicly accessible solutions for generating colour schemes. Tools were thoroughly evaluated based on their functionality and important features. Results show that most of the tools are primarily intended for web developers and designers, as is evident from supported colour spaces and export options. Few tools can also be used for generating colour schemes with spot or process colours, but none of them supports colour management option or specifies which colour space is used for interpreting these values. Almost all tools allow users to manually add colours to the scheme either by defining their numeric values or using some type of colour picker tool. More than half of them also provide an option for generating colour scheme based on specified base colour and selected colour harmony rule.*

Keywords: colour schemes, colour tools, colour schemes generators, colour palettes, colour applications.

1. INTRODUCTION

The colour is a basic component of visualisation in digital and conventional media. It has a significant impact on the perception of visual design (Feisner and Reed 2013) and it is important to all participants in the process of planning, developing and promoting graphic products. Designers are interested in a psychological and presentational aspect of colours, while to the technologists the colour represents one of the most important quality attributes.

One of the biggest challenges for both novice and professional designers, when initialising a new design process, is how to select appropriate colours for a project. That is dependent on many different factors: clients demands, designer's personal colour preferences, emotional effects of colour, psychological meaning, colour symbolism, current fashion or trends, etc. Generally, designer's goal is to generate perceptually harmonious colours combination or colour scheme (also called colour palettes). Colours are said to be in harmony when their juxtaposition produces a satisfying unity or balance to the viewer (Paterson 2004). In other words, colour harmony can be defined as a set of colours that produce a pleasing effect when seen together. Throughout the history, many scientists, art theorists and practitioners tried to determine which colours combinations are harmonious and therefore give rise to the pleasing effect. Today it is well known that although many attributes have an effect on colour harmony, harmonious colours can be often represented as uniformly spaced points in a colour classification system (Burchett 2002). However, based on extensive review of main theories of colour harmony, Stephen Westland came to the conclusion that what is considered harmonious is to a large extent subject to trend, personal preference and other cultural influences (Westland 2007). What is more, colours are never used alone but within certain context and space (different proportions, geometry, area of coverage) that also have influence on colour harmony. Based on a large-scale experiments on colour harmony, which lasted fifty years and comprised ninety-five thousand participants, a comprehensive list of conditions and attributes of colour harmony have been determined (Nemcsics 2007, Nemcsics 2008, Nemcsics 2009, Nemcsics 2009, Nemcsics 2011, Nemcsics 2012, Nemcsics and Takacs 2013, Nemcsics and Takacs 2014).

As can be seen, choosing colours that are harmonious, usable and efficient it not an easy task. In addition many designers don't have sufficient background knowledge about colours and art theory, which could help them with the selection of colours. As a result, designers usually spend a great deal of time and expend significant effort in choosing appropriate colour combinations.

There are many books available, mostly for interior designers and artists, that contains lists of colour schemes and background information for choosing harmonious colours (Press and Kerrigone 1992, Ingham, Homes et al. 2004, Eddy 2006). Graphic designers usually use colour indexes and books with colours schemes for guiding principles and reference or inspiration (Marks 2006, Krause 2007).

As computers became a primary design tool in the last decades, a lot of applications and tools have emerged that facilitate selection of colours. Traditionally, colours were selected by specifying their numeric values or selecting them with colour-picking tools, which are embedded in design software (e.g. Photoshop). Today, an enormous amount of tools are available for generating colour schemes. So-called colour scheme composers or generators are built for different platforms and have different functionality and supported features. Most of these tools focus only on the harmony of hue component and provide rules for creating colour harmony in terms of a hue wheel. There are six basic harmony rules based on a colour wheel:

- Monochromatic harmony: colours with the same or nearly the same hue,
- Complementary harmony: colours lying opposite each other on the colour wheel,
- Analogous harmony: colours with similar hues, lying next to each other on the colour wheel,
- Triadic harmony: three colours whose hues are each separated by about 120 degrees on the colour wheel,
- Split-complementary harmony: involves three colours, with two being either side of the complement of the third on the colour wheel,
- Tetradic harmony: double complementary scheme, two complementary pairs lying opposite each other on the colour wheel (Stephen Westland 2007).

To make above schemes harmonious, the lightness, saturation and extension (area of coverage) of the colours selected from the hue circle need to be adjusted to equalise their visual strength (Fraser and Banks 2004).

Based on concepts from art, perceptual science and psychology, Meier, Spalter et al. have developed a plug-in for Adobe Illustrator, called Interactive Palette Tools (IPTs) (Meier, Spalter et al. 2004). This set of interactive tools provides several methods to facilitate the creation of colour schemes. One of the most useful is image and composition tool, which provides different predefined compositions and reference images for the selected palette. Images are typical of artworks, natural objects, or photographs. Composition panel allows users quick and easy way to experiment with relative sizes of colour fields and their location, what according to many authors also have a major effect on the perception of colour harmony (Stephen Westland 2007).

Hu et al. proposed a method to generate harmonious colour scheme in HSL colour space according to conventional harmony principles 'familiar factors' and 'rhythmic spans'. The term familiar factors refer to sharing of attributes among colours to gain harmonious colour combinations. This is achieved by fixing one dimension of H, S, L for all colours in the colour scheme and then varying at least one of the other two dimensions (Hu, Pan et al. 2014). As an extension to the previous project, Hu, Zhang et al. also proposed a method for generating colour schemes that are based on user's preference (Hu, Zhang et al. 2015). Colour scheme is constructed according to the before mentioned method, and then determined by the six attributes of colour component relations: representative value of hue, representative value of saturation, representative value of lightness and span of hue, span of saturation and span of lightness.

Morreti, Lyons et al. presented a tool for creating colour schemes for graphical user interfaces, called Colour Harmoniser, which adapts and extends classical colour harmony rules, combining algorithmic techniques and personal taste (Moretti, Lyons et al. 2013).

Due to a large number of colour schemes generators, the purpose of this study was to provide a systematic and comprehensive review of current and publicly accessible solutions for generating colour schemes. Tools were thoroughly evaluated based on their functionality and important features.

2. METHODOLOGY

In this research, ten different tools for generating colour schemes were analysed: Coolors, Adobe Color CC, Paletton, Color Explorer, Colourcode, Colordot, Colormunki, Spectrum, Open Color Companion (OCC) and Sip. Most of them are free of charge and web-based, so they can be used on different devices, regardless of which operating system the user is using. Spectrum, OCC and Sip are commercially available and only works on MAC and iOS operating systems.

All of the tools were evaluated based on their functionalities and important features for generating colour schemes. Primarily, we focused on how many colours (patches) can be included in a colour scheme, which colour harmony rules are supported and if the colours in the scheme can be adjusted or reordered. Functionality was defined based on supported colour spaces, ability to extract colours from the image and export options. In addition we also determined if the web-based tools support online community and provide options for exploring and sharing colour schemes. In the end, we present our findings regarding user experience.

3. RESULTS AND DISCUSSIONS

Results show that most of the tools support RGB colour values and its transforming values – either HSB/HSV or HSL (Table 1). Only 40% of tools allow CMYK values and barely 30% of tools support colorimetric values (LAB or XYZ and xyY). Because none of the tools that support multiple colour spaces, except SIP, doesn't specify the names of the colour spaces, we tried to determine them by converting the values in MATLAB using different ICC profiles. We found out that sRGB colour space is being used for interpreting RGB values, while for the CMYK values we couldn't determine the names of the colour spaces. OCC and Sip also support RGBA colour notation, which has been presented with the CSS3 specification (CSS Color Module Level 3) and use an additional fourth channel for defining transparency of colour – alpha channel. RGBA notation is being widely used in web development area. Coolors and Colormunki are the only tools that support spot colours – colours from libraries such as Pantone®, Munsell or Copic®. That can be useful for graphic designers that mostly design print media and frequently use spot colours. In addition, Colormunki provides extensive information about selected spot colours, such as its CIELAB values and its corresponding CMYK values for different printing substrates and conditions (Uncoated Paper, Ink Jet Glossy, Coated Paper, Newsprint, Ink Jet Matte). It should be noticed that authors of this tool didn't specify which ICC profile was used to gain this values. Even thought ColorExplorer allow users to add colours from TOYO®, FOCOLTONE® and TRUMATCH® colour matching systems, it only provides its RGB values and not the original CMYK (process) values.

As few as 40% of analysed tools provide an option for extracting colours from the image. The image can be either selected from the local storage or uploaded from another server by providing URL address of the image. ColorExplorer and Spectrum are able to extract a different number of colours from the image, while Adobe Color CC and Coolors can extract only five colours at once. Adobe Color CC and ColourExplorer offer additional settings for extracting colours from the image. Adobe Color CC provides five different colour modes (colourful, bright, muted, deep and dark), whereas with ColourExplorer the level of colour analysis refinement can be determined by the user. With Adobe Color CC and Coolors colours can be also manually selected from the image and Spectrum provides an option for selecting analysed area on the image.

Available export formats of each tool can be found in Table 1. Furthermore, Figure 1 shows how many tools support a particular format. Over half of the analysed tools offer a possibility to export colour values in the notation of CSS syntax or in one of the CSS preprocessors syntax (SASS or LESS). This can be very useful for web designers and could streamline the process of defining colours. What is more, OCC and Sip support other notations of colour values that are widely used in the development of web or native applications (JSON, XML, SWIFT, UIColor, NSColor). The only export option of Adobe Color CC is saving colour schemes to a personal library, which is part of Creative Cloud. Hence, all the colour schemes can be directly accessible from Adobe applications. This can be very useful if a designer is mainly using Adobe applications when working with colours, but can also be a major drawback if the colours are needed for some other purpose (e.g. defining colours in CSS or CSS preprocessors). Some tools also support exporting colour schemes as PNG or PDF format, which can be helpful for sharing colour schemes with clients. Only Colormunki supports CxF format, which is universal file format for digital colour communication that has been recently standardised. CxF is based on XML markup language and supports device-dependent and device-independent colour spaces. In addition, it can also contain metadata, such as information about colour measurement conditions and properties of colour patches. When exporting colour scheme in a CxF format, Colourmunki saves spectral data of each patch to the file. Only Colourcode allows exporting and sharing individual colour that is part of a scheme.

Table 1: Supported functionalities of colour schemes generators

Tool	Supported colour spaces	Colour extraction from the image	Export options
Coolors	HSB, RGB, CMYK, Pantone, Copic	Yes	PDF, PNG, SASS, SVG, COPIC
Adobe Color CC	HSB, RGB, CMYK, LAB	Yes	Synchronise with Adobe CC
Paletton	RGB, LAB	No	HTML, CSS, LESS, SASS, XML,TXT, PNG, ACO, GPL
ColorExplorer	RGB, HSV	Yes	ASE, ACO, PNG, TXT
Colourcode	RGB, HSL, HSV, CMY, CMYK, XYZ, Yxy	No	SASS, LESS, PNG
Colordot	RGB, HSL	No	/
Colormunki	Mansell, Pantone	No	CIELAB data file, CXF 2.0
Spectrum	RGB, HSV	Yes	CSS, ASE, PNG, CSS3 HSL, SASS
OCC	RGB, RGBA, HSL	No	SASS, LESS, CSS, JSON, SWIFT, OCO
Sip	RGB, RGBA, HSL, HSB, CMYK	No	SIP, ASE, CRL, PDF, HTML, JSON, XML, SASS, LESS, UIColor, NSColor, webpage

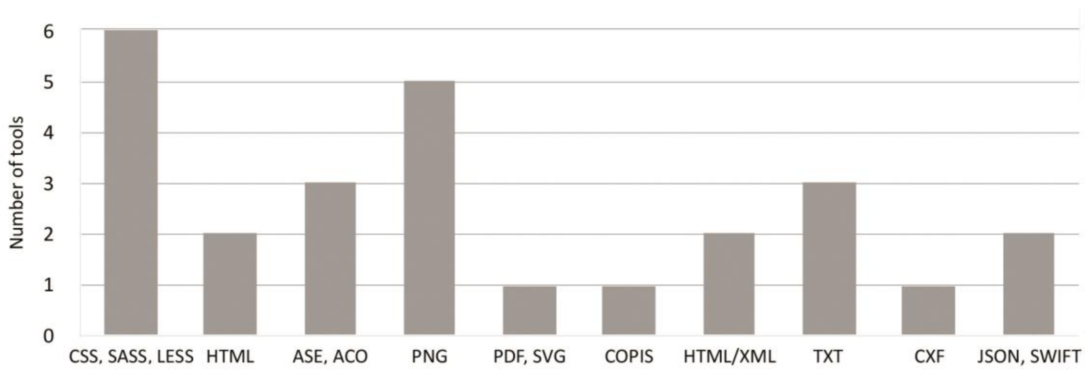

Figure 1: Number of tools that support the particular export format

Important features of colour schemes generators can be seen in Table 2. Half of them provide an option to generate a colour scheme by specifying the key or base colour and use paths in a colour wheel to guide the selection of related colours. The paths are set according to colour harmony rules. The most common harmony rules are monochromatic (also called "single hue"), analogous (also called adjacent), complementary, split-complementary, triad (also named triadic) and tetrad (also called equiangular). Some of the tools also provide additional rules – Adobe Color CC: Compound and Shades, Color Explorer: Square, ColorMatch 5K Classic and Sweet Spot Offset, Colourcode: Monochrome & Dark Gray, Monochrome & Light Gray, and Quad. The Coolors allows only monochromatic harmony rule to be selected. However, some of the harmony rules have to be taken into account, even when this option is not selected, otherwise the generated colours would not be harmonious. Rather than using a colour wheel for selecting colours, Coolors simply generate a pseudo-random scheme when user hit a spacebar. If the user is satisfied with the colour, it can lock it and than hit a spacebar to generate adjacent colours again.

Table 2: Features of colour schemes generators

Tool	Colour harmony rules	Adjusting colour scheme	Number of colours	Order changing
Coolors	Monochromatic	hue, saturation, brightness, temperature	4	Yes
Adobe Color CC	Monochromatic, Analogous, Triad, Complementary, Compound, Shades	Not supported	5	Yes
Paletton	Monochromatic, Adjacent colour, Triad, Tetrad	hue, saturation, brightness and contrast	1, 2, 3, 4 (four shades of each)	No
Color Explorer	Single Hue, Analogous, Complementary, Split-complementary, Triadic, Square, ColorMatch 5K Classic, Color Explorer	average lightness or saturation, normalise lightness or saturation, compile colour set, apply styles and filters	Unlimited, 8 when colour harmony rule is considered	Yes
Colourcode	Monochrome, Monochrome & Dark Gray, Monochrome & Light Gray, Analogic, Analogic & Complement, Complement, Triad, Quad	Not supported	up to 10	Yes
Colordot	Only manual selection	Not supported	Unlimited	Yes
Colormunki	Only manual selection	Not supported	Unlimited	No
Spectrum	Monochromatic, Analogous, Complementary, Split Complementary, Equiangular	Not supported	Unlimited	Yes
OCC	Only manual selection	Not supported	Unlimited	Yes
Sip	Only manual selection	Not supported	Unlimited	Yes

Colourcode also takes a different and innovative approach for generating colour schemes. Instead of using paths to guide the selection of colours and selecting points on the colour wheel, the user changes colours by moving the mouse cursor over the individual patch. By moving the cursor left and right the user select the hue and by moving the cursor up and down the lightness. Saturation of the colour is determined with scrolling. Adjacent patches are set simultaneously according to preselected colour rule. Colordot uses a similar approach, except that colour patches have to be added manually to the scheme and colour harmony rules are not supported. Sip, OCC, and Colormunki also doesn't support colour harmony rules and only allows manually selection of colours. Colours can be added to the scheme either by defining their numeric values (OCC, Sip), picking them with colour picker tool (Sip) or choosing them from colour library (Colormunki). Moreover, ColorExplorer provides an option for importing colours from an HTML, CSS or TEXT file, which can be very helpful if someone has to collect colours from an existing project.
60 % of all tools allow users to add an unlimited number of colours to the scheme. Even though ColorExplorer does not limit the number of patches in the colour scheme, only eight colours are made at once, when patches are generated according to one of the harmony rule. The user can then create another harmonious group of colour and add them to the scheme. Coolors, Adobe Color CC and Paletton allow only fixed number of patches, even when they are added manually to the colour scheme. One of the most imported features of Spectrum is that it allows an arbitrary number of colours, even when they are generated according to one of the harmony rules. Colourcode supports up to 10 colours, whether are set manually or based on colour harmony rule. When a user defines more colours that are needed by selected colour harmony rule, shades of colours are added to the scheme.

Only three tools provide an option for adjusting colours in a scheme as a whole. Schemes can be adjusted according to a hue, saturation, brightness, contrast or temperature. ColoExplorer also provides some predefined styles and filters that can be applied to a colour scheme.
Almost all tools allow users to change the order of colours in a scheme. In addition, ColorExplorer provides extensive options for sorting and modifying colours in a scheme. Individual colours can be sorted by hue, saturation, lightness or intensity, averaged by lightness or saturation and normalised based on a lightness or saturation.
Most of the tools support some kind of online community for saving, exploring or sharing created colour schemes. Coolors, Adobe Color CC, ColorExplorer and Colormunki allow login users to save created schemes on a cloud. All of these tools, except ColorExplorer, also support exploring schemes from other users and searching them by a specific tag. This can be very useful for getting great ideas and inspirations about colour combinations. Each tool provides different options for sorting search results. All of the desktop applications also allows users to save an unlimited number of schemes, but they do not provide options for exploring others people's schemes.
None of the analysed tools have any major usability issues that could prevent users from accomplishing their goals. However, all of the web-based tools are not optimised for viewing them on smaller devices – design is not responsive. In addition, Coolors, Colourcode and Colordot do not even work on touch devices, which is a major drawback. Although Adobe Color CC and Coolors are also available as native mobile applications, the user still has to install the application, which takes unnecessary additional space. Furthermore, the Coloors mobile application is only available for Android systems and is not free of charge.
In spite of before-mentioned deficiencies, the best tool from the user experience perspective is in our opinion Coolors. Its main advantage is that is simple to use and has an attractive and user-friendly design. The procedure of generating new colour scheme is also attractive and effortless. Initially, an arbitrary colour scheme is presented to a user across the entire screen. If the user is not satisfied with a presented scheme, he/she can simply generate a new one by hitting the spacebar. In this way, users can quickly generate colours schemes, without unnecessary steps. Each colour of a scheme can by simply adjust by moving sliders or typing numerical values. In addition, all colours can be simultaneously adjusted by changing their hue, saturation, brightness or temperature. Another user-friendly feature of this tool is an interactive tutorial, which is presented to new users to familiarise them with a tool functioning. The interface design is minimalistic and occupies only upper part of the screen, as a result most of the screen is used for displaying colours. Most of the buttons are presented only with icons that are clean and intuitive. In addition, they also include tooltips for better understanding their purpose.

4. CONCLUSIONS

Most of the tools for generating colour schemes are primarily intended for web developers and designers, as is evident from supported colour spaces and export options. Few tools can also be used for generating colour schemes with spot or process colours, but none of them supports colour management option or specifies which colour space is used for interpreting these values.
The colour schemes generators differ in their functionality and supported features. Almost all tools allow users to manually add colours to the scheme either by defining their numeric values or by using some type of colour picker tool. More than half of them also provide an option for generating colour scheme based on defined base colour and selected colour harmony rule.
By far the most powerful tool is Colour Explorer, which provides extensive options for working with colours, but also it can be overwhelming or too complex for most of the users. Among most intuitive and simple to use are Coolors and Adobe Color CC, which also provides extensive libraries of colour schemes that can be used for an inspiration. This is one of the most important features that was unfortunately neglected with desktop applications.

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Typography & Graphic art

Original scientific paper

CONSUMER RESPONSE TO TYPEFACE RHETORIC IN AD HEADLINE: A PRELIMINARY STUDY

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Abstract: *This paper reports a preliminary results of the consumer response analysis towards rhetorical figuration of typefaces in print advertisements. Reinforcement of advertising effectiveness has been the key point in visual marketing and communication research. However, this task has become increasingly difficult in the contemporary advertising environment where extensive use of visuals leads to "information anxiety". So far, rhetorical figures have proven as an effective way to increase ad likability, engaging consumers in higher cognitive processes that eventually lead to better memory and conative functions. Reported downside relates to reduction of cognitive entropy. Nevertheless, research has neglected rhetorical figuration in typeface design. Considering that a typeface is one of the most ubiquitous elements in the advertised message, this paper addresses a preliminary analysis of relation identification between the levels of typeface rhetoric and consumer affective response. Taken together, we proposed the following hypothesis: affective response to a typeface figuration will be higher for more complex i.e. irregular rhetorical figures (tropes) and lower for more regular figures (schemes). Three levels of rhetorical figuration were used in the study, ranging from the less to more complex. Participants were asked to rate their emotional response using the Self-Assessment Manikin (SAM) scale. Targeted stimuli had been presented as it would be in the real world environment. The results reveal no significant difference in affective response to previewed advertisements. Implications and future research are discussed.*

Keywords: affective response, visual rhetoric, typography, advertising effectiveness, visual communication

1. INTRODUCTION

Typeface has emerged as a powerful tool in visual and marketing communication. The importance of this visual tool is acknowledged by both practitioners and scholars who suggest a strong relationship between typeface attributes and emotions. This semiotic trait of the typeface is based on the type's associations of personality and/or association established through convention (Brumberger, 2003; Mackiewicz & Moeller, 2004). For example, design characteristics of a typeface can determine the tone of writing (Doyle & Bottomley, 2004; Morrison, 1986; Rowe, 1982). Therefore, consumers might associate typefaces with certain attributes such as elegant, friendly, direct. This feature has been examined as a typeface appropriateness (Brumberger, 2003) congruency (Childers & Jass, 2002), and semiotic resource (Leeuwen, 2006) that is employed to help manage impressions (Henderson, Giese, & Cote, 2004). On the other hand, the persuasiveness of advertising relies on the use of rhetorical figures applied to both pictorial and verbal part of an advertisement (Delbaere, Mcquarrie, & Phillips, 2011; McQuarrie & Mick, 1996, 2003). The findings indicate stronger argumentative power of rhetorical figures over mere ornamentation (Kjeldsen, 2012). Rhetorical figures present an image that is deviating from reality which leads to the increase of attention and memory (Pieters, Warlop, & Wedel, 2002; Pieters, Wedel, & Batra, 2010). However, the existing research fails to consider how the application of the rhetorical figures in a typeface design contributes to the overall affective response. Therefore, the purpose of this study is to contribute to the concept of understanding rhetorical devices in relation to typeface design.

2. THEORETICAL BACKGROUND

2.1 Affective response

For assessing advertising effectiveness, one must first consider affective response of consumers due to an extensive use of emotional appeals in advertising. Empirical work has proven that cognitive attitude is not dominating over affective and conative which was previously believed (Morris, Woo, Geason, & Kim, 2002). Affect is perceived as one component of an attitude and persuasive force. In fact, dimensions like pleasure, arousal and dominance have been empirically proven to be prevailing in organizing human judgments for perceptual and symbolic stimuli (Bradley & Lang, 1994a; Mehrabian, 1970; Osgood, Suci, & Tannenbaum,

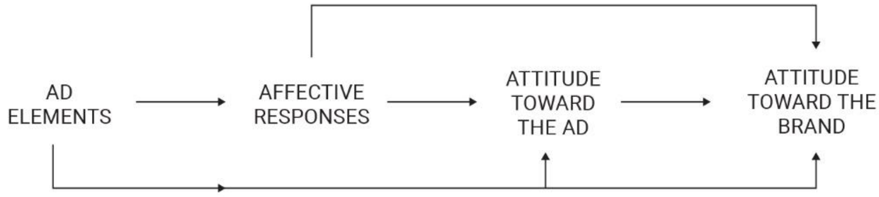

Figure 1: The communication model in advertising context

1957; Posner, Russell, & Peterson, 2005). Furthermore, research that examines the role and relationship of emotion as the mediator of responses to advertising reveals that cognition can drive affect (Edell & Burke, 1987; Holbrook & Batra, 1987) and that affect can directly influence attitude (see Figure 1) (Brown & Stayman, 1992; Cohen & Areni, 1991). For example, recent study (Chan, To, & Chu, 2015) used affective response as a measure of behavioural intention when examining repurchase intention of status-conscious consumers in buying luxury goods. The study shows that 60% of the total variance in purchase can be explained by affective response.

An interesting marriage is the one between rhetorical figuration and affective elaboration. Scholars argue that affective elaborations (which reflect content-related feelings) can independently increase the persuasive effect of a message when compared to cognitive elaborations (Batra & Ray, 1986; Rosselli, Skelly, & Mackie, 1995). On the other side, the most commonly conjectured emotional response from rhetorical figures is pleasure (DeRosia, 2008). The recent study (Kim, Baek, & Choi, 2012) of structural examination of two types of elaboration, cognitive and affective, where metaphoric and nonmetaphoric contexts were compared demonstrated that affective elaboration influences ad-related thoughts, whereas cognitive elaborations affects the view on advertisers. Therefore, metaphors, as irregular rhetorical figuration, can provoke affective responses.

2.2 Associative power of typeface characteristics

An effective visual and marketing communication depends on a good type design and its proper application (Henderson et al., 2004). Word-driven media, such as print advertising, considers "the grammar of typography" an obligatory element. According to Arnheim (1969) whenever we perceive we engage in an active thinking process and the inferred outcome is that viewers actively make judgments when they look at visual data. Their perceptions of a particular data, typeface included, is formed partially on the viewer's knowledge, experience and level of information they have accumulated prior to the interaction with the data in question. Schriver (1997) stresses out the importance of the rhetorical appropriateness of well-chosen typography, discussing the role of typeface mood, personality and tone. She implies that a good writer must consider the relationship between the typeface, genre of the document and its audience. In advertising context, semantic quality of typefaces is examined. Findings indicate that a certain typeface is more effective when there are shared features with the product being advertised (Grohmann, 2008). Childers and Jass (2002) investigated the influence of typeface semantic associations on consumers' attitudes, brand perception and brand recall. Their findings indicate that these attributes strongly influence brand perception. Furthermore, the authors assert that we should conceptualise typefaces as an independent ad element that transfers meaning, making the message easier to perceive and place in consumer's memory. Similarly, McCarthy and Mothersbaugh (2002) see typography as an executional element of print advertisements that has the ability to influence motivation, opportunity and ability to process adverting messages.

Application of symbolism and rhetoric is an integral part of visual marketing, aiding strategical organization of ad elements (D. Mick, 1986; D. G. Mick & Politi, 1989; Scott, 1994). For example, metaphor can assign a meaning to a letter form i.e. specific characteristics of letter forms may have metaphorical potential (Hanno & Lupton, 1988). The structure of a metaphorical message is based on artful deviation stimulating cognitive elaboration in processing "figurative speech". According to taxonomy developed by McQuarrie & Mick (1996) there are regular and irregular (more complex) figurations i.e. figurations that deviate to a greater extent. Their findings indicate that rhetorical figures have the ability to motivate additional processing of advertisements. Therefore, we propose the following hypothesis:

> **H1**: Rhetorical devices applied to a typeface design will increase the affective response to an ad as a whole. Particularly, [illegible]

3. METHOD

3.1 Participants and procedure

A total of 44 undergraduate university students participated in the experiment. The average age of the participants was 22; 58% of the participants were female and 42% were male. Upon their arrival participants were randomly assigned to one of the three treatment conditions. Participants were seated in front of the computer and exposed to a digital booklet containing instructions, two target ads and four filler ads. After each ad sample, a 7-point semantic differential measurement scale was displayed on the screen. The first ad in the booklet was a warm-up ad sample to familiarise subjects to the type of stimuli and rating items they would encounter. Participants were notified they would see a set of advertisements for new brands not yet on the market. Also, they were told that an advertising agency is collaborating with researchers in an attempt to better understand consumer’s behaviour. They were encouraged to view ads as they would in their natural surroundings (when viewing magazines) and work through the ads at their own pace. About 15 minutes were required to complete the study.

3.2 Stimuli material

Several pretest studies were carried out for selection of the typeface (according to the level of semantic associations/figuration), and product categories. A pretest was conducted, using 32 undergraduates, to obtain an understanding whether the consumers acknowledge the difference between the typeface attributes when rhetorical devices are applied. The typefaces were selected from online type foundries. Participants rated 20 unique typefaces on a modified т-point semantic differential scale indicators with endpoints of “clever-artful/matter of fact” taken from Delbaere, Mcquarrie & Phillips (2011). Overall means from the scale measures (clever-artful = 7.15; matter of fact = 7.05) indicated that participants perceived variability along the regular and irregular target attributes. Additionally, authors examined advertised products in several magazines targeted toward younger population, and selected 15 product categories for pretesting to determine which of the products were interesting to both female and male participants. Participants made their evaluation of advertisement on 5-point scale anchored by “Is this product for you?”. Toothpaste (*M* = 4.3) and transport agency (*M* = 3.9) were selected as unisex product for target ads. According to Vaugh’s Grid (1980), these products belong to second (ƭƻǿ űƘƛƴƪƛƴƎ) and third (ƘƛƎƘ ŜƳƻűƛƻƴƪ·ƭ) quadrant of product categories.

3.3 Independent variable

Visual rhetoric stems from verbal rhetoric which is characterized as an artful deviation of the emitting message in order to persuade (Corbett, 1990; McQuarrie & Mick, 2003). Rhetorical devices can be classified as regular and simple (schemes), or irregular and complex (tropes). Following prior research, we use Mcquarrie & Mick’s (1996) taxonomy of rhetorical figures, and Hanno & Lupton’s (1988) samples of altered typeface patterns, according to rhetorical schemes and tropes, for the typeface manipulation in the ad stimuli, as shown in Figure 2.

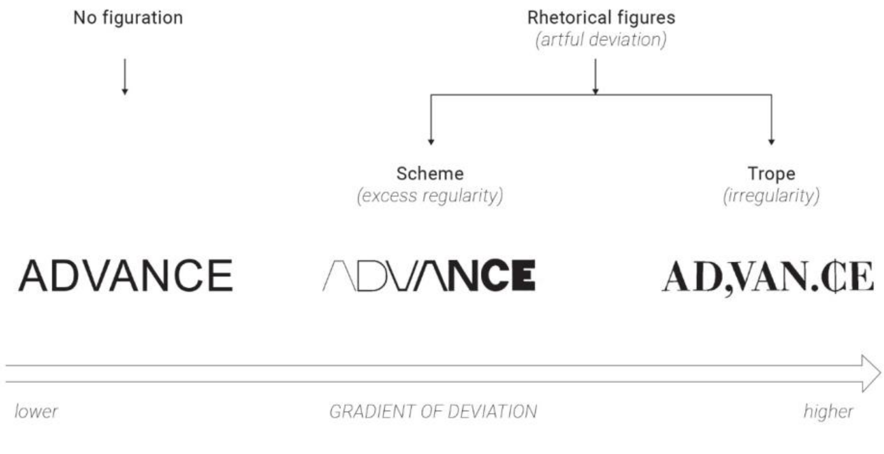

Figure 2: Alternation of typeface attributes according to non–rhetorical and rhetorical devices. The scheme presents how incongruity increases from nonfigurative to scheme to trope.

Rhetorical figure manipulation consisted of two sets of three typefaces for an ad headline, each set for one product type. Both set contained one nonfigurative version, one scheme, and one trope (see Figure 3).

Figure 3: Stimuli design example

3.4 Dependent measures

A picture-oriented instrument, the Self-Assessment Manikin (Bradley & Lang, 1994b) was used to assess internal feeling states of the participants. The single-item scale was used to measure the affective response of the participants. This instrument builds on the previous semantic differential scale devised by Mehrabian and Russell (1977), the 3-dimensional structure (pleasure, arousal, dominance) with a 9-point scale. Instead of rating 18 bipolar adjective pairs, participants were given a nonverbal graphic equivalent to rate each advertisement in the experiment. The instrument is shown in the Figure 4.

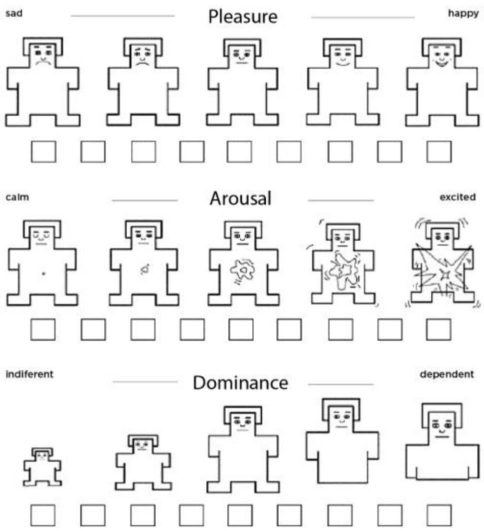

Figure 4: SAM scale

4. RESULTS AND DISCUSSION

The results show no main effect of typeface figuration on affective responses. An analysis of variance (One-way ANOVA) for the first target advertisement indicated that the effect of the typeface figuration on the affective dimension pleasure was not significant at the level of p > .05, *F* (2,39) = 1.421, *p* = 0.254, ǿăŜŜ ¢Ι·π ōťŜ мύ. There was no significant effect of the typeface figuration on the dimension Ι·№ƻdzăΙ·ƒ at the p> .05 level F (2,39) = 2.552, p = 0.091. Also, there was no significant effect of the typeface figuration on the dimension dominance at the p > .05 level F (2,39) = мΦмпм, p = лΦоол.

Table 1: Means (M) and Standard Deviation (SD) of ratings for the affective response (dimensions: pleasure, arousal, and dominance) to typeface levels of rhetorical figuration, for the first target ad

	Pleasure		Arousal		Dominance		
Typeface manipulation	M	SD	M	SD	M	SD	N
Trope	5.43	1.016	3.79	1.578	3.93	2.018	14
Scheme	6.07	0.997	4.86	1.167	5.00	1.468	14
No figuration	5.57	1.070	3.57	1.989	4.21	2.259	14

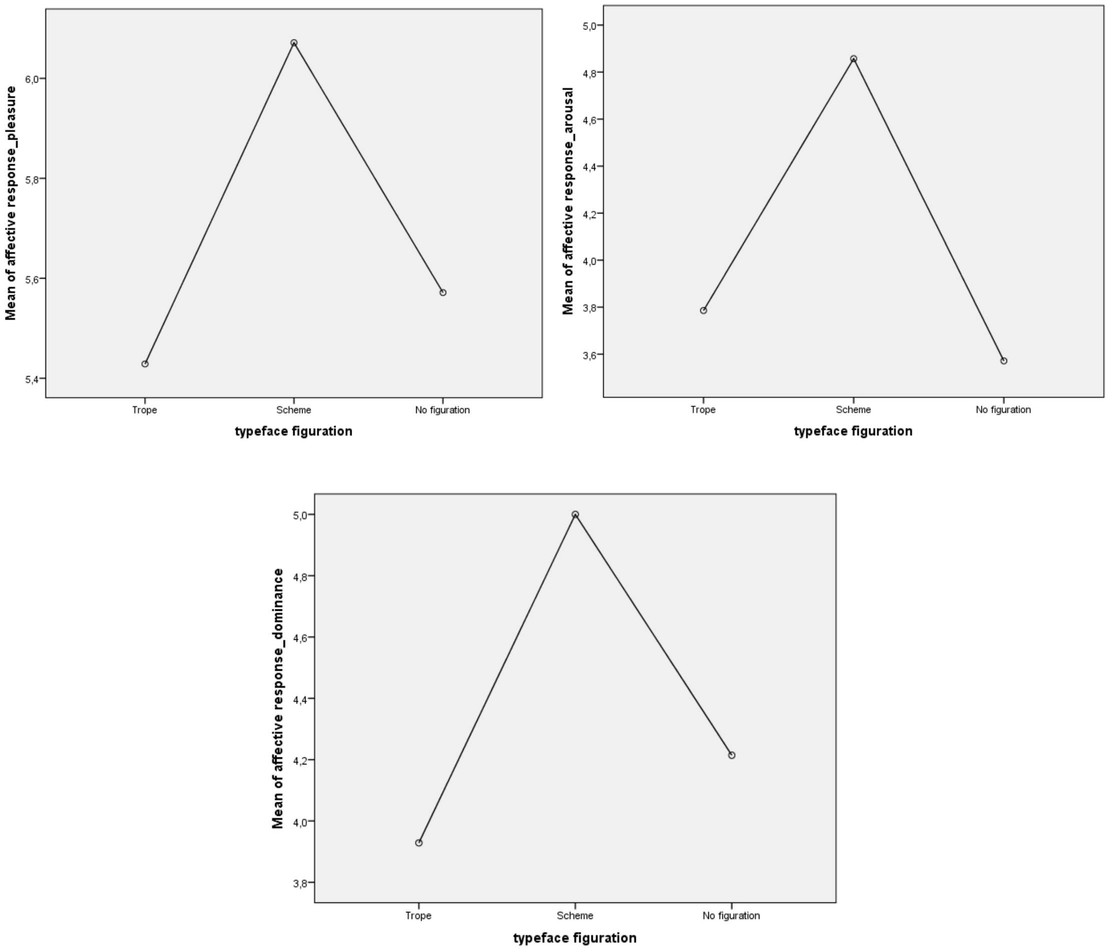

Figure 4. The relationship between dependent and independent variable for the first target advertisement (tooth paste). The effects of typeface figuration (no figuration, scheme, trope) on the three dimensions of the affective response (pleasure, arousal, dominance).

The same procedure was carried out for the second target advertisement. The typeface manipulation check showed no significant difference in consumer's affective response. For the dimension pleasure, the effect of the typeface figuration was not significant at the level of p > .05, *F* (2,39) = 1.119, *p* = 0.337, ὁăŜŜ ȼǀ·π ōſŜ ʜύ. For the dimension arousal, the effect of the typeface figuration was not significant at the level of p > .05, *F* (2,39) = 0.855, *p* = 0.433. The effect of typeface figuration was not significant for the dimension dominance at the level of p > .05, *F* (2,39) = 0.315, *p* = 0.731.

Table 2: Means (M) and Standard Deviation (SD) of ratings for the affective response (dimensions: pleasure, arousal, and dominance) to typeface levels of rhetorical figuration, for the second target ad

	Pleasure		Arousal		Dominance		
Typeface manipulation	M	SD	M	SD	M	SD	N
Trope	6.43	0.756	5.21	1.424	3.93	2.018	14
Scheme	5.93	0.917	4.71	1.773	5.00	1.468	14
No figuration	6.21	0.975	4.36	1.985	4.21	5.259	14

Previous research demonstrates how rhetorical devices increase advertising effectiveness. The results of this preliminary study do not comply with these findings, indicating no effect of rhetorical figuration in a typeface design on consumer's affective response. In order to interpret these results, we need to consider effects of ad elements (picture, text language, text aesthetics) that employ rhetorical devices separately, as well as jointly. Namely, one possible explanation for this effect might be the well-established picture superiority effect. When both visual and verbal are semantically processed effectiveness equates to that of the visually organised stimuli (Childers & Houston, 1984). In a study that compares visual and verbal rhetorical figures, the results replicate the picture superiority effect (McQuarrie & Mick, 2003). If we were to take rhetorical figuration from the pictorial part and control it for the picture realism (Gkiouzepas & Hogg, 2011), we might expect stronger influence of the typeface design on the semantic level.

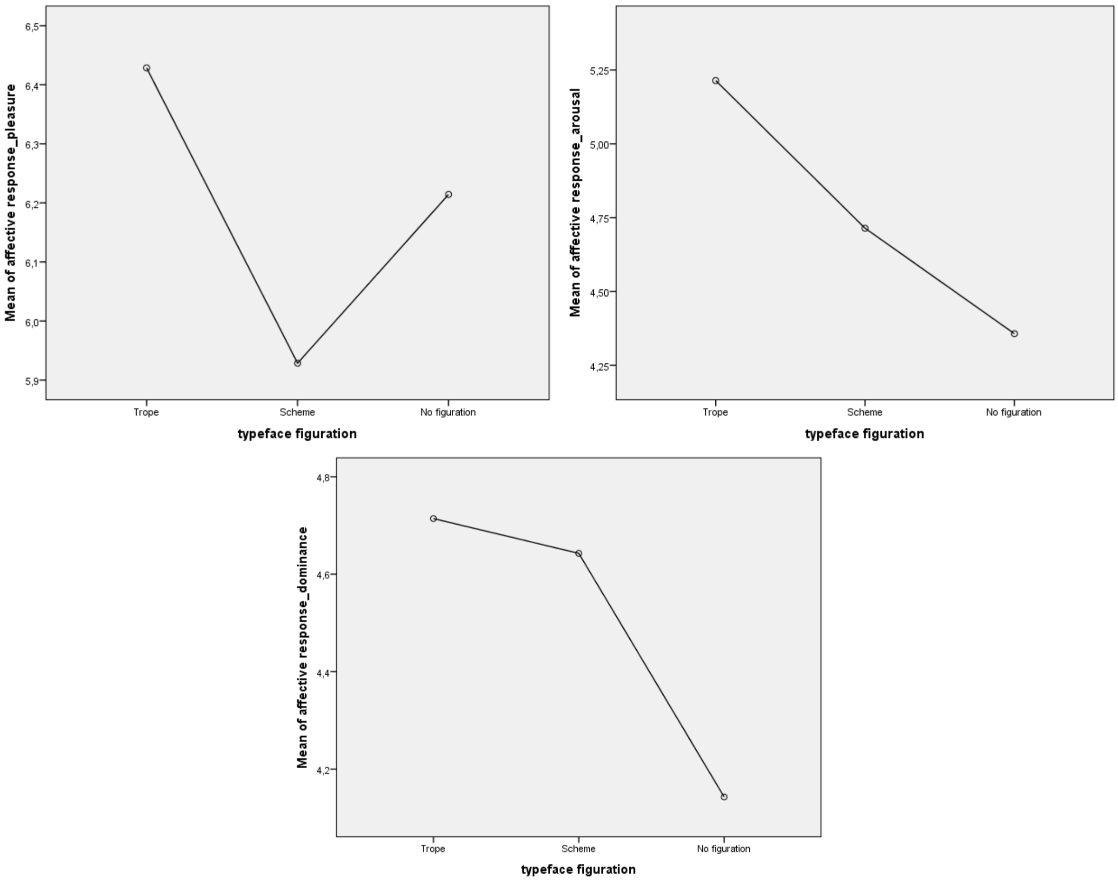

Figure 5: The relationship between dependent and independent variable for the second target advertisement (rail service). The effects of typeface figuration (no figuration, scheme, trope) on the three dimensions of the affective response (pleasure, arousal, dominance).

Another implication that stems from our results relates to the relationship of the rhetorical figuration and the type of the product. As we can see from the graphical presentation of the first target advertisement for a tooth paste (see Figure 4), participants who viewed the ad with headline set in a typeface with a trope (M = 5.43) rated the ad lower on the scores of pleasure dimension than the ones who viewed an ad with a typeface set in more regular figuration i.e. scheme (M = 6.07). For the second target advertisement (see Figure 5) ratings for pleasure dimension were higher for an ad with a typeface set in more irregular figuration (M = 6.43) than for the one set in a scheme (M = 5.93). This relatively small, but evident, distinction may be explained by the way we process and perceive product types (Stafford, Stafford, & Day, 2002). If we fall back on the conclusions of DeRosia [28] that pleasure is the most conjectured emotional response from rhetorical figures, we might presume that higher ratings for the pleasure dimension for the second advertisement for the rail service implies a kind of relationship between a product type and rhetorical figuration. Specifically, we might conjecture the connection between an emotional products/services and rhetorical tropes as more irregular and complex figurative operations.

5. CONCLUSIONS

This preliminary study set out to examine the relationship between consumer affective response and rhetorical figuration in typeface design. We found no main effect of figurative typefaces on emotional response. However, the affective ratings of participants reveal interesting behavioural patterns. For example, in this study mean ratings for pleasure dimension of the high emotional product (rail services) were higher than the ones for the low thinking product (tooth paste) when we examined manipulation checks. These results are consistent with previous research on product type perception, indicating that not only pictorial and verbal aspects of an advertisement contribute to the consumer's perception, but also the "dressing up" of the written word in a form of the typeface design. Taken together, the future research needs to control for the figurativeness of visual rhetoric in the pictorial and typeface design. Additionally, when inspecting consumer affective response researchers might take into consideration the control for the type of the product and the level of figurativeness of the typeface design.

6. ACKNOWLEDGMENTS

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Original scientific paper

READABILITY OF TEXT SET UP WITH UNIWIDTH TYPEFACE OF DIFFERENT FONT WEIGHTS

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Abstract: *This study examines readability of uniwidth slab serif typeface designed in three different weights. More specifically, it investigates how these three different weights prepared as uniwidth fonts affect both reading time and reading comprehension. The term uniwidth is applied to proportionally spaced typeface which character widths are consistent along its weight axis. One character has the same letter width throughout all weights. With uniwidth typefaces, the line lengths of text paragraph remain the same in the heavier weight because each character (regardless of its weight) shares the same width. To study the effect of letter spacing on readability of texts on the screen, participants had the task to read paragraphs of text set with different font weights. The main variables that were observed were reading time and comprehension. For comprehension, we used questions to make sure that the text was understood. The main purpose of this study is to examine possible disadvantages of uniwidth typefaces regarding readability, specifically when they are set in a various number of weights. Results indicate that font weight and inter-letter spacing did not have a significant influence on the readability of text set up with uniwidth typefaces. Therefore, these typefaces could be used without degradation in reading performance for these two different typefaces and in all three different inter-letter spacing.*

Keywords: uniwidth typeface, inter-letter spacing, font weight, readability

1. INTRODUCTION

Uniwidth typefaces are a relatively new concept in typeface design. The term uniwidth is applied to proportionally spaced typefaces which character widths are consistent along its weight axis. One character has the same letter width throughout all weights. With uniwidth typefaces, the line lengths of text paragraph remain the same in the heavier weight because each character (regardless of its weight) shares the same width. One problem that may occur with uniwidth typefaces is degradation of character recognition and reading comfort when they are set up with thick stroke weights. Thick stroke weights could lead to small spacing between letters, so-called inter-letter spacing. The review of the literature focusing on effects that stroke boldness and letter spacing have on reading time and comprehension does not allow drawing definite conclusions based on previous research since there are different results. However, the impact of different weights and letter spacing on reading performance is researched on a variety of proportionally spaced and monospaced typefaces.

Bernard J.B. et al. (2013) suggests that by reducing or increasing the thickness (boldness) of letter strokes, reading speed is not affected, until the letter strokes become very thin or very thick. In a study by Geske J. (1996), concerning effects of stroke boldness on reading performance, legibility of Helvetica font was tested in three different sizes and three different styles (regular, bold and italic). Results indicated no significant differences for legibility in the normal typeface, while bold typeface significantly increased the legibility in most cases. However, this research did not take into consideration measuring readability, which is affected by variables such as line length, and leading. Chung S. T. L. (2002) examined whether reading speed can be improved in central and peripheral vision by increasing the letter spacing. As expected, reading speed decreased with eccentricity and was faster for the larger print size. Reading speed increased with letter spacing, up to a critical letter spacing, and then either remained constant at the same reading speed or decreased slightly for larger letter spacing. Increased letter spacing beyond the standard size, which presumably decreases the adverse effect of crowding, does not lead to an increase in reading speed in central or peripheral vision. Nevertheless, this experiment was done using rapid serial visual presentation (RSVP) which presents only one word at a time to the participants rather than whole paragraphs of text as in normal reading.

In another study, Perea M. et al. (2012) examined if the slight increase of inter-letter spacing has a positive impact on readers' recognition of visually presented words, and whether increased inter-letter spacing affects the reading times and comprehension of a short text. They failed to find any significant

difference in overall reading times (in words per minute); only that wider inter-letter spacing was read slightly faster than the default inter-letter spacing. In addition, the comprehension score was almost the same in the two spacing conditions.
Arditi A. et al. (1990) compared the effects of fixed and variable (proportional) spacing on reading speed and found proportionally spaced typefaces to yield better performance at medium and large character sizes and fixed pitch to be superior for character sizes approaching the acuity limit. The data indicates at least two crowding effects (a phenomenon in which the presence of proximal contour elements is associated with reduced ability to identify what would otherwise be quite legible) at the smallest sizes: one that interferes with individual character identification and one that interferes with word identification.
In previous studies, increased letter spacing does not necessarily mean shorter reading times. Considering that in uniwidth typefaces the space that the character occupies remains the same throught different font weights, crowding effect may occur in heavier font weights. Crowding refers to the decreased visibility of a visual target in the presence of nearby objects, more specifically it refers to the spatial interaction between characters. Crowding among individual letters has been suggested as a factor contributing to slow reading (Chung, S. T. L., 2002).
The goal of this study is to determine if there are any advantages of using uniwidth typefaces, set in numerous weights, and how does it affect reading performance. This study looks at two basic research questions:

- Does the stroke thickness of uniwidth typefaces affect reading time and comprehension?
- Does the inter-letter spacing of uniwidth typefaces affect reading time and comprehension?

In this paper, we evaluated readers' performance measuring reading time and comprehension (Weisenmiller, E.M., 1999; Chandler, S.B., 2001). Based on previous researches we expect that the reading time will be slightly longer for thinner and bolder weights. As far as comprehension, stroke boldness and inter-letter spacing should not have significant influence.

2. MATERIALS AND METHODS

2.1 Participants

Thirty-four participants, ranged from 18 to 31 years old, participated in the experiment. All participants were naïve to this kind of visual experiment and had normal or corrected-to-normal vision. One participant was excluded from experiment because of lack of correction lenses, and nine of them were excluded because of errors in comprehension part of the test. Therefore, obtained data of reading times was extracted from a total number of twenty-four participants.

2.2 Stimuli

Two different typefaces (FF Hertz and Constanta) were used in the experiment. Both of them were designed as uniwidth (with same letter width throughout different weights). FF Hertz is classified as modern typeface and Constanta as slab serif typeface. Constanta typeface was designed on Department of graphic engineering and design as results of one of the bachelor thesis. Three different font weights of both typefaces were used in the experiment (Light, Regular and Extra Bold). Three paragraphs of text, set at 15 px cap-height and 10 px x-height, were used to evaluate reading speed. Monitor screen had resolution of 1920x1200 px (518x323mm). The texts were taken from popular science magazine and were around 270 words long with 65-75 characters per line (Bernard, M. et al, 2002). Paragraphs were set in both typefaces and all three weights. One text was set with FF Hertz sentence case, second with FF Hertz uppercase, and third with Constanta uppercase. These texts were used in all weights (Light, Regular, and Extra Bold). Each weight is presented to separate group of participants. Therefore, each group was consisted from eight participants.

2.3 Design

We used 2x3 multivariate factorial design for analysis. Two factors were manipulated in the experiment: typeface (FF Hertz or Constanta) and font weight (thin, regular and bold). For uniwidth typefaces, font weight determines their inter-letter spacing. Participants' reading time and answers were collected as the dependent variable.

2.4 Procedure

Participants were tested in darkened room. Practice trials for each typeface and each font weight preceded the experiment to familiarize participants with the procedure. These trials were conducted under the same conditions but with different paragraphs of text. Participants sat comfortably in a chair and rested their chin on a holder in order to achieve the constant distance of 57 cm between eyes and stimuli (Bernard, M. et al, 2002). Visual angle for uppercase letters was 0.406^0 and 0.271^0 for lowercase letters. One paragraph of text was shown at a time. Participants had the task to read all six paragraphs (three trial and three test paragraphs). Participants were instructed that they press the keyboard button when they are ready for the task and to press it again when they finished reading. Measuring of time started and stopped with each press of the button. After each paragraph, one comprehension question related to the text was presented to prevent participants from skimming the text. From three presented answers, only one was correct. Between each question and next paragraph of text, one blank page was inserted with a marker where the next text will appear. Reading time was measured using digital stopwatch with the precision of three decimals. Reading times and answers were collected for each participant.

3. RESULTS

Figure 1 represents values for reading time of three independent groups. The first group was reading both typefaces in both sentence and uppercase values in light font weight, the second group in the regular and third group of participants in extra bold font weight.

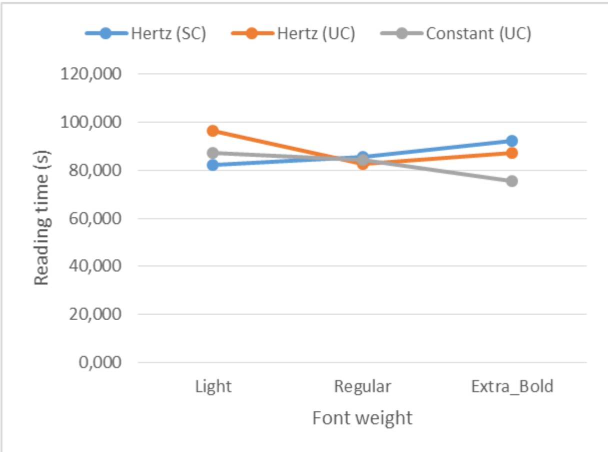
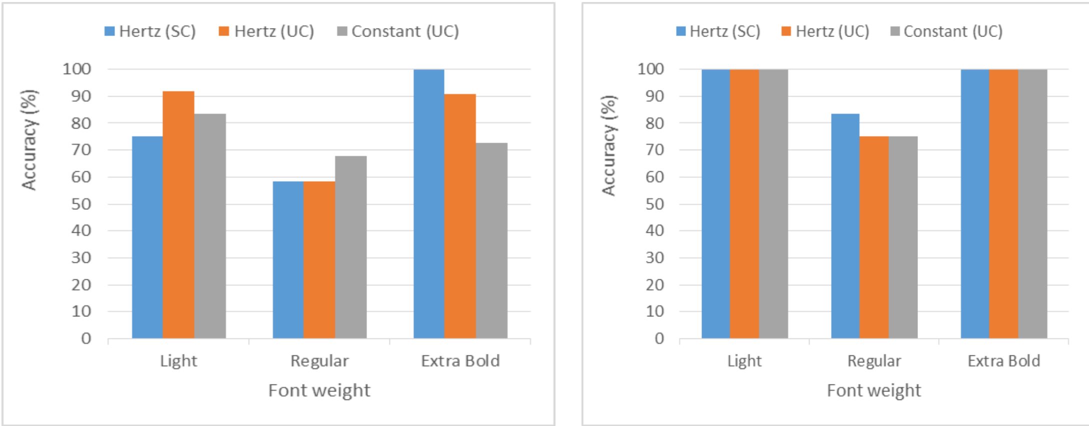


Figure 1: Reading times for FF Hertz sentance case (Hertz SC), uppercase (Hertz UC) and Constant uppercase (Constant UC) in light, regular and extra bold font weights

The mean value of reading times for FF Hertz sentence case typeface was shortest for light font weight and then rise as font weight was higher. FF Hertz uppercase had shortest mean reading times for regular font weight and longest for light font weight. Constanta uppercase had shortest mean reading times for extra bold font weight and then dropped, as font weight was lighter.

Two-factor univariate analysis with different groups was conducted to show the influence of font type and font weight on participants' reading times. Font weight of these two uniwidth typefaces determines the inter-letter spacing. Thinner font weight leads to wider spacing between characters and thicker weights lead to narrower inter-letter spacing. Twenty-four participants were divided into three groups. The first group only read light typefaces (wider inter-letter spacing), the second group read regular typefaces (normal inter-letter spacing) and the third group read extra bold typefaces (narrow inter-letter spacing). Influence of interaction between font type and font weight was not significantly important, $F (4, 63) = 1,384$, $p = 0,25$. Influence of font type was also not significantly important, $F (2, 63) = 0,905$, $p = 0,41$. The same case is for font weight, $F (2, 63) = 0,47$, $p = 0,627$.



a) *b)*

Figure 2: a) Accuracy presented as percentage of correctly answered questions in trials and comprehension test and b) results only for comperhension test

In Figure 2a, percentages of errors in comprehension test (including practice trials) are shown for all typefaces and font weights. The highest percentage of errors is noticed in regular font weight for all typefaces. In Figure 2b only percentages of errors in real test trials are presented. Participants had difficulties in comprehension only in regular font weight for all typefaces. Uppercase letters for both typefaces led to the higher error rate. Error rates were 16,67 % for regular FF Hertz sentence case and 25 % for uppercase FF Hertz and Constanta typefaces.

4. DISCUSSION

Reading times in all three groups (font weights) had statistically similar values. These results are partially in conflict with results of Bernard J.-B. et al (2013) who found that reading time is affected only at very thin and very thick font weights. This mismatch in our results could be explained due to lack of extremely light and extremely bold font weight in FF Hertz and Constanta. This is especially the case for Constanta typeface, which has small differences in stroke thickness across all font weights. If we compare only uppercase variants of FF Hertz and Constanta (Constanta has only uppercase letters designed) for both light font weight and extra bold font weight Constanta had shorter reading times. For regular font weight, FF Hertz had slightly better reading times. Nevertheless, these improvements were not significantly important. Accuracy was impaired only in the second group (regular font weight). In this font weight, uppercase letters for both typefaces had the higher error rate. This result could be addressed to text skimming at this font weight but that was not the case. Our participants did not read significantly faster at this font weight compared to other two weights. Other explanation could be that at this common stroke weight, participants were only concentrated on reading the text without focusing on context. This assumption should be tested using a larger sample.

Influence of inter-letter spacing on reading time and comprehension was not significantly important. In research of Chung S.T.L. (2002), increased inter-letter spacing in central and peripheral vision contributed to increasing in reading speed, but only until the certain point. Further increase in letter spacing did not lead to faster reading. In our study, we have increased inter-letter spacing in case of thin font weight and decreased in inter-letter spacing in case of thick font weight. However, these changes in letter spacing were in boundaries that they could not affect reading speed nor accuracy in any significant matter. Opposite to findings of Chung S.T.L., our results showed that increasing or decreasing of inter-letter spacing did not significantly affect reading speed. Only the accuracy was affected at the normal inter-letter spacing (regular weight) which is opposite to findings of Chung S. T. L. However, our findings, regarding the influence of inter-letter spacing on reading speed and accuracy, was similar to findings of Perea M. et al. (2012). They did not find any significant differences in reading speed nor comprehension by changing the inter-letter spacing. Apparently, in our case, at higher font weight did not come to crowding effect. This would probably be the case if stroke weight would exceed some kind of boundary value.

5. CONCLUSIONS

The goal of this study is to determine if there are any disadvantages using uniwidth typefaces, set in numerous weights, and how does it affect reading performance. The first experimental question was does the stroke thickness of uniwidth typefaces enhance or reduce reading time and comprehension?
Results show that font weight did not significantly influence reading time. However, FF Hertz sentence case had best reading time at light font weight. An uppercase variant of FF Hertz had the shortest reading time at regular font weight and Constant uppercase at extra bold font weight. Our first hypothesis was that reading times would be longer for thinner and thicker font weights. For FF Hertz uppercase that was the case in contrast to Constanta uppercase. Stroke thickness did affect comprehension of text in some manner. Participants report wrong answers in regular font weight for both typefaces. Reading times were not significantly affected in case of wrong answers so font weight did not affect the reading performance in any significant way. Therefore, our first hypothesis was not confirmed.
The second experimental question was does the inter-letter spacing of uniwidth typefaces affect reading time and comprehension? Our second hypothesis was that smaller inter-letter spacing for uniwidth fonts (bolder font weights) would decrease reading performance. Reading times were only decreased in the case of sentence case FF Hertz typeface. For Constanta uppercase, results were quite opposite. Reducing inter-letter spacing slightly improved reading speed. Comprehension was degraded in normal inter-letter spacing (regular font weight), without significant degradation in reading time. Therefore, the second hypothesis was also not confirmed.
These findings indicate that font weight and inter-letter spacing did not have the significant influence on the readability of text set up with uniwidth typefaces. Therefore, these kinds of typefaces could be used without degradation in reading performance for these two different typefaces and in all three different inter-letter spacing. Further research should take into consideration different typefaces and larger sample of participants.

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PICTOGRAMS ON PACKAGING: A COMPARISON OF OBJECTIVE AND SUBJECTIVE MEASURES OF THEIR NOTICEABILITY

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Abstract: *Safety pictograms convey information to consumers who should be warned and protected from consequences that may arise as a result of the misuse of a product. The noticeability of the safety pictograms on the packaging is a prerequisite for the effectiveness of this communication. There are few methods for measuring the noticeability of the pictograms. In general, they can be based on objective or subjective estimations. This paper investigates the association between the objective and the subjective methods (namely eye-tracking and subjective scores) in order to examine whether expensive eye-tracking procedures can be replaced with low-cost procedures, such as subjective evaluation. Since the packaging is common medium for transmission of safety information by the pictograms, stimuli used in the study are samples of packaging that differ according to shape, colour and transparency. The results of the investigation of these variables provides wider insight in possible moderators of noticeability and gives clearer directions for future research in the field of communication role of the packaging.*

Key words: pictogram, packaging, noticeability

1. INTRODUCTION

Safety messages on the packaging have a role in protecting the user from the possible consequences of the misuse of the product. These messages commonly have the form of pictograms. The pictograms are simplified pictures that represent some object, concept or activity, and their meaning is understandable for the most. Some of the reasons for the often usage of the pictograms are breaking the language barriers, improving the memorability and enhancing the noticeability of the safety message. Speaking of noticeability, some studies have shown that the safety warnings which contain the pictograms quickly catch the users' attention and increase its noticeability (Laughery et al., 1993; Young, 1991). The noticeability of safety message on the packaging is a prerequisite for the effectiveness of the warning information. In other words, if users do not detect the warning, we cannot expect that they will process it or comply with it.
Drawing on the previous research, it is apparent that the noticeability of safety messages has been measured in a variety of ways. In the most cases, it has been measured indirectly by means of other variables such as memory. For example, in their study of health warning labels on alcohol beverage containers, Kaskutas and Greenfield (1991) conducted a survey six months prior to and six months after the enactment of the warning label law. Their method was based on the number of the respondents who reported having seen the warning labels, which reflected whether the respondents noticed the warning message. Indirect methods like this one are generally simple for use and they do not require special equipment. On the other hand, they reveal data that do not present clear relationship between the noticeability and influencing variables, which leaves space for ambiguous interpretations. Hence it is more suitable to use methods that gather data more directly. In general, direct methods can be based on objective or subjective estimations. This study focuses on eye tracking technology as an objective technique and on subjective scoring as a subjective measure.
Eye tracking method provides the information on which parts of the visual display participants are looking at any given time (Poole and Ball, 2005). It is based on the recording the participants' eye movements. Eye movements occur by alternating between saccades and fixation. A fixation refers to the time spent looking at the particular area on display, while saccade refers to eye movements while shifting the focus from one area to the next (Calitz et al., 2009). The sequence of fixations and saccades forms a scanpath which reflects participant's observing strategy. The observing strategy presents the directions of visual attention and provides insights on how the participant structures the visual information (Schiessl et al., 2003). That is why eye tracking can be used for objective evaluation of the noticeability, visibility and distinctivity of visual signs in specific surrounding. It is also very useful in investigation of scanning patterns while searching for target information (see Laughery et al. (1993) for the example). Researchers have measured variety of variables in order to determine participants' visual attention to warning messages. The most common

measures were time to notice the information (Laughery et al., 1993) and time spent on viewing the information (Cowley, 2009).
Perception of visual stimuli relies on individual characteristics to a certain extent and these individual aspects can affect attention. In comparison with technical data gathered by eye tracking, subjective assessment provides data that give wider insides about personal impressions of end users. In most cases, self-reports reveal additional valuable information that is independent of eye tracking quantitative measures, such as opinion or supplemental explanations of individual responses. While conducting the subjective evaluation, researcher should be aware of its potential difficulties and try to reduce it by planning the adequate experimental procedures. In order to get representative results, the number of participants should be large, which makes the process time-consuming. Furthermore, observation should be carried out in controlled conditions that are uniformed for each participant. Even if these requirements are fulfilled, the interpretation of collected data should made with consideration of the effects of participants' individual differences, like psychophysical attributes, personal experience and subjective judgement of evaluation procedure. Hence it is advisable to use homogeneous group of observers. In general, having the benefits and limitations in mind, subjective visual assessment offers great opportunities for insights into different aspects of safety communication by information on packaging. The key is in thoughtful design of experimental design and its careful procedure.
While comparing subjective scoring and eye tracking, it is clear that both methods have some merits and disadvantages. The most important benefit of eye tracking is direct relationship between the processes of detecting the visual stimuli and the accompanying measured data, while its disadvantage is the cost of the eye tracking equipment. On the other side, subjective scoring is less expensive from the point of experimental apparatus. The aim of this study was to compare the results gathered by these two methods in order to get closer to answering the question whether expensive eye-tracking procedures can be replaced with low-cost procedures, such as subjective evaluation. Besides, this study investigated how packaging characteristics (particularly shape, colour and transparency) affect the noticeability of the pictograms applied on the packaging.

2. METHODS

The noticeability of safety pictogram was investigated by two methods – one objective and another subjective. The measure of objective assessment was time to fist fixation on the pictogram, while the measure of subjective assessment was the score based on personal evaluation. The following sections describe the procedures, samples and equipment used in each of the methods.

2.1 Objective method

The objective method was based on eye tracking technology. The stimuli were presented on a Lenovo computer display (model LEN L1900pA) and viewed from a distance of 60 (+/–1) cm. The resolution of the computer screen was set to 1280 x 1024 pixels with a refresh rate of 60 Hz. Fixations and time to first fixation on the pictogram were recorded with Tobii Eye Tracker X60 with a sampling rate of 60 Hz and an accuracy of 0.5 degree. The presentation of the eye-tracking stimuli was created using the Tobii Studio 3.2.1. software.
30 observers participated in eye tracking testing. All of them were students at the University of Zagreb, Faculty of Graphic Arts, who voluntarily participated in the experiment. Their ages ranged from 21 to 24 years of age (M = 22.73, SD = 0.91). 63% of the participants were female and 37% were male. All of the participants had normal vision or corrected-to-normal vision.
Packaging samples were presented on screen in the form of three-dimensional models. Figure 1 shows the examples of the packaging samples. The samples were designed especially for the purpose of the study and they differed according to following packaging characteristics. The colour was varied at four levels (yellow, blue, red, multi-coloured), shape was varied at two levels (rounded, angular) and the transparency was also varied at two levels (transparent, nontransparent). Combination of all of these levels resulted with 16 samples.

Figure 1: The examples of the packaging samples

The eye tracking experiment was conducted on in a slightly dimmed room isolated from outside distractions. The room was located within the Faculty of Graphic Arts at the University of Zagreb. Each student individually participated in the experimental procedure. Before the measuring the fixations on the samples, the calibration was performed in order to relate an observer's gaze angle to locations at the display (Goldberg and Wichansky, 2002). After that, the participants were familiarized with the samples by seeing one example of the packaging that was excluded from the later analyses. They were asked to look at the presented sample in a way as they would do if they observed it in their realistic everyday environment. They were informed that presentation of the samples is time-limited. The presentation started by displaying the white symbol "x" in the middle of the black screen. Its purpose was to drive the participant's attention to a neutral starting position. After that one of the samples were shown. Its presentation time was 5 seconds. Then again the black screen with white "x" was displayed in order to compensate for fatigue effects and to prepare the participant for the next sample. Samples were displayed randomly to avoid ordering effect. After the experiment ended, subjects were thanked for their participation and debriefed.

2.2 Subjective method

Subjective method was based on subjective scoring during visual assessment. 30 observers participated in visual assessment. All of them were students at the University of Zagreb, Faculty of Graphic Arts, who voluntarily participated in the experiment. Their ages ranged from 22 to 24 years of age ($M = 23.07$, $SD = 0.64$). 53% of the participants were female and 47% were male. All of the participants had normal vision or corrected-to-normal vision.

Observers were asked to take the Ishihara Colour Vision Test before the experiment to ensure they did not have any colour defects. The experiment took place in the XRite Macbeth Judge II-S Light Booth located in a dark windowless room at the Faculty of Graphic Arts at the University of Zagreb. Macbeth D50 lighting source with 5230 K colour temperature was used for lighting the booth. Luminance level was 1227 lux. Overhead lighting was turned off. The observers viewed the samples at an angle of approximately 45° at a distance of around 30 cm. Before they started with the evaluation, participants were informed about the experimental procedure by using a sample that was not included in the later analysis. The observation time was unlimited. The participants' task was to evaluate the safety pictograms on the packaging by rating their noticeability on the basis of 7-point Likert scale ratings (7 = excellent, 1 = unacceptable).

Design of the packaging was identical to the design of the samples presented in the previous eye tracking experiment, except in this case the packaging samples were printed and folded in their final shape, so the participants could touch them and view them from all sides like they do in everyday life. Packaging dimensions were 60 x 60 x 100 mm. Nontransparent packaging was made of cardboard, while transparent packaging was made of plastic material with attached foil with print.

3. RESULTS

To test whether the packaging manipulations would affect the noticeability of safety pictogram, three separate tests were conducted with packaging shape, packaging transparency, and packaging colour as independent variables and time to fixate the pictogram as dependent variable. The Kolmogorov–Smirnov test of normality revealed that the assumption of normality was violated in all cases (all $p < 0.001$), and therefore nonparametric methods of statistical analysis were used.

The median and 1st and 3rd quartiles in parenthesis are reported in the results. Mann-Whitney U tests showed that angular packaging took significantly longer to detect the pictogram than rounded packaging

(Mann-Whitney U = 18873.5, $p < 0.001$). This result is corroborated by Figure 2 that represents the scanpaths of the two participants for angular and rounded samples. The median time to detection of the pictogram on the angular packaging was 2.41 (2.01 – 2.64) and in the case of rounded packaging it was 2.12 (1.25 – 2.31). Transparent packaging also took more time to notice the pictogram, Mdn = 2.31 (1.98, 2.52) than non-transparent packaging, Mdn = 2.29 (1.84 – 2.45), but the Mann-Whitney U test did not reveal a significant difference between these two conditions (Mann-Whitney U = 27123.5, $p = 0.269$). The median times to first fixation on the pictogram on the yellow, blue, red and multicoloured packaging were 2.24 (1.89 – 2.58), 2.36 (1.91 – 2.51), 2.18 (1.87 – 2.36), 2.31 (1.63 – 2.41), respectively, with no significant difference according to the Kruskal-Wallis test ($\chi^2(63) = 7.25$, $p = 0.06$).
Spearman correlation analyse was performed to evaluate the association between objective and subjective measures, particularly between the time to first fixation on the pictogram and subjective scores of its noticeability (Figure 3). Spearman correlation coefficient was -0.72, indicating that longer times to detection of the pictograms are correlated with lower subjective scores, and this relationship was significant ($p = 0.002$).

Figure 2: Scanpaths of two participants that reflect fixation order before fixating the pictogram

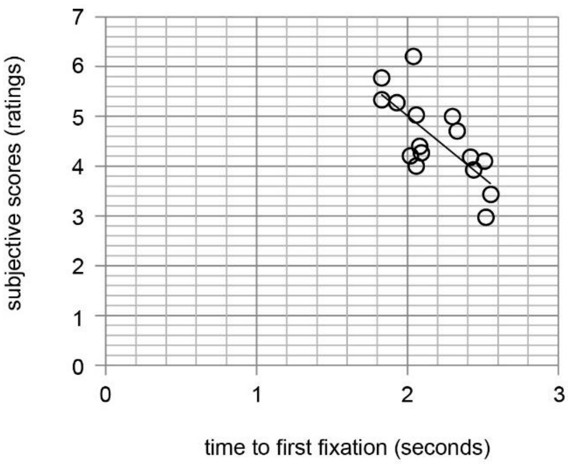

Figure 3. Graph shows correlation between objective and subjective measures

4. DISCUSSION

4.1 Packaging variables

The results showed that packaging can affect the noticeability of the pictogram. Among all the packaging characteristics included in our study, the angular shape was the significant factor that lengthened time to pictogram detection. This is in line with previous study (Kovačević et al., 2013) which showed that the safety pictograms on the samples of the cylindrical commercial packaging were evaluated as superior in comparison to angular ones. In that study, the noticeability of pictograms was measured only by subjective assessment without supplementing the objective measures. Despite this shortcoming, the results showed clear congruity with the results in this study. Adequacy of rounded shapes of packaging and containers was also indicated in Schenieder’s investigation of children's attraction toward the containers of harmful substances (Schneider, 1977). His results showed that rounded packaging have tendency to improve children’s safety when it comes to controlling accidental childhood poisoning by packaging design. However, there are notable differences in methodology, such as packaging sample selection or experimental procedure, so the comparison between the results revealed by this study and those reported in mentioned researches should be made with caution.

The transparency of packaging material and packaging colour did not affect the noticeability of pictogram. The lack of the colour effect is somehow intelligible, mainly because the power of the colour mostly comes to the fore when it is combined with some other colour, creating the contrast between the packaging colour and the colour of the pictogram. For example, while investigating the noticeability of computer icons, Huang (2008) found the effect of colour on visual search time at the basis of five different figure/background colour combinations. It seems that our study did not cover enough colour combinations that could explain how colour would drive users’ attention to pictogram in different colour context.

In the investigation of transparency effect, our study showed that pictogram was detected slightly easier on the non-transparent packaging. This could be explained by clearer visibility of the elements printed on the packaging surface that is opaque. Nontranslucent packaging material does not expose potentially visually disturbing parts of the product. However, it should be noted that transparency effect was not statistically significant. This was surprising, mainly because some previous studies have shown that visibility through the packaging material can affect the perception of the packaging (Vilnai-Yavetz and Koren, 2013).

4.2 Comparison of objective and subjective method

Users’ subjective evaluation was in accordance with visual response recorded by eye-tracking technology, indicating a strong correlation between objective and subjective measures. In other words, quickly fixated pictograms were rated as more noticeable. The strength of this relationship is relatively surprising given that subjective scoring was based on individual attitude and personal preferences that may greatly vary across the group of users. The reason for the consistency of these results probably lays in the homogeneity of the group of the participants. Besides that, it is possible that strong differentiation between examined samples enabled clear and undisputable self-reporting outcomes within pictogram evaluation, which homogenized the results.

Although our study showed the concurrence of subjective measures, we cannot expect that this will always be the case. In practice, it is hard to control over many other influencing variables that are highly dependent on the individual subject (Manhartsberger and Zellhofer, 2005). Even if this difficulty is reduced by careful experimental design, researcher should have in mind that, like any self-report measures, subjective scoring may not be accurate reflection of true users’ impressions (Martin and Hanington, 2012). That is why the objective measurements are more effective tool in testing the visual stimuli and should be used when possible. Eye tracking as the most common objective method of investigating human visual responses gives technical information on exactly which parts of packaging participants are fixating, and provides viewing patterns during visual search. Besides, it provides accurate time calculations such as fixation duration or time to detection of particular visual element. In our study, these directly gathered objective measures has been shown as effective in analysing the influence of packaging manipulations. Still, in some other circumstances, the eye tracking technology could be too expensive (costly equipment) or inappropriate for use (unrealistic experimental environment). The researcher should be aware of these limitations before planning the experimental procedure.

The subjective scoring method also has been shown as effective in our study. Despite its strong correlation with eye tracking measures, we cannot say that it is always reasonable to use it as a replacement for eye tracking. It is true that subjective scoring does not require expensive equipment, but it is time-consuming and involves a large number of participants. In many cases these difficulties can override the benefits of this method.

5. CONCLUSIONS

Two main findings were revealed by our study. First, among packaging shape, colour and transparency, only the shape affected the noticeability of safety pictogram. This result suggests that, in early stage of packaging design, designer should take into account that pictogram could be less noticeable on angular packaging. In line with that, the pictogram on angular packaging should be designed as prominent visual unit that stands out among other graphical elements. This is especially important if the product is unsafe and ignoring the safety pictogram can lead to harmful consequences. Another finding is that subjective responses can strongly support objective eye tracking measures, so both methods can be used in testing the best design solutions and deciding about the direction a design should go. However, the benefits and weaknesses of each method should be taken into consideration when choosing an appropriate experimental procedure.

There are several limitations to this study. First, in both experiments only young participants were included. Since the visual acuity and attention processes change over time, it is plausible that older participants respond differently on packaging samples. Furthermore, the number of the levels of the experimental factors was quite small. Future research should examine more levels of packaging characteristics, including more pictogram/packaging colour combinations. Besides that, future studies should use other methods based on feedback from potential users and examine the relationship between these responses and eye tracking data.

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LITHUANIAN GRAPHIC DESIGN: ON THE CROSSROADS

(Creating the features of State image by means of graphic design)

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Abstract: *The essential feature of graphics design in Lithuania is the weakness of deep historical roots and fluctuation of traditions. The first qualified examples of applied graphics, dedicated to state institutions and aristocracy image, were developed in the late middle ages by the professional artists coming from abroad. The nearest expanding neighbors where orientated to the opulent Imperial style aesthetic values, which were too splendid for our modest motherland. At least the ethical and political circumstances made this "Imperial trace" (both Russian and Polish) not appropriate in Lithuanian context.*

The other approach was based on the finding the roots of graphic design and communication in folk arts and crafts.This made a deep influence on graphics as a topic of fine arts in the first years of 20 th century and made peculiar results, interacting with the traces of Art Deco in between-wars period of our „first" independence. During the Soviet years the huge wave of primitive realism arosed, impelled by huge ideological pressing. That trend induced the appearance of west-orientated "Silent modernism", not rebelling, but silently developed in "parallel reality". In the period after restoration of independence Lithuanian graphic design appeared on the crossroad again, searching for the explicit authenticity of National visual identity, starting from our national symbols and finishing by persuasive examples of branding and corporate identity.

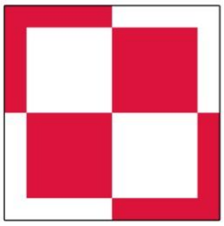
Key words: National graphic identity, Graphic Design, Lithuania

1. THE ROOTS OF NATIONAL IDENTITY

The development of graphic identity in Lithuania started from the expressive image of knight rider, first mentioned in the middle of 13 th century by the second Grand duke of Lithuania Narimantas. This sign, depicting white rider on red background, named Pagaunė (*Pogonia* in polish language)for the first time used as a State symbol in 1366. It was one of the few Coats of Arms in Europe, resulting directly from the image of State Leader and his surrounding. For the first time it was depicted in 1485 in Bavarian chronicles, but obviously, it's a copy of earlier drawing. In addition to it, two more clear graphic symbols where used: The Poles of Gediminas, having local pre-christian origins, which later played an exceptional role in Lithuanian graphic design, and two-traversed Wladyslav cross (named after son of Grand duke and Polish king Jogaila). The contrast and readability of symbols had a strong functional meaning, especially on the battlefield, tracing the movement of the units; the most known application of these features was the famous Grunewald battle in 1410. At that time the identity symbols of other noblemen where fare from the European heraldic level; as a result, the Polish counterparts had a poor opinion on the Lithuanian estate's culture (Trinkūnas, 2009). The situation changed in 1569, when after Lublin Union joint Polish-Lithuanian federation was created, and polish noblemen „shared" their coats of arms with Lithuanian counterparts; later it lead to intensive polonization of Lithuanian aristocraty and graphic culture in general. Creating the main symbol of joint state, the original design solution was made: the shield was divided into 4 square plates; two of them were dedicated to red Lithuanian knight, the other two – to white polish eagle. The result is fixed for ages on the enterance gates of Wawel castle in Krakow and the geometrical stylization of it („red-white chess") is still used as emblem of Polish army (fig. 01). Alas, all the achievments of heraldics and graphic design were lost at the end of 18th century together with state independence.

The Coat of Arms of Grand Duke Vytautas (from Bavarian State archive, 1485)

The State Coat of Arms on Wawel castle gates (mid.XVII a.)



The contemporary insignia of Polish army

Figure 1: Consolidation of two State symbols of Polish-Lithuanian commonwealth.

2. THE ESTABLISHMENT OF THE NATIONAL STATE AND „FIRST INDEPENDENCE“

The Establishment of Lithuanian national state in 1918 had a lot of unexpectedness and imprompt moments. The Graphic visualization of State insignia met huge difficulties, as all the symbols of old Rzecpospolita were expropriated by Poland, and the relations between two countries got rising tension. Lithuania needed urgent renewal of national identity, but the main ideas came not from artists, but from politicians. For example, there was only one artist (Antanas Žmuidzinavičius) in the Committee of Lithuanian Council, responsible for National flag selection. The choise was based on popular colors of Lithuanian folk clothes. As a result, the final composition of 3 colors, fixed in first state Constitution in 1922 (and being in use till now), was more common to tropical Africa or South America, than Eastern Europe. Later, the quantity of powerful artists and designers grew, but most of them after finishing the art studies abroad, were more influenced by Art Deco features, than local folk traditions. First of all, design was understood as series of typical „fashionable“ element‘s applications rather than search for individual expression. One of examples is famous designer Jonas Prapuolenis, who decorated functional examples of self-made furniture with some formal „folk style“ inlay and textile decoration. The search of National identy was interrupted by new occupation. Many artists of this period left Lithuania during WWII, „frozing“ this style in their after-war creations.

3. SOVIET PERIOD

During this period, starting from 1940, the role of Art and Design in forming the National identity was totally denied – all the solutions in this field where ideologized and usually made outside the country. Most of the works, especially during the first period (1946-54) were ideologically suppressed and adopted to All-Union demands; the skilled specialists found the creative expression possibilities in small „non-ideological“ applied graphic, including postcards, packaging, illustration etc. On the example of famous Lithuanian designer Feliksas Daukantas (1915-1996), we can trace an evolution from repeating random folk-style decoration (which can be estimated as keeping national features) to revealing of essential features of materials and structures, experienced both in graphic design and leather souvenirs crafts The design projects of Jonas Prapuolenis experienced the same transformation, which, as appeared later, were very close to common European late Modernism processes. In Soviet Union context those features were noticed and the artists/designers from Baltic republics were often invited to represent USSR applied arts „on European level“. The first sucessful attempt was made at Soviet Union Trade exhibition in London in 1968, which mobilised the best Lithuanian design efforts.

4. THE RETURN OF INDEPENDENCE

The process of returning of independence started on 23rd of August, 1987, and just after one year some insignia, including the National flag and Coat of Arms, were rehabilitated, and after 2 years, in 1990, after proclaiming the independence, became official state symbols again (the traditional Gran Duchy red flag with Vytis first was recognized as Presidential, but later was reshaped as „historical“ one). Some symbols got recognition again, and new significant symbols appeared, including logo of Sąjūdis, using some old elements and marking the raise of new social activities (fig. 2). On the wave of national euphoria the National flag (tricolor) and other symbols were applied widely, including the commercial use and advertising, sometimes in very unusual and inappropriate context, so it caused, together with total economic difficulties, a large disappointment and devaluation of national values (Dubonis, 1998). This process can be explained partly by unlimited, unestetical and unregulated use of State insignia and it‘s attributes, and also by collapse of public expectations of Independence benefits in short-time period. The absence of outside intervention treatment and rapidly growing property differentiation also complicated the consolidation of society on common social-political platform, marked by National graphic identity. Later, the Flag and other symbols regained their popularity again, especially during large official celebrations and international sport events.

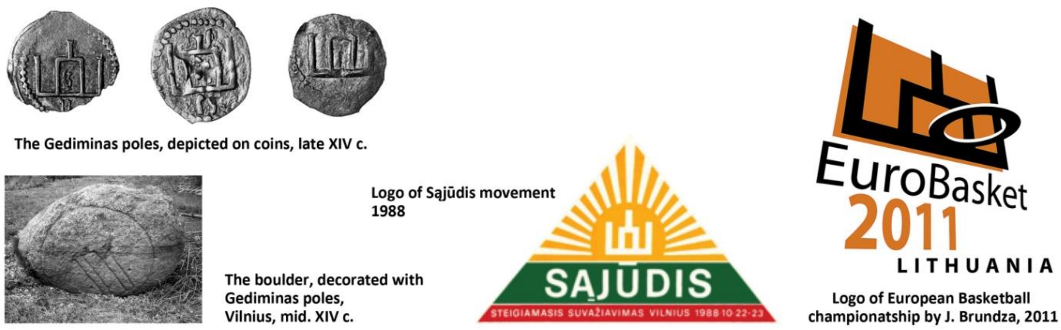


Figure 2: Using of ancient symbol of Gediminas‘ Poles in old and contemporary context

5. CONTEMPORARY EVOLUTION

Approx. 10 years after, when the social atmosphere reached some stability, the social and commercial interest to National insignia started growing again. Formally, it was mostly targeted to younger generation, which met some benefits and identified themself whith continuing Independence. This process, supported by growing social interest, is going on today.

One of the inherent and essential features of contemporary evolution of National graphic identity is the interpretation of above mentioned national symbol, illustrated on the State Coat of the Arms – Vytis, riding knight with rised sword. It‘s present redaction, created by artist Arvydas Každailis, was approved in 1991 Alas, it‘s use in visual communication, especially in the field of commerce, is rather complicated because of small and archaic details, which are strictly reglamented by state law (Každailis, 2009). So, the artists and designers seek not only to find some apropriate and „readable“ solutions, based on contemporary graphic language, but to approximate them to the taste and preference of our society and to adopt them (on professional level) to the needs of commercial communication. Between contemporary means we can mark the different kind of publications, including such small forms as post stamps and, of course, Euro coins, and some tryings to adopt the Coat of Arms to digital communication, including it‘s animated version.

One of the first contemporary projects belongs to Lithuanian-Canadian artist Telesforas Valius and is made in 1966. The linear figure is based on the imprint on ancient bronze coin, issued in 1385. Evaluating it as a logo we need to mark the clearness and originality of the silhouette. This symbol is often used in small size, seeking to stress the archaic origins of our state; one of it‘s interpretation was used to mark the celebration of Millennium of Lithuanian name in 2009. One more interpretation of medievial symbol, based on late-XVIII century drawing, is been successfully popularized by marketing means, advertising and sport events, including famous Dakar race. The complicated detailed drawing is used in flat or linear form and is filled with dynamic decorative meaning.

The official Coat of Arms of Lithuania by A. Každailis, 1991 | Vytis figure stylization by T. Valius, Canada, 1966 | State promotion project by R. Jucaitis, 2009 | Vytis (Pogonia) promotion in Belorussia, 1992

Figure 3: Contemporary interpretations of Vytis symbol.

One more successful try out was made in 2011 by designer Robertas Jucaitis (LGDA). The logo, dedicated to popularization of Lithuania's name around Baltic sea, was also based on archaic drawings and combined two popular symbols of our state – Vytis knight and Amber stone (fig.3). It was perfectly evaluated by design specialists, but did not acquired enough support by state institutions and wasn't distributed by means of marketing to meet larger response by mass consumption.
One of internationally recognized attempts of analysis and creative interpretation of graphic heritage was made in 2011 by graphic designer Edvardas Kavarskas (LGDA). Creating the series of packaging for Limited edition of alcohol drinks with obliged „Lithuanian" name, he sucseeded to avoid the traditional way of exploiting wealthy pseudo-heraldic symbols, changing them with clear rhythmical compositions including „national" colors. This project was awarded at few packaging competitions, and warmly adopted by younger groups of consumers (fig. 4).

Chair, winning Grad Prix at Paris exhibition by J. Prapuolenis, 1937 | Sketches of beverage labels by F. Daukantas, 1954-56 | Limited edition beverage graphics by E. Kavarskas, 2011 | Textile pattern and souvenir decoratiopn by LT Identity, 2013

Figure 4: Interpretation of national graphic motifs in different periods

"LT identity" – the long-continued and most famous project of fashion designers Ieva Ševiakovaitė and Jolanta Rimkutė, featuring graphic designer Edvardas Kavarskas, that consists not only of clothing, but also design and different daily items with strong graphic expression. All of these items reflect the faith of the designers to create the expression of new identity of Lithuanians by unusual means, including the main basic features and based on creative attitude to the past and a brave steps towards the future Designers constantly analyze current cultural experience of Lithuanian citizens, looking for new symbols, signs of current personal and national identity and interpreting it in a creative way. The collections included in this project play an important role in forming a positive attitude of Lithuanian citizens (especially young ones) towards themselves and their motherland.

6. POLITICAL CIRCUMSTANCES

The strong and convincing image of Lithuanian state symbols can help solving some actual social and political problems.
Among the features of European consolidation process, headed by European Union, some observers mark the common federalisation trends between EU and former Soviet Union. The East-European countries, which were liberated from Soviet oppression only 25 years ago, react very sharply on these „federalisation" attemps; the last political events showed the validity of these reactions. The strong image

of the State, including it's visual presentation, can help consolidate the Lithuanian society in the process of „integration, but not federalisation".

The process of mass emigration stays very actual from the very beginning of 2000, and now poses a threat to the future exsistence of independent and national Lithuanian state. Only in 2015 we lost up to 40 000 inhabitans leaving for Western Europe, and it is likely that most of them will never return back. Of course, graphic design has no power to stop this process, but it can help to create the positive image of native country, which will be also actual for next generation of emigrants, who can become non-speaking Lithuanian language anymore.

Rising of military tension in Eastern Europe also exsites the conflicts in the field of ideology and even history interpretation. As example, the officials of Belorussia in recent years, including some historians, continue discussing the reliance of State symbols, including the Vytis knight, to Lithuanian state (Razauskas, 2008). It is assessed as appropriation of some parts of historical hertitage and even the disorientation of Lithuanian State institutions, including the Armed forces (there's a possibility to mistake the insignia during the military conflict or to use it for some propaganda purposes). The clear and modern visual image, applied to mass communication, can help winning the possible ideological conflict, or at least to separate the identification of different institutions and units.

7. CONLUSIONS

- The old, even pre-historic etnical symbols, modificated up-to-date, can be used expressing modern social-political ideas and approaches (the example of Gediminas' poles)
- The application of effective „fashionable" elements to social communication can add short-time benefits, but will turn obsolete in historical perspective.
- Strong and coordinated presentation of State image elements, based on the use of coherent identity guidelines and their creative interpretation, can help solving social problems, forming positive social attitude.
- Today, the creation of strong National identy elements should reject ortodox graphic forms, be adapted to contemporary means of communication and should have an intensive social feedback.

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LEGIBILITY OF ECO FONTS

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Abstract: *The modern way of life represents a big burden for the nature; therefore, the importance of environmental protection is nowadays on the increase. Ecology is influenced by worldwide environmental protection. When thinking about ecological design, the solution of raw materials and materials that consume energy should be taken into consideration as well. Environmental friendliness has hence become a necessity in the modern way of life. Furthermore, the development of ecological design is of the essence. Within the context of ecological design, typographers also design fonts that spend less ink during printing. Nevertheless, these fonts need to be legible. In this research, we focused on the legibility of two eco fonts (i.e. Ecofont Vera Sans and Ryman Eco) in comparison with a conventional, non-eco widely used font (i.e. Times New Roman). The purpose of the research was to determine the eco font legibility in print media compared with the conventional font. For the purpose of the research, six different texts were selected. We took into account the length of the text, the number of characters per line and the number of lines. We put each text into one of the three fonts and two font sizes. The fonts were 10 and 8 points in size. The texts were printed by using an ink jet printing technology. We printed them on two different paper grades, i.e. mat coated and gloss coated papers. The legibility of printed texts was tested with the time of reading and a dichotomous question at the end of reading. Standard lightening conditions were measured with a spectrophotometer during the legibility testing. The typographic tonal density of all printed fonts was measured. The results showed that the eco fonts were read faster than the conventional, non-eco, font while the typographic tonal density was the lowest at the non-eco font.*

Keywords: typography, legibility, eco font, typographic tonal density, ecological design

1. INTRODUCTION

The modern way of life represents a big burden for the nature; therefore, the importance of environmental protection is nowadays on the increase. The field of ecology was at the beginning a part of biology, and it only later became an interdisciplinary science which covers natural sciences and human behaviour that influences the world changes (Vuk, 2000). Ecology is influenced by worldwide environmental protection. When thinking about ecological design, the solution of raw materials and materials that consume energy should be taken into consideration as well. Environmental friendliness has become a necessity in the modern way of life (Radonjič, 2008; *Zakon o varstvu okolja*, 2015). Furthermore, the development of ecological design is of the essence. Within the context of ecological design, typographers also design fonts that spend less ink during printing. Nevertheless, these fonts need to be legible.
The communication through a page or a screen requires the reader to translate symbols into meaning. Legibility refers to how easily this process is performed. To make reading possible, the text must be characterised by three properties (Reynolds, 1979):

- The property of visibility, so that a clear image of adequate size is received by the retina. The visibility requirements depend on the extent of viewer's eyesight.
- The recognisability or perceptibility of letters and words making up the text. This is affected by the factors such as type style and form as well as by the reader's reading skills.
- The property of comprehensibility. Comprehension is affected not only by the content of the text but also by its visibility and perceptibility, and by the verbal capacity and intelligence of the reader.

Legibility has been studied using different methods (Reynolds, 1979; Možina, 2001), e.g. visibility, perceptibility at a distance, perceptibility in peripheral vision, speed of perception, ocular movement, rate of work and other criteria. The rate of work is the most satisfactory measure for the legibility of a continuous text. The methods which have been used include the speed of reading aloud, speed of reading silently, speed of skimming or scanning the text (e.g. subjects are asked to locate specific items in the list of food ingredients or/and to locate specific target words in a text), and rate of comprehension (e.g. subjects are asked to answer open-ended or dichotomous questions). The rate of work is also useful in

studying the presentation of more complex materials (e.g. timetables and directories) (Reynolds, 1979; Možina, 2001).
A large number of studies on legibility points to its importance. There is a big discrepancy in understanding what makes a text legible. However, it is possible to determine some general guidelines that can help create a legible text. There are some typographic characteristics to be observed to make a text more legible. For a small type size, it is known that the differences in stroke weight and typographic tonal density (or typographic tonality) are significant (Možina et al., 2010; Rat et al., 2011), since they influence text legibility. Furthermore, a number of other typographic characteristics needs to be observed in order to make a text more legible, i.e. distinctive character features (counter shape), x-height, ascender, descender, serifs, contrast (stroke weight), set width, type size, leading (i.e. space between lines) etc (Reynolds, 1988; Možina, 2001; Gaultney, 2001; Tracy, 2003). The contrast depends on the difference between thick and thin strokes of a given letter. The set width defines the width of a letter (e.g. the same typeface style and the same size can have different letter width) (Bringhurst, 2002; Možina, 2003). In this research, we focused on the legibility of two eco fonts (i.e. Ecofont Vera Sans and Ryman Eco) in comparison with a conventional, non-eco, widely used font (i.e. Times New Roman).
The purpose of the research was to determine the eco font legibility in print media compared with the conventional font. For the purpose of the research, six different texts were selected. We took into account the length of the text, the number of characters per line and the number of lines. We put each text into one of the three fonts and two font sizes. The fonts were 10 and 8 points in size. Moreover, the typographic tonal density was taken into consideration as it refers to the relative blackness or shades of grey of type on a page. It can be expressed as the relative amount of ink per square centimetre, pica or inch (Keyes, 1993). The changes in various type features can create variations in typographic tonal density (Reynolds, 1988; Možina, 2001; Možina et al., 2007). The texts were printed by using an ink jet printing technology (Kipphan, 2001; Kumar, 2009). We printed them onto two different paper grades, i.e. mat coated and gloss coated papers. The legibility of printed texts was tested with the time of reading and a dichotomous question at the end of reading.

2. EXPERIMENTAL

The differences among different typefaces, type sizes, used papers and legibility were researched with legibility testing and the analysis of typographic properties.

2.1 Methods and Materials

In the research, the legibility of two eco fonts (i.e. Ecofont Vera Sans and Ryman Eco) was compared with a conventional, non-eco, widely used font (i.e. Times New Roman). The Ecofont Vera Sans (cf. Figure 1) is the oldest eco-friendly font, which was made in 2009. It is supposed to save 20% of more ink when compared to an ordinary sans-serif font (*Ecofont*, 2016). The font Ryman Eco (cf. Figure 2) was designed in 2014. It has serifs and uses on average by 33% less ink than standard fonts (*Ryan Eco*, 2016). The conventional font Times New Roman (cf. Figure 3) was designed in 1931 for the use in newspaper. It is different in stroke width and it has serifs (McLean, 1996). All three fonts were tested in two different sizes, i.e. 10 and 8 pt.
The test form was designed with the program Adobe InDesign CS6 and was used as a PDF file. We used two different papers, i.e. mat coated (EMBLEM Coated Paper, 140 g/m^2) and gloss coated paper (Papergraphics Micro-porous Satin Photo, 195 g/m^2). Black prints with 100% and 50% intensity were made with the ink jet technology, using the printer Canon IP 8400PG (Canon, Japan).
The differences in typographic tonal density of tested fonts were measured with an image analysis (ImageJ). This software gives the opportunity to measure, analyse and provide output values, e.g. area, number of particles, circularity and percentage of coverage (*National Institutes of Health, Research Services Branch*, 2015).

Figure 1: Font Ecofont Vera Sans

Tipografija

Figure 2: Font Ryman Eco

Tipografija

Figure 3: Font Times New Roman

2.2 Legibility

Different texts from the Slovenia edition of the journal *National Geographic* were printed in different fonts and type sizes onto different papers. Six different texts had between 10 and 13 lines, with 50–60 type characters in each line.

The observers (N = 40) were people aged between 18 and 25 years with a normal or corrected-to-normal vision. They read the texts at the same conditions of lighting measured with a spectrophotometer X-rite EyeOne (i1) (X-rite, Germany) and viewing distance between 300 and 400 mm. They were divided into 2 groups of 20 people. Each group read all 6 combinations of two repeated-measures factors (3 typefaces × 2 type sizes) on different paper. Among different groups, the texts were presented in random order contributing the Latin square design, which was used for counterbalancing the order of the texts, i.e. to randomise the measurement process and to eliminate possible effects of fatigue. Each group received the texts in a different order. For each tested individual, we measured the reading time and the answers for each text were analysed.

3. RESULTS AND DISCUSSION

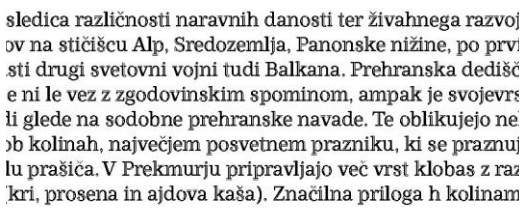
3.1 Typographic properties of prints

The typographic tonal density (TTD) of each font, each in different size, on each used papers was measured (cf. Tables 1 and 2). Parts of the texts and their binary pictures which were used as the base for image analysis, e.g. for measuring TTD, are presented in Figures 4 and 5.

The results show a higher TTD at the font Ryman Eco (cf. Tables 1 and 2) due to the wider stroke width of letters. The lowest TTD was observed at the font Times New Roman; however, the measured values are lower than those of Ecofont Vera Sans. The Ecofont Vera Sans letters have almost no differences in stroke width and have a big counter size, while the Times New Roman letters have a smaller counter size and stressed differences between the stroke width; its thin strokes are the thinnest among the tested fonts.

The obtained results show the biggest differences at the typefaces used in 8 pt size (cf. Tables 1 and 2). The typographic tonal density at smaller typeface sizes is usually higher due to a smaller counter size of letters and leading.

There is only a slight difference in the value of TTD between the used papers (cf. Tables 1 and 2). On average, the value of TTD is barely noticably higher on the gloss coated paper.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ob kolinah, največjem posvetnem prazniku, ki se praznuj
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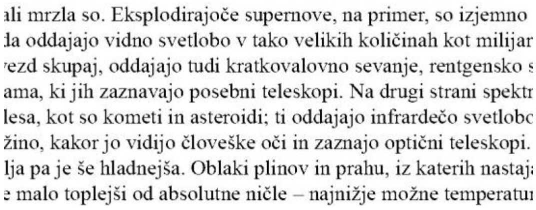
Figure 4: Binary picture of measured text in Ryman Eco font, 8 pt in size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lja pa je še hladnejša. Oblaki plinov in prahu, iz katerih nastaj
e malo toplejši od absolutne ničle – najnižje možne temperatu

Figure 5: Binary picture of measured text in Times New Roman font, 8 pt in size

Table 1: Value of typographic tonal density (TTD) of tested typefaces according to type size (10 and 8 pt) on mat coated paper

Text no.	1	2	3	4	5	6
Font	Ryman Eco	Ryman Eco	Times New Roman	Times New Roman	Eco Vera Sans	Eco Vera Sans
Type size (pt)	10	8	10	8	10	8
TTD (%)	19.95	20.91	15.78	17.40	17.56	18.71

Table 2: Value of typographic tonal density (TTD) of tested typefaces according to type size (10 and 8 pt) on gloss coated paper

Text no.	1	2	3	4	5	6
Font	Ryman Eco	Ryman Eco	Times New Roman	Times New Roman	Eco Vera Sans	Eco Vera Sans
Type size (pt)	10	8	10	8	10	8
TTD (%)	19.63	20.77	16.21	17.61	18.25	18.90

3.2 Legibility of prints

The first group of 20 observers (average age 21.85 years) read different texts on mat coated paper. 30% of observers were male and 70% female. While reading the texts, the average lightening in the room was 548.80 lux. The second group of 20 observers (average age 22.50 years) read different texts on gloss coated paper. 25% of observers were male and 75% female. While reading the texts, the average lightening in the room was 557.00 lux.

Figures 6 and 7 show the influence of the used typefaces, type sizes and papers on the speed of reading. Figures 8 and 9 show the average percentage of correct answers to different text questions.

On average, the reading speed was higher at the prints on mat coated paper (cf. Figures 6 and 7). At all examples, the texts printed with the Ryman Eco were read the fastest, regardless of the used papers. On average, the texts printed with Eco Vera Sans were read the slowest, the only exception was the text on gloss coated paper printed with Times New Roman in 8 pt type size. In previous research (Možina et al., 2010; Rat et al., 2011), it was established that the legibility of Times New Roman can be impeded at smaller sizes. The interaction between higher TTD and faster reading was noticed. A larger counter size gave a higher TTD value and consequently resulted in faster reading.

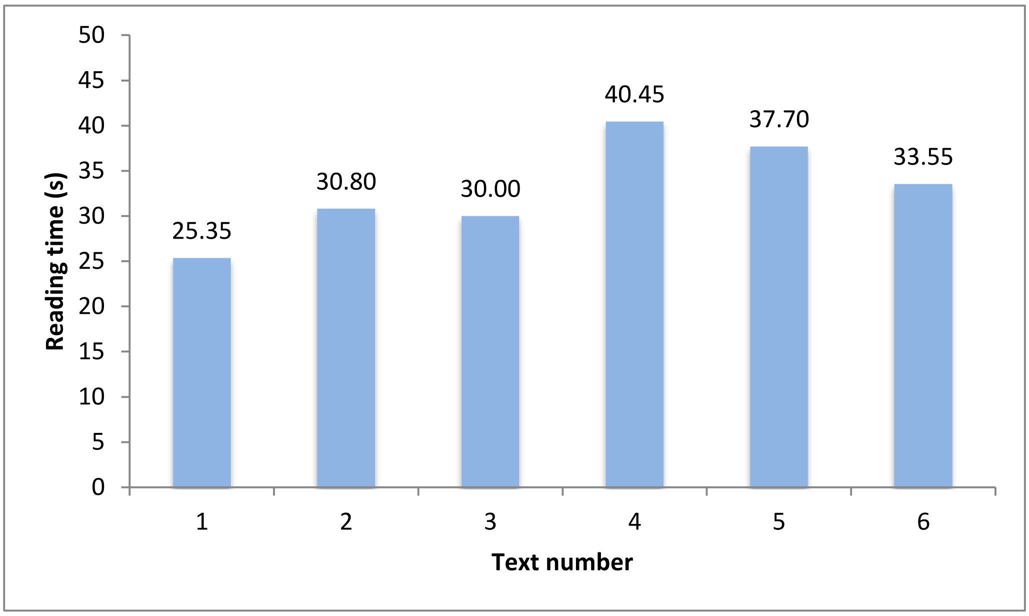

Figure 6: Average reading time of each text on mat coated paper

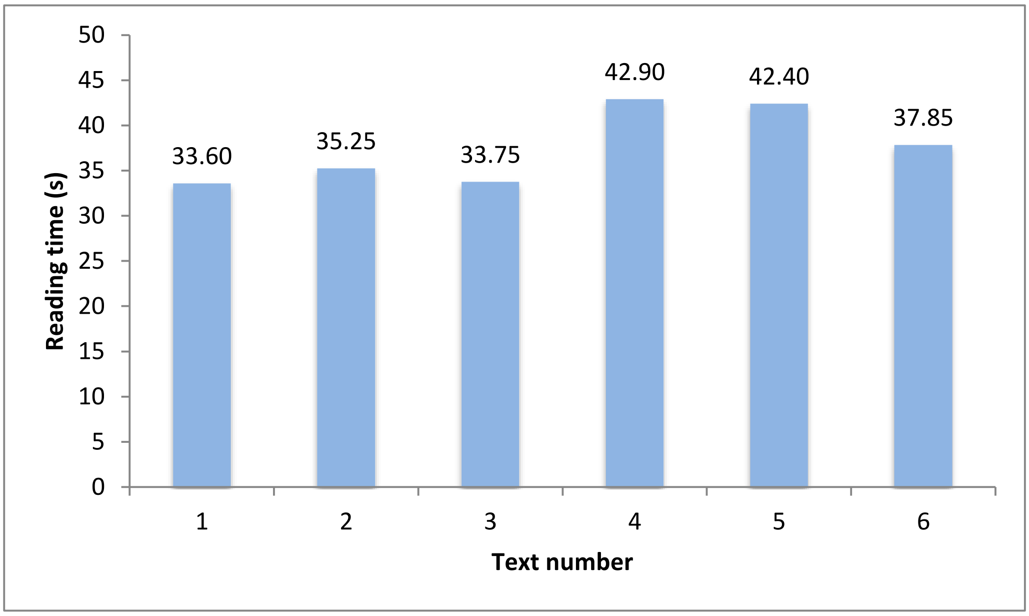

Figure 7: Average reading time of each text on gloss coated paper

The average percentage of correct answers for the texts printed on mat coated paper was 79.96%, on gloss coated paper slightly lower, i.e. 66.60% of correct answers (cf. Figures 8 and 9). The texts that were best understood were those printed in Times New Roman and Eco Vera Sans, regardless of the used paper. Nevertheless, we have to stress that the speed of reading was the slowest at these texts. Moreover, we have to point out that the question for the second text was most likely prepared inadequately, since both groups of observers gave only 35% (mat coated) or 25% (gloss coated paper), respectively, of correct answers. Therefore, the research in that point should be thought through again and repeated. Especially, since the speed of reading was the fastest at the Ryman Eco font.

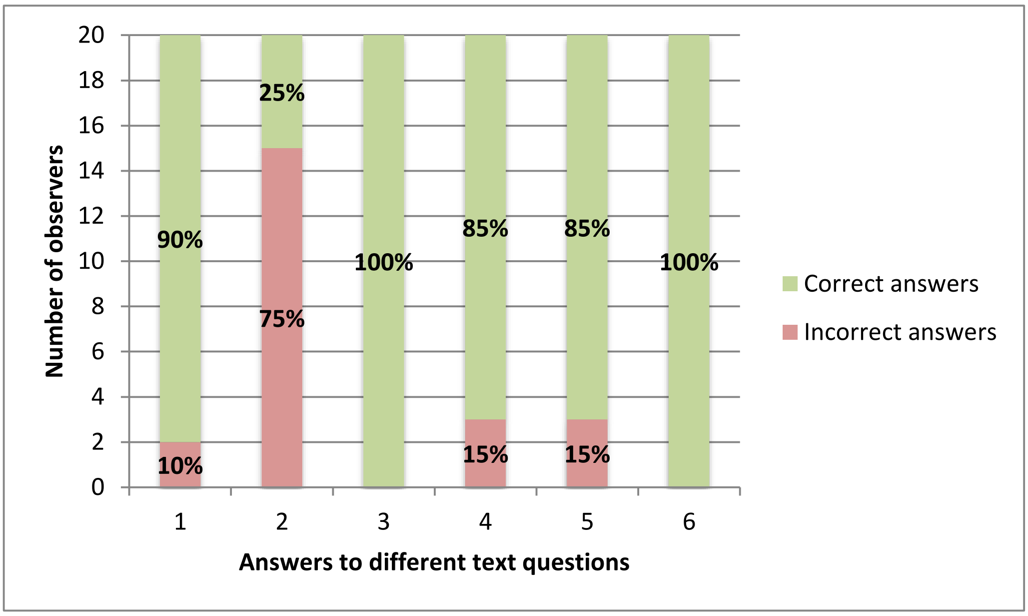

Figure 8: Answers to questions for text read on mat coated paper

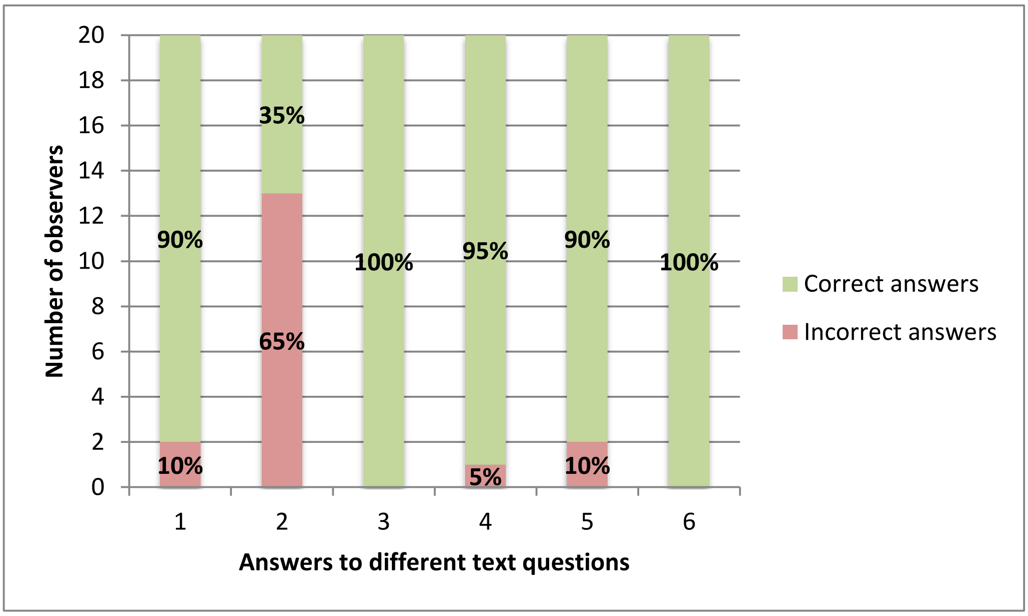

Figure 9: Answers to questions for text read on gloss coated paper

4. CONCLUSIONS

The results of the research show that the eco-friendly designed fonts are read faster than the conventional ones. On the other hand, it was observed that eco fonts printed with the ink jet technology do not use less ink than the standard or conventional fonts, as it is advertised. The typographic tonal density of eco fonts was higher than of the non-eco font. We should take into consideration also some other non-impact printing technologies. In that case, we might give some recommendation about the usability of eco fonts. Especially, as it was found out that the reading speed was faster at the eco font, while the answers to questions were the worst at one text printed with the font which was read the fastest (i.e. Ryman Eco). Consequently, the research should be thought through again and repeated, in order to be able to give a proper conclusion about the usability of the Ryman Eco font vs. Eco Vera Sans or the widely used conventional font Times New Roman.

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Designing and analyzing digital media

ANALYSING OF THE GRAPHIC DESIGN ELEMENTS PLACEMENT OVER THE STAND ACCORDING TO THE PRINCIPLES OF DESIGN

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Abstract: *There can be no question that design influences life profoundly. Creative thinking, product design reflecting inspiration and messages exert influence over all humanity and even direct them to a gradually increasing degree. Product overview which makes a sensation on the tracers and affects the target audience with areas and designs from the times when face-to-face product promotion and sales were done in the qualifications to answer the needs in ancient times until today transformed into a visual feast almost like a magnet that makes it attractive. The reality is inevitable now that either two or three dimensional or moving digital demonstrations as multimedia are the most convenient and attractive solutions for introducing and selling a product. From the industrial revolution until today the way people perceive things enables perceiving the environment and communicating when needed with certain structural (anatomical), dimensional (anthropometry) and even psychological characteristics as a result of the physical and mental abilities developed through technology Concordantly each designer in charge about different specialties such as interior design, graphic design, product and packaging design also can affect the physical and intellectual abilities of people by using a multidisciplinary approach and creating integrated solutions for the problems. In this context, a review about displaying units, basic design principles of graphic design elements layout over the stand, and the relation between the anthropometry and ergonomic structure of people and messaging was discussed. The designing aspects and implementation of the relationship between space and graphic design elements layout such as balance, visual hierarchy according to gestalt principles were studied through the examples. In this article, where the development of swage block materials will also be studied, a place was given to the impact on the perception of graphics products and design elements such as color, shape, texture, tone and form in two-dimensional and three-dimensional design through the examples for displaying and graphic design elements placement over the stand. In the exhibition of industrial products the concern for delivering the message has occurred in typographic elements since the industrial revolution and these values have changed as a result of interest in visual design. In addition, consuming perception became evident where image, text and also visual attributes are examined. The design elements and principles which will be stated here can be a basic framework of analysis for graphic design elements placement over the stand even though they are not very comprehensive*

Key words: Exhibition Design, Graphic design, Visual communication, Communication design

1. INTRODUCTION

Creative thinking, product designs that reflect inspiration and messages affect, even lead the all humanity with an increasing power. In other words, design has a profound influence on life. Emerging markets, face-to-face product promotion and sales have been the indispensable part of commercial life ever since ancient times. Considering those times of face-to-face promotion and sales to answer the needs, today design of fairgrounds and exhibition areas have turned into a visual feast that affects and arouses interest in the target audience and makes the product promotion magnetically attractive. Environmental or experiential graphic design which is the most important tool of this visual feast has become a key element that provides product or even the stand to be recognized by the audience.

"Examples of Experiential Graphic Design include wayfinding systems, architectural graphics, signage and sign programs, exhibit design, retail design, and themed or branded spaces. Increasingly XGD involves the use of digital technologies and systems that present dynamic content through motion graphics and make possible rich interactions between a user in a place and the information being provided. Operating at the intersection of communications and the built environment, the field embraces a wide range of disciplines including graphic design, architectural, interior, landscape, digital and industrial design." (Dixon, 2016)

The "Easy Fair Concept" productions that have been getting popular with the increasing demands recently can also be shown as an example. "Easy Fair" will be the subject of another article in the future

in terms of design. Nevertheless it has been discussed within the following subject below as the supporting element of the basic review. Technological and scientific developments since The Industrial Revolution have made human life much easier. Rapid change of technology and life has developed the way of communicating and obtaining information. These developments have led humans to need and require more information. Thus, the need and the requirement for information in life has steadily increased. The state of chaos which was caused by the information conglomeration within the informational convergence might lead to confusion for human perception. Within this context, graphic design, info graphic and exhibition design have become more important in sense of design and perceptibility of the message that desired to be transmitted or the needed information. To ensure that the exhibited products are reached to the recipients, designers from different disciplines can lead the information that reached to the target audience by multidisciplinary approaches. "Graphic design which is a part of this team is a profession that supports information and communication design solutions in business from past to present. And the graphic designer is the part of the team that provides the message to reach target audience from design to production phase by contributing to this solution. Solutions vary according to the each type of commercial production and the promotional requirements in the areas of industrial design communication and implementation. The printing technology which is one of these solutions has a significant place in determining the information, communication and the direction of the target. Printing technology which is one of the production areas of visual communication from the invention of the printing press and paper to the present day has been supporting to solve the existing problems in multiplication and transmission. Designed product or a message could reach to the millions by means of mass production technology" (Beris, 2015). Dynamic digital demonstrations such as two or three dimensional or multimedia have been admitted that they are remarkable solutions preferred to promote and sell a product with multidisciplinary approaches. For the common multidisciplinary applications and designs of new information systems, ergonomic recommendations and the needs of guidelines have been increasing day by day.
Human perception provides the ability to detect and to contact with the environment when it is required by certain structural (anatomical) and dimensional (anthropometry) and even psychological features with improving physical and intellectual abilities with the help of technology from the industrial revolution to the present day. Concordantly, each designer employed in various fields such as the space design, graphic design, design of product and packaging can influence physical and intellectual abilities of people and produce integrative solutions to the problems with a multidisciplinary approach. Designers have also quite a spacious working area with the help of the pace of industrial and technological changes. It is inevitable to give a place to more comprehensive extended course syllabuses which is examining the psychological interactions of audio-visual and sensual structure in universities.

2. METHODS

In this paper, qualitative researches based on records and documents have been used in the field research. It has been referred to the scanning methods of resources recorded on the internet or resources such as professional books and periodicals and this study has been formed within the context of collection of the data of the impression and research based on the work experience from the past years.

3. DESIGN AND THE HISTORY OF EXHIBITION

Architecture and graphic design have built our living space together from centuries ago to the present day. Although different design disciplines have a language of their own, they have provided humanity a common communication language by working together.

"*Architecture speaks of form, space, and purpose, celebrating human continuity and offering experiences that both function and inspire. Graphic design—typography, image, and symbol—communicates the subtleties of time and place and tells cultural and visual stories, clarifying a building's purpose and echoing its architectural message"* (Poulin, 2012).

In ancient times, cave paintings, classical inscriptions, historical space wall decorations and plastic works of art the visual representation of the space have been a part of graphic design and architecture in terms of graphic style and scripture design at the same time. Environmental graphic design has been integrated with our environment in shaping our living areas with informative and directive billboards, advertising boards and signs. It is stated that markets and exhibition spaces which hold an important place in the development of commercial life that mentioned above, improved fairgrounds especially with The Industrial Revolution when concepts of fair, exhibition and stand have been formed from 1700s have turned into the fields of interaction where big flashy shows are represented (Küçükerman, 2002).

"In these exhibitions, various types of entertainment were being held as well as the trade which is the main objective. As a fact, at that time, even coming to a town from a few miles away was like a real adventure too. That's why the first of the exhibits was like an important meeting point. Without a doubt, it was a great opportunity for entertainment and show organizers when such a large crowd came together" (Küçükerman, 2002).

The first known international exhibition was opened in the "Crystal Palace" building that represents the industrial strength of that period in London, England which is one of the strong industrial countries in Europe. This exhibition that was founded in opened with the name of "Great Exhibition of the Works of Industry of All Nations" (Figure 1) in 1851 is stated to be the first international fair to exhibit more than 22.000 product with the participation of countries which sustain the economics of the period and new market seeking from Spain to Russia from the Ottoman Empire (Figure 2) to India from all around the world (Küçükerman, 2001).

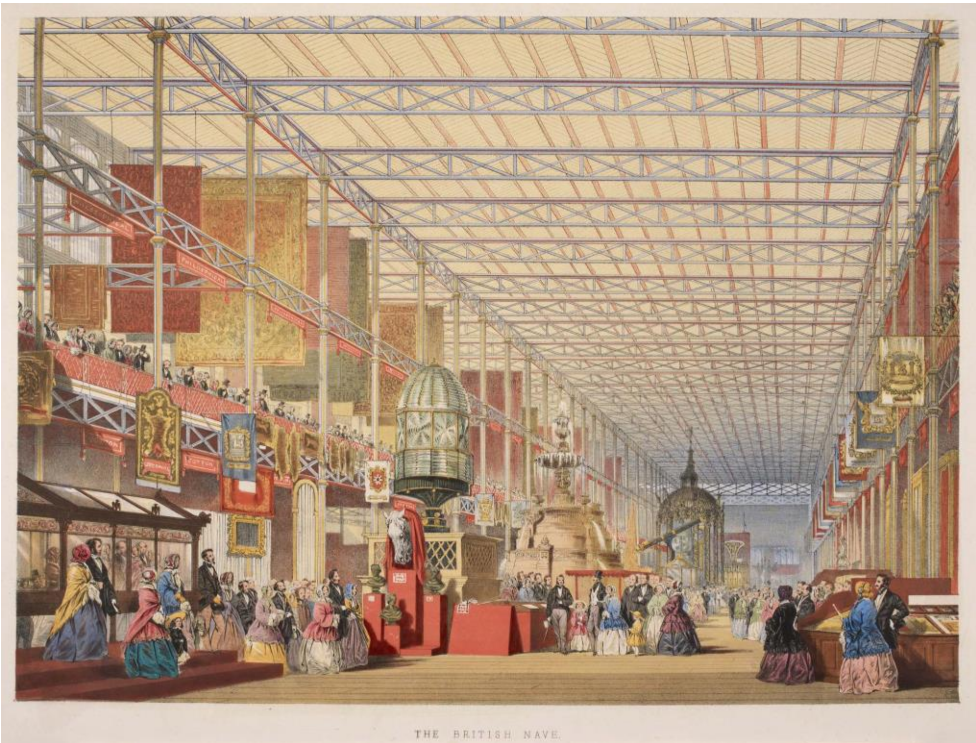

Figure 1: 1851 London Exhibition and a view of the large inner squares of the "Crystal Palace" building
Source:https://www.bl.uk/victorian-britain/articles/the-great-exhibition

Figure 2: One of the Ottoman pavilions from London fair called
"Great Exhibition of the Works of Industry of All Nations".
Source: https://www.bl.uk/victorian-britain/articles/the-great-exhibition

It has been expressed that markets were mostly the first exhibition examples in the second half of the 18th Century in London and daily products were usually exhibited in these exhibitions. In 1754, "The Royal Society of Art's" had started to give these awards with the aim of supporting merchants, producers and artists every year. Only a hardware store could be provided to display those award winning products. Within this context, it has been stated that the first exhibition of industrial products (Figure 3) was performed in London (Küçükerman, 2002).

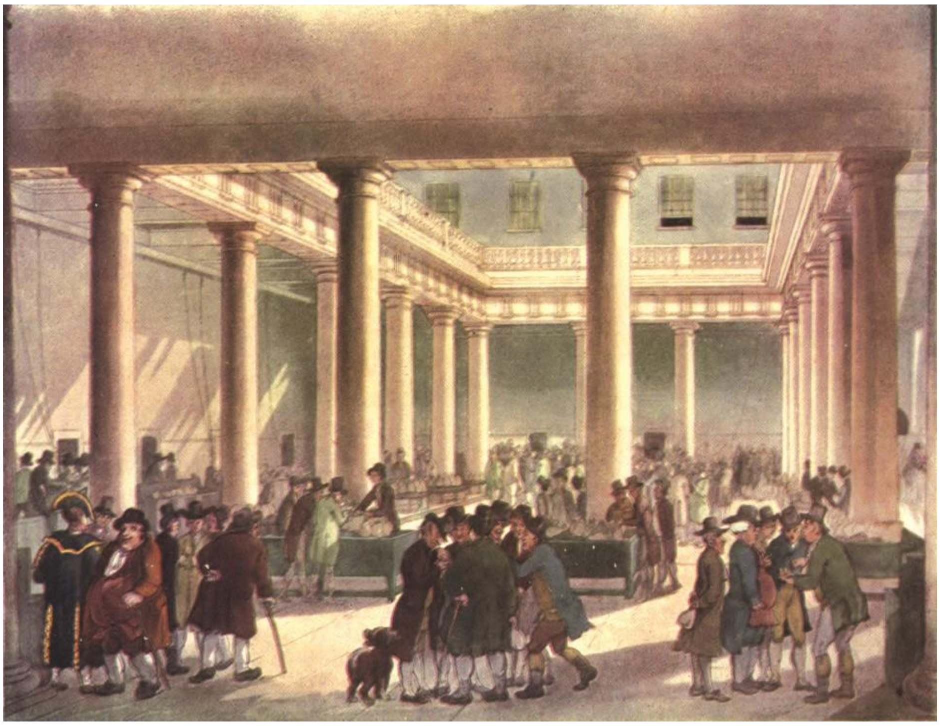

Figure 3: The Corn- Exchange in The Microcosm of London or London in Miniature, 1809
Source:https://commons.wikimedia.org/wiki/File:Microcosm_of_London_Plate_033__Corn_Exchange.jpg

It has been expressed that, as a reflection of these developments, in France, in the last period of the 1700s after the revolution, the future of the most famous royal period factories such as “Sevres, Gobelin ve Savonneires” were imperiled. Accordingly, in 1789, against the risk of the products of these factories remain unsold, it was decided to hold an exhibition at St. Cloud Cathedral to find a new market. One the day before the exhibition, Napoleon Bonaparte hadn’t let public to cause a disturbance, he had cancelled the opening and about eight years later in Dorsay Hotel in Paris in 1797 (Figure 4) they had the opportunity to hold a more expanded exhibition.
The success of this exhibition had led to the opening of the annual exhibitions in France by the government and the first exhibition had been held in Champ de Mars which was built in 1789. Until the year 1827, national exhibitions were continued to be held at various times by the effect of the political structure. The growing interest in exhibitions had also affected the display durations. Even in 1849, an exhibition which was held for the twelfth time, had been open for six months and had host to 4500 participants (Küçükerman, 2002).

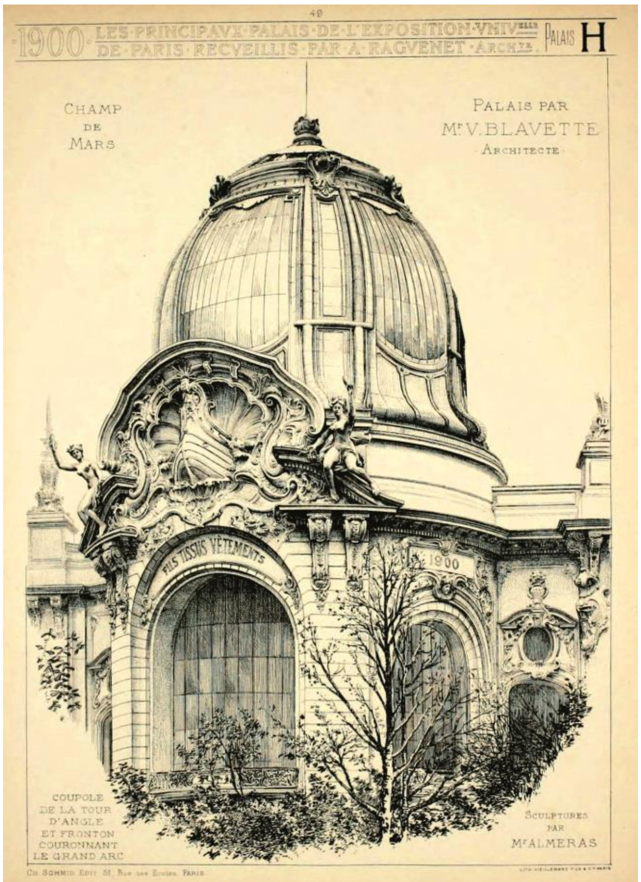

Figure 4: Detail of a domed pavilion entrance of the palaces on the Champ de Mars for the 1900 Exposition Universelle, Paris
Source: http://archimaps.tumblr.com/post/82445310627/detail-of-a-domed-pavilion-entrance-of-the-palaces

Throughout the 19th Century, exhibitions held in Europe or U.S.A. had been transformed into a political arena where political consensus was more important rather than economic returns in the first place and even where countries flex their muscles to meet the growing interest and the demand and also to strengthen the international trade relations. “At the end of the 19th Century, Ottoman Emperor Sultan Abdul Aziz was invited as the guest of Honor to the Paris Exhibition. The main purpose of this invitation was to strengthen relations between the two countries. On the other hand, Queen Victoria of England who was in competition with France, had declared Abdulaziz that it would be an honor to welcome himself in London. This big trip to Europe had been planned in details and they had moved by 5 ships at the end of of June” (Küçükerman, 2002)
It is known that the starting point of the aforementioned exhibitions is France. Paris which hosted many unforgettable international exhibitions in between 1847 and 1937 has become synonymous with the

word “Exposition” which means exposition. “Bureau International des exposition” (BIE) has been regarded as the approval authority of international exhibitions. The word Expo was used as the short name of international scale exhibitions for the first time by BIE in 1960s. Interestingly, the major world exhibitions are now accepted as equivalent to the Olympic Games from the cultural and economic perspective” (Poulin, 2012). It is stated that 20th Century Graphic Design understanding has emerged from our environment that we've created through cultural, social and economic structure long before the discipline of design which was defined many years ago in the history of Art and architecture whose current name is -environmental graphic design- with the reflection of the industrial revolution.

“*Urban streetscapes, office buildings, museums, convention centers, airports, public parks, shopping malls, and entertainment centers all have been transformed by the use of environmental graphic design. This design discipline has evolved not only by its technical improvements but also by its integral relationship over time to art, architecture, and cultural movements*” (Küçükerman, 2001).

Adolf Loos (1870-1933) who was Austria's one of the greatest architects at the beginning of the 20th century stated that “architecture ornament is a crime” in his design manifesto titled Ornament and Crime (Poulin, 2012). Groundbreaking experiences with newly formed art movements such as Dutch de Stijl (1917) and Russian Constructivism (1919) has paved the way of the a new approach for graphic design in the construction of the modern era. Leading designers and architects of that period such as Peter Behrens, El Lissitszky (Figure 5), Herbert Bayer and Walter Gropius were under the influence of this, too. Avant-garde visual thinking has influenced graphic design significantly particularly in Western Europe for a long time throughout the twentieth century. Graphic designers, influenced by art movements in the 1920s, have made more different designs in the exhibition areas. The basis of this difference is that the evolving design understanding and art movements with The Industrial Revolution has provided a new aesthetic for the design of the stand (Locker, 2011).
Innovative and revolutionary political and artistic movements throughout the 20th Century have rebuilt the environment and the social life by graphic design solutions. Graphic design has become the visual aspect of communication everywhere now by means of this new language of communication. In the middle of the 1920s, it is possible to see that graphic designers have discovered many different details of design in exhibition areas. It is a fact that Bauhaus school, in which these designers were first students then lecturers- which we can give El Lissitzky as an example- from the period of it is founded to the periods it was closed and opened again and has held education in the fundamentals of modern design, is perhaps the first most important design school of the world. It is stated that Bauhaus education makes so many artistic forms an eternal and a descriptive whole. Design principles’ being an important part of basic design education especially in the Fine Arts today is a proof this.

Figure 5: *A new kiosk (left side), and A multmedia booth for a fair (right side), Herbert Bayer, Weimar, 1924*
Source: https://static.dezeen.com/uploads/2015/10/Bauhaus-exhibition_Vitra-design-museum_dezeen_936_25.jpg

3.1 The Contemporary Exhibitions

With historical changes in the political and social level of urban life and with the pervasive influence of this rapidly developing technology, the physical and intellectual development has accelerated. This rapid change encourages people for more consumption with product designs that reflect creative thinking and inspiration and with a power with increasing messages. Of course, this is the basis of the commercial phenomenon and it is the only basic concept that keeps designers and industry together. Today's commercial exhibitions known as fairs or in other words consumer exhibitions are the most important supporters of commercial products to capture new markets. At a time everything “goes with the wind”, designers are able to tell their stories by graphic design products that reveal the product designed in a small or a giant place that can catch the attention of visitors within only a few seconds. The language of the narration of these stories still is possible with the opportunities of technology. Not just language of the narration but language of production has got richer with the invention of the computer, incredible technological advances in printing technology and the increase in the diversity of all kinds of materials. Everything that can be imagined with alternative materials and intelligent systems that are suitable for the pace and the purpose of modern times has evolved into producible designs. Compared to the ancient times, creating her/his design quickly with a click has given the designer more convenient and more aesthetic times which she/he can produce. She/he will adapt to the developments more will provide the ability to transmit “good-correct” messages quickly by developing intelligent systems with the values of natural life. Whether it is commercial product or an artistic product the reason of the establishment of exhibition areas which represent these products to the audience and draw their attention is defined as “something to be exhibited has a story to tell” (Velerade, 1988). And the graphic designer creates a visual text area in the exhibition in a sense, to convey this story by bringing theme and typographic texts together. This visual text is specified as a hyperlink between manufacturer and consumer at the same time. As designers can design a sensuous exhibition space that will, they can also provide insight of the visual text by appealing to visual perception which is generally accepted as the most powerful human perception in fairs.

“Every design is for humans or in the wider sense or for livings. Hence, presented design and products must be associated with the natural limits of human perception strictly” (Dernie, 2006).

Today's exhibition spaces are defined with 4 basic titles for designers:

- *Social Content Exhibits*
- *Trade Fairs*
- *Art Galleries*
- *Museum Exhibitions*

Display unit varieties feature various types of design principles based on whether a permanent or temporary in addition to their functionalities and purposes. Social content display stands draw the audience into the story with more aesthetic and stunning designs. Again, these stands to be exhibited in an interior or an exterior space influence the choice of materials in production in terms of designer. A winded race turned into a visual feast can be mentioned from the times where first international fairs were displayed for months to present day where fairs last only 3-4 days.

“Actually this race accelerates in a way that can be in every aspect today. The giant exhibits were open for six months in 1850s today, are converted into giant events for a couple of days” (Küçükerman, 2002).

“In Sweden’s expo pavilion, the verticality of the tree trunks suggests a Swedish forest, whilst a gobo projected onto the floor evokes dappled light coming through the tree canopy. A ‘gobo’ is a theatrical lighting device that can create the illusion of light falling through a venetian blind, or water flowing under a bridge. They can be custom made into signs or logos, and the addition of coloured gels and a motor to rotate them can help to create movement and mood” (Poulin, 2016).

The designer presents the sense of space and tells her/his story with various partitions and shows where the audience passes from the stage to stage. These partitions allow visitors to remain for a long time in this scene with light, color, sound, form, material and height values according to the story desired to be transmitted. If visitors cannot perceive the place and the offered product, they don’t show any interest to the exhibition. To prevent slipping of the interest to other artificial structure rather than the main story, leading visitors in the space, informational and typographic directions ensure the stand to be understood easily. It is a known fact that the relationship of people with the space is emotional and it reveals their reactions in terms of perception, thus, each item at the space can help people to uncover their emotions. (Figure 6).

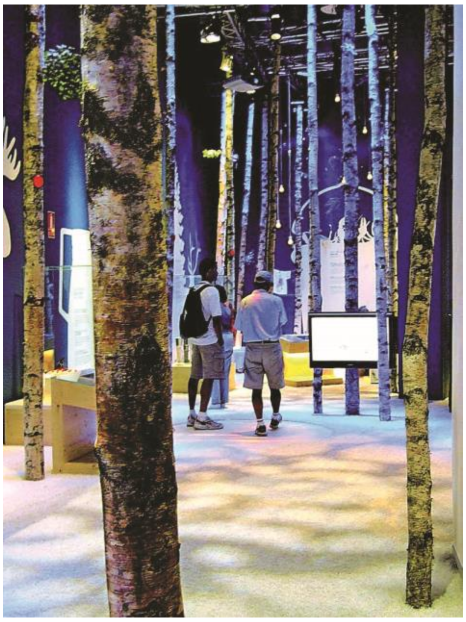

Figure 6: Swedish Pavilion, World EXPO 2008, Zaragoza, Spain
Source: LOCKER Pam, Exhibition Design, pages: 93, Ava Publishing SA 2011, Switzerland

"*Some exhibition spaces may offer the visitor a passive experience, where information is delivered predominantly through images, text and objects. In contrast, exhibitions designed to be interactive will immerse the visitor in a different kind of experience, where they may take on the role of 'performer' as well as audience.*" (Poulin, 2016)

Figure 7: Mercedes Benz Pavilion, IAA Auto Show 2013 Messe Frankfurt, Germany
Source: http://blog.mercedes-benz-passion.com/wpcontent/uploads/2048_IMG_8020.jpg

Giant car companies in trade shows, put their logos in the heart of the pavilion also for the sustainability of the corporate identity, and create a center of attraction without a doubt by preferring the branding approach (Figure 7). As seen above, the Mercedes-Benz has created an illusion which doesn't give visitors a break challenging its rivals with its huge pavilion by spreading its overwhelming superiority to an area of approximately 9000m2 on 3 floors. It gives its arch rivals a "you cannot even be a rival to me" feeling by increasing the competition even more with the design that gives a lethal effect feeling. In the pavilion, "Blue-efficiency", that is to say motor structure of newly produced cars, has created a powerful story in its design by referring its working without harmful emissions with using the colors blue and purple. In almost all exhibition spaces, audio-visual presentation with multimedia demonstrations are important communication channels that transfer storytelling to the audience within seconds whether it is commercial or social by the means of technology. They draw the audience who comes to the huge exhibition spaces into like a magnet into the center of attraction by the illusion they created. This effective method which stands out among other stimulants come from everywhere around is also a new opportunity for the graphic designer that enables her/him to build versatile –multidisciplinary- approaches. However, it is possible to see fair stands passing into another dimension these new technological possibilities for the last twenty years. It is a period surrounded by the illusions that fascinate us like an installation, sculpture or a work of art.

"The designer is the artist of today, not because he is a genius but because he works in such a way as to re-establish contact between art and the public, because he has the humility and ability to respond to whatever demand is made of him by the society in which he lives, because he knows his job, and the ways and means of solving each problem of design" (Küçükerman, 1973).

3.2 The Place of Anthropometry and Ergonomics in the Design

Industrial design products, or in other words, each design produced is offered for the use of humanity. The generated object's ability to reach people is strongly related to the ability of anthropometry which is interested in human body and the transmitted message being perceived by humans. In a more general sense, to ensure that a product can be preferred or used, it is important to design the product according to human's anatomical, physiological and psychological features. Although the relationship between physical measurements human and his ability to work has been known since the ancient times, "Anthropometry" was held in detail for the first time by German physiologist Blumenbach (1752-1840) who was one of the founders of physical anthropology with The Industrial Revolution. According to Blumenbach who was known as a naturalist at the same time, modern man is determined by an evolution occurred as a result of climate, participation and social environment.

"*Anthropometric studies give you information about the measurements of human body and what "average" means (Figure 8). This is directly related with all the elements of exhibition from furniture to graphics. Other ergonomics works on the ways of using human with the design of the space. Can visitors move easily? Are fire escape routes clearly described?*" (Poulin, 2016)

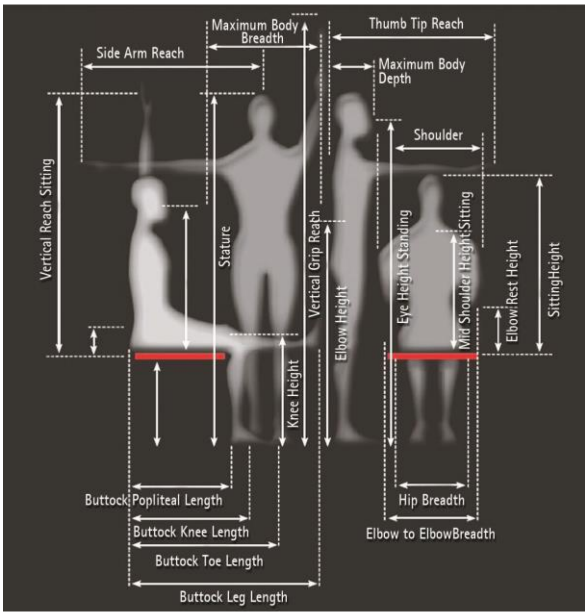

Figure 8: ANTHROPOMETRIC MEASUREMENTS; Anthropometric study provides the exhibition designer with knowledge of the dimensions of the human body and what it means to be 'average'.
Source: LOCKER Pam, Exhibition Design, pages: 48, Ava Publishing SA 2011, Switzerland

With other words, Ergonomics is a branch of science dealing with the relationship between objects, people and environment. It examines the interaction of tools we use in every area of our lives and our movements with designs. In this context, the designing is obliged to make the product suitable for use according to intended purpose and physical and intellectual abilities of the human and environment. The fact that this product designed in ideal structure can be used by the owner of it without any training is essential for the continuity of the industrial system. Therefore, a designer who developed him/herself within the anthropometric and ergonomic ideal structure can easily present the comfortable, convenient and environmentally friendly designs.

3.3 Gestalt psychology and the importance of visual perception

Gestalt psychology or Gestaltism (In German, it means shape and form), in cognitive processes is a psychology theory especially concentrated on the “perception” and “perceptual organization” issues. that it has appeared in Germany in the first 20 years of the 20th Century. A group which consists of theorist psychologists such as Johann Wolfgang von Goethe, Christian von Ehrenfels, Max Wertheimer, Wolfgang Köhler, Kurt Koffka It is stated and Ernst Mach from Germany is defined as the first team to examine Gestalt theory, perceptual organization systematically in the 1920s (KUCUKERMAN, 1973). The political changes -that is defined as the period when National Socialism came to power- that interfered with this efficient development has led Koffka, Wertheimer, Kohler and Lewin to escape to United States in order to continue their works. According to this theory, the whole implies a different meaning than the sum of its parts. Human perception detects the whole integrity rather than disintegrating the whole. That is, theoretician psychologists argue that the organism organizes the life again by adding a little bit of itself to the sensations come from the outside. Wertheimer has defined the stimulus variables which determined how certain stimulants would be grouped, how to configure or to interpret them. Perception of an object in the same manner under different conditions is called “Perceptual Invariance”. That is, it is the tendency for perceiving objects in the same way in different environments and conditions. These principles are generally are held in 5 basic structures:

- Figure and Ground
- Similarity
- Proximity
- Closure
- Continuation

The shape-surface relationship striking aspect of these principles in terms of graphic design is the perception of the whole in the surface where the constituent parts of the whole are located. This is a result of the tendency of the organization that human brain has. There is a unity in perception; we see the whole not the pieces in our perception. In other words, an object makes sense with its relationship with the environment and the surface where it is located, does not make sense alone. It is known that we have grouping and linking the forms and the structures in our perceptions (Figure 9).

Figure 9: The Rubin vase is unstable because it can be perceived as a white vase on a black background or two black faces looking at each other on a white background. (left side), Initially, there is no stable figureground relationship in this image. However, after a moment, the Dalmatian pops out and the figureground relationship stabilizes. (right side) Source: Lidwell W., Holden K., Butler J., Universal Principles of Design, pages: 97, Prockport Publishers inc., 2010, USA

In the light of these theories, it is important for graphic designers that the eye a tendency of perceiving object primarily. The thing to be stated with this guide information is that color, form and composition play an important role while getting started with designing the visualization of message. This becomes even more apparent especially in the design of information. The color arrangement has a great importance in figure-ground relationship. The contrast effect and the balance of the contrast relationship in colors create a strong awareness in perception. In this way, the figure stands out and is provided to be perceived clearly.

Another important topic in visual perception is the golden ratio. The golden ratio appears in nature, art and architecture. It is possible to see this ratio from seashells to pine cones and even in the human body. Piet Mondrian, Michelangelo and Leonardo Da Vinci used the golden ratio extensively in their paintings. It is possible to see this ratio in architecture in the Great Pyramid of Giza, Stonehenge, the Parthenon, and in the Cathedral of Chartres (Figure 10). Although there is no definitive evidence, it is indicated its emergence is dated back to 2400 years ago (Golden Ratio, 2016). The basic principle of it is to keep the ratio of two adjacent or associated lengths at a rate of 1,618. Even a rectangle drawn with this rating looks pleasing to the eye. It is available to use from art to architecture, from aesthetic to plastic surgery in every area of life.

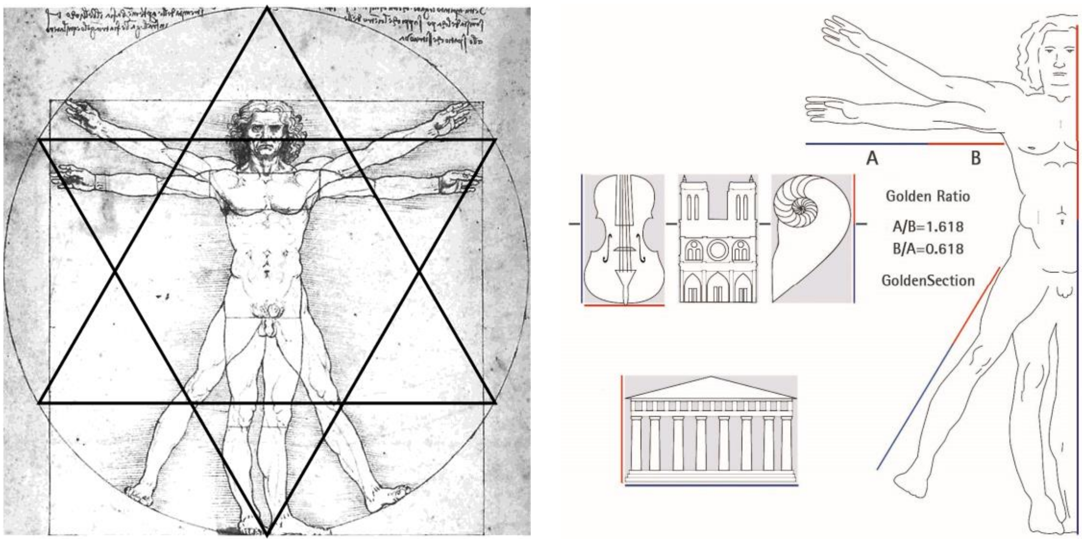

Figure 10: In each example, the ratio between the blue and red segments approximates the golden ratio (right side). Note how the ratio corresponds with a significant feature or alteration of the form.
Source: Source: Lidwell W., Holden K., Butler J., Universal Principles of Design, pages: 115, Prockport Publishers inc., 2010, USA

Typographic and visual design analysis of the stand situated in exhibitions and fairs, whether large or small scale, it is suggested to solve the problems in a functional structure on the base of principles of perception and communication. It is important to design visual and typographic designs considering limited time and busy visitor flow to provide proper communication in the exhibition. This principal settlement provides a major contribution to the success of the stand design. To say that this graphic language is dominant in almost all of the international fair organizations today reinforces this proposal and its importance.

Lettering form in the stand design is considered to be an important bridge to grab the attention of visitors and to provide information. Placement of information about the product or message requires a correct graphics solution. The first suggestions come to mind first are font selection that provides visitors to see it easily and to read texts easily and to design with the surface contrast influence for fast perception. Texts to be written short, simple but powerful statements, the editing below 12 words, to be placed on the surface with using contrast effect with a solid color if it is possible are important in terms of readability. According to researches, long texts more than 12 words are not read by the audience. A number of arrangements are made where the distance is also a factor to ensure readability in general. The relationship this distance with the text placement is as follows:

- A written text in size of 15 cm can be read from about 30-40 meters.
- A written text in size of 10 cm can be read from about 20-25 meters
- Written letters in size of 5 cm can be read from about 10 meters.

Again, the design of information in a hierarchical order is important. The logo that represents the corporate identity should be written primarily, slogan or main headings should be written in capital letters, and more detailed sub-texts should be placed in the stand with lower cases considering mentioned suggestions above. The hierarchy is seen as a requirement that meets needs from the lowest level to the highest level. A good design must be able to follow the hierarchy which is a principle of requirement and should able to meet the needs. In order to provide this basic order it is presented schematically with 5 levels of hierarchy. (Figure 11)

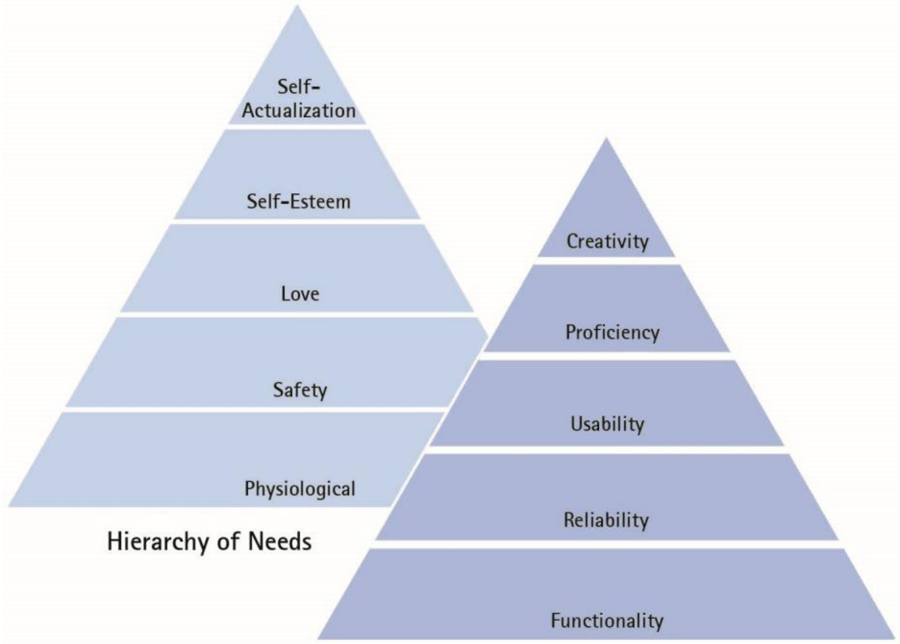

Figure 11: The hierarchy of needs specifies that a design must address lower-level needs before higher-level needs can be addressed. The perceived value of a design corresponds to its place in the hierarchy— i.e., higher levels in the hierarchy correspond to higher levels of perceived value. The levels of hierarchy are adapted from Maslow's Hierarchy of Needs.
Source: Lidwell W., Holden K., Butler J., Universal Principles of Design, pages: 125, Prockport Publishers inc., 2010, USA

4. CONCLUSIONS

Markets in ancient times, face-to-face product promotion and of sales have developed commercial life, today's fair and exhibition areas have turned into a visual feast which is intriguing to the target audience, attracts the target audience and makes the product promotion attractive. Experimental or in other words environmental graphic design which is the most important tool of this visual feast today has become the most important factor which provides the product or even the stand can be perceived by the viewer.
In other words, the space is organized almost exclusively with graphic design. From giant car companies to mobile technology companies, so many companies shaping the world economy, prefer fair organizations to reach new markets or to promote their new products in international fair organizations. This also shows that the exhibition areas are the preferred spaces to promote a product or a message desired to be transmitted, to provide information or to sell. Everything that can be imagined has turned into producible designs with many alternative materials and intelligent systems convenient for the pace and the purpose of modern times. Designs that will allow thousands of manufactured goods to be sold and to able to reach the consumer will be possible with an aesthetic sensitivity within the framework of the limited production of the industry, wildlife values and with materials developed by intelligent systems. Especially Visual Design being an important tool in the transmission of information increases the importance of graphic design education. Today, the winded race of the fairs lasted only 3-4 days have turned into a visual feast and fair stands have now passed into another dimension with rapidly evolving technological possibility in the last two decades. This period is surrounded the illusions that we're fascinated by unique works like installation, sculpture or a work of art. The increase in the need for fast and functional exhibitions in the design of the stand makes graphic productions called "Easy Fair Concept" more popular. For the last 10 years, with both time-saving structures with serial production and

with producing from eco-friendly materials with intelligent systems make it more popular. The development of so many display types, development of swage block materials and intelligent systems in ink systems offer graphic designers new design opportunities. In the same way, with the development of intelligent systems and increasing varieties of display units, have made be given place to more comprehensive course syllabuses examining interactions of audio-visual sensory and the psychological structure inevitable in the field of design education at the university as it is in other professions. It is possible to give university departments where graphic design and engineering come together as an example and this also may be an indication that demand will get widespread.

5. ACKNOWLEDGMENTS

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SURF: DETECTION, DESCRIPTION AND MATCHING OF LOCAL FEATURES IN 3D COMPUTER GRAPHICS

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Abstract: *Recognition of individual objects in an image or a sequence of images – video – continues to be one of the more challenging tasks in computer vision. Unlike for humans, it is still difficult for computers to find and correctly identify in an image an actual person, animal, car or any other object that can possibly be scaled, rotated, illuminated by different types of illumination or partially covered by other objects. Various approaches to this problem are known from the literature, including template matching, edge detection, and eigenface extraction. Our paper is a preliminary report on the implementation of SURF (Scaled-Up Robust Feature), a robust local feature-based method for finding a match between object features and image features, in 3D computer generated scenery. A 3D computer generated scene can be visually perceived by an observer as long as three basic elements are defined: first, virtual camera, i.e., simulation of the observer's visual system, second, constellation of 3D objects in the scene and third, virtual illumination. Quality of object(s) visualisation in the image depends on numerous parameters: camera angle and perspective, illumination, texture and materials, simulation of atmospheric phenomena, object's position, size, rotation and location in relationship with other objects in the scene. In our study, influence of several parameters that might affect the performance of the algorithm was tested, such as object scaling, rotation, and object occlusion. The process of extracting the features, their description and finally matching is described. Presented and discussed are the results obtained on a number of practical examples, i.e. images of varying complexity and number of details that were produced in 3D modelling software 3ds Max. The method was evaluated studying isolated objects as well as objects that were rotated, scaled and/or partially covered by other objects in the scene.*

Key words: SURF, feature detection, feature extraction, computer vision, 3D computer graphics

1. INTRODUCTION

Accurate automatic, i.e. entirely computer-based, detection and recognition of individual objects in a digital image continues to be a challenging task in the field of computer vision and is an area of active current research. Variety of approaches has been implemented in the past in order to solve this problem, such as template matching, edge detection, and eigenface extraction. Many of these solutions, however, are not general and suffer from various drawbacks: they, for instance, exhibit suboptimal performance when the objects that need to be detected – human faces, pedestrians, cars, animals, industrial products, etc. – undergo scaling, rotation, change in lighting conditions and/or are partially obstructed from view.
Our paper is a partial report on an implementation of a more recent robust local feature-based method known as SURF (Scaled-Up Robust Feature), which has been used successfully on a large number of different computer vision problems ever since its introduction in 2006. Rather than investigating images depicting natural scenery, we decided to experiment with computer-generated imagery produced by 3D modelling software 3ds Max. Using this approach we were in a position to either experiment with or control a large number of parameters that might have an influence on the object detection performance, which would clearly not be possible if we studied photographs taken by a digital still or video camera.

1.1 Local invariant image features

A local feature – also known as an *interest point* or *keypoint* – can be described as an image pattern which differs from its immediate neighborhood (Tuytelaars et al., 2008). Typical examples of image properties that vary across an image include intensity, color or texture and local features can be either points, edges or small image areas. Measurements are often done on a region centered on a local feature and converted into descriptors. These can then be used for various applications.
Three families of feature detectors can be identified. First, local features may have a specific semantic meaning in the context of a certain application: detection of edges is important in aerial images since these features often denote roads. Second, features can provide a limited set of well localized and individually identifiable anchor points. This can be useful in matching or tracking applications, such as

camera calibration or 3D reconstruction. Third, a set of local features is frequently used as a robust image representation that enables the subsequent object- or scene recognition. Scene classification, image retrieval and video mining are examples of practical applications of this class of features.
Although local features in an image often correspond to edges, corners or junctions that our visual system use as vital cues in interpreting the image (Figure 1), this is not necessarily the case. The main requirements for an optimum local feature are repeatability, distinctiveness/informativeness, locality, quantity, accuracy and efficiency. The most important property is repeatability: if we have two images of the same object or scene, taken under different viewing conditions, a high percentage of the features detected on the part of the scene visible in both images should be found in both images. Repeatability is closely related to invariance/robustness to various influences that might affect the appearance of an image, such as noise, blur, change of camera viewing angle, illumination and geometric transformations.

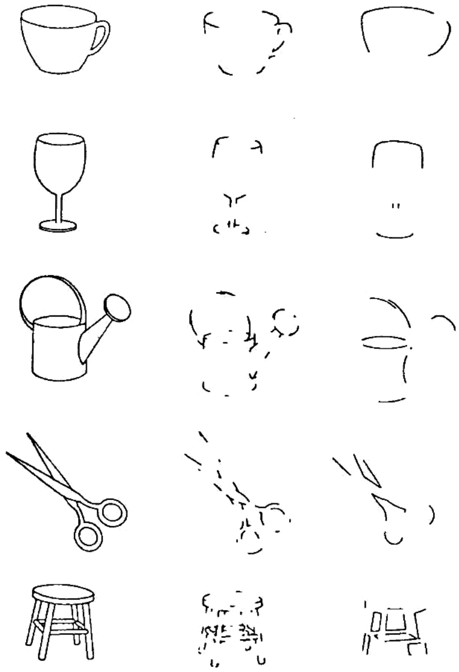

Figure 1: Importance of corners and junctions in visual recognition (Biederman, 1987)

One of the image processing operations where the local features often excel global ones is image segmentation. A typical example is content based image retrieval (CBIR): traditionally, similarities in global features such as textures, colors or shapes between the query image and the database images have been exploited in order to find appropriate match(es). This approach works well only as long as the user is interested in the overall composition of the image, rather than in the foreground object itself; global features generally cannot distinguish foreground from background, and they mix information from both parts together. In addition, image clutter and occlusions can present a serious problem so such systems are limited to less complex imagery with a clean background or where the object can be segmented out relying e.g. on motion information.
Local feature detectors/descriptors overcome many of the difficulties presented above. Figure 2 gives an overview of some of the most frequently implemented corner, blob and region detectors together with their ability to be rotation-, scale- or affine invariant and the degree of their repeatability, localization accuracy, robustness and efficiency. As can be seen, many of the corner- and blob-identifying detectors are invariant under the moderate rotational and scaling changes of the object while region-based detectors are also affine invariant. Numerous advanced feature description strategies – mathematical procedures on how the neighborhoods of interest points are represented and described – have been developed during the last decades: Gaussian derivatives, moment invariants, steerable filters, complex features, and many others. Their discussion is well beyond the scope of this article and can be found in the pertinent literature, e.g. (Tuytelaars et al., 2008).

Feature Detector	Corner	Blob	Region	Rotation invariant	Scale invariant	Affine invariant	Repeatability	Localization accuracy	Robustness	Efficiency
Harris	√			√			+++	+++	+++	++
Hessian		√		√			++	++	++	+
SUSAN	√			√			++	++	++	+++
Harris-Laplace	√	(√)		√	√		+++	+++	++	+
Hessian-Laplace	(√)	√		√	√		+++	+++	+++	+
DoG	(√)	√		√	√		++	++	++	++
SURF	(√)	√		√	√		++	++	++	+++
Harris-Affine	√	(√)		√	√	√	+++	+++	++	++
Hessian-Affine	(√)	√		√	√	√	+++	+++	+++	++
Salient Regions	(√)	√		√	√	(√)	+	+	++	+
Edge-based	√			√	√	√	+++	+++	+	+
MSER			√	√	√	√	+++	+++	++	+++
Intensity-based			√	√	√	√	++	++	++	++
Superpixels			√	√	(√)	(√)	+	+	+	+

Figure 2: Commonly used local feature detectors (Tuytelaars et al., 2007)

1.2 SURF (Scaled-Up Robust Feature) blob detector/descriptor

Our study focuses on the performance of SURF, the local invariant feature detection and description algorithm developed by Bay et al. in 2006 (Bay et al., 2006). The method bears a lot of resemblance with the Scale-Invariant Feature Transform (SIFT) (Lowe, 1999). SIFT algorithm consists of four main steps (Lowe, 2004):

- Scale-space extrema detection: a difference-of-Gaussian (DOG) function is implemented which searches over all scales and image locations in order to find potential scale- and orientation-invariant interest points;
- Interest point localization: at each candidate location, a detailed model is fit to determine location and scale. Interest points are selected based on measures of their stability;
- Orientation assignment: to each interest point location, one or more orientations are assigned based on local image gradient;
- Interest point descriptor: the local image gradients are measured at the selected scale in the region around each interest point. These are transformed into a representation that allows for significant levels of local shape distortion and change in illumination.

Despite its similarity, SURF algorithm differs from SIFT in several ways (Lindeberg, 2012):

- It is based on Haar wavelets rather than on derivative approximations in an image pyramid;
- Interest points are approximations of scale-space extrema of the determinant of the Hessian rather than of the Laplacian operator;
- Feature vector entries are computed as sums and absolute sums of first-order derivatives $\sum L_x$, $\sum |L_x|$, $\sum L_y$, $\sum |L_y|$ rather than of histograms of coarsely quantized gradient directions. SURF descriptor vector typically consists of 64 floating point values.

Compared to SIFT, the performance of SURF is similar, but computations are reported to be somewhat faster.

2. METHODS

All objects were created in the 3D modelling software 3ds Max. Scene setting included the simulation of a rectangular space, i.e. background rectangular object with the dimensions of l=h=w=100 cm and position x=y=z=0, four photometric lights (intensity= 10000.0 cd, D65) and two target cameras (Figure 3). Four objects were modelled. In terms of geometry details, two objects had high LOD (Level Of Details), i.e. *butterfly* and *warrior*, and two objects had low LOD, i.e. *airplane* and *cup*. Rotations and translations of these objects were performed with the tools for basic object transformations (move, rotate). Images were rendered with Mental Ray® (Nvidia). Output format for the rendered images was .tiff, 1000×1000 (grayscale, lossless). SURF feature detection, extraction and matching experiments were performed in MATLAB 2013a using its Computer Vision Toolbox.

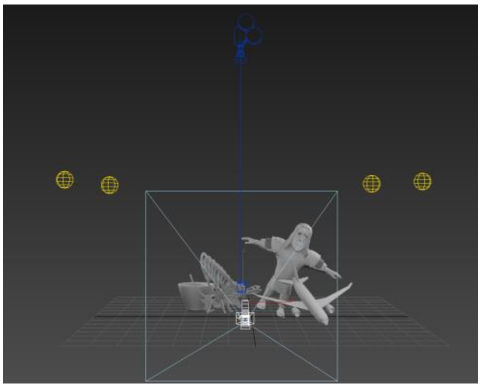

Figure 3. Scene setting with the background, photometric lights and two target cameras.

3. RESULTS AND DISCUSSION

Since the ultimate goal of our computer vision task is to detect – locate – a particular object in an image of a cluttered scene given a reference image of that object, the following three-step algorithmic approach of feature detection, description and matching was applied (Matlab, 2016):

- Feature detection: first, interest points in the object image that have unique content – in our case blobs – were found using SURF algorithm. The same was done for the scene image;
- Feature extraction/description: in this step a descriptor was computed based on the regions centered around the detected features. This involves a transformation of a local pixel neighborhood into a compact vector representation that allows comparison between neighborhoods regardless of changes in the object orientation or scale.
- Feature matching: Once features on both the object and the scene images had been detected and extracted, matching between their corresponding descriptors was examined. When trying to locate the object in the scene, several outliers, i.e. false matches, may be present, so a mathematical procedure – in our case a geometric transform known as RANSAC (Fischler, 1981) – was necessary to eliminate outliers.

First, four simple, texture-free objects – *butterfly*, *warrior*, *airplane* and *cup* – were investigated in isolation, i.e. without any interaction with other objects. Figure 4 shows all detected SURF features superimposed on each of the four objects that were rotated around z-axes for 22.5 degrees. Each cross represents the coordinates of the interest point itself, i.e. indicates the center of a distinctive pattern found in the image. Each circle corresponds to the feature descriptor and indicates the scale of the pattern: whether it is small or big. To enable easier visualization, only circles corresponding to the 30 strongest features for each object are displayed.

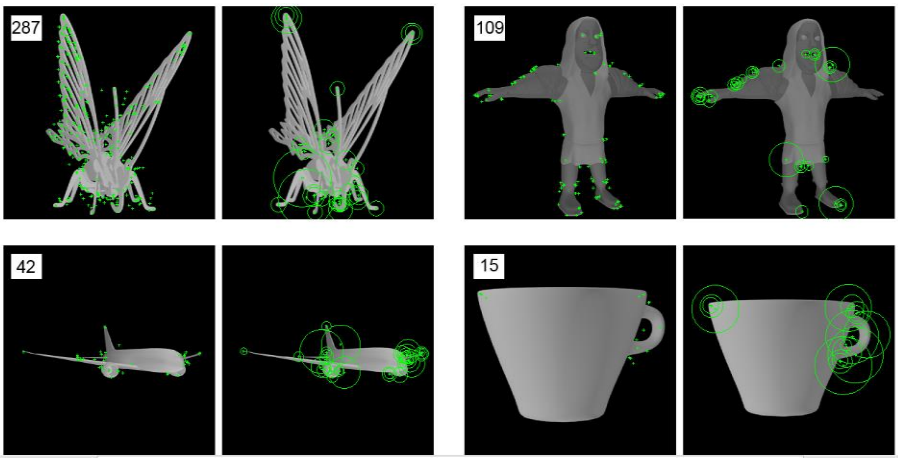

Figure 4: Four investigated objects and their SURF features. The number of all detected features is shown in the top-left corner of each image

It is evident that the number of SURF points that the algorithm detects depends on the image complexity: the most intricate object with the biggest number of details – *butterfly* – provides by far the largest number of distinct locations, while the simplest one – *cup* – is characterized by only a few interesting points.
Next, we wanted to explore, how in-plane (around y-axis) and out-of-plane (around x- and z-axes) object rotations affect feature matching using SURF algorithm. Results for the y-axis rotation angles of 22.5, 45, 67.5 and 90 degrees for the *butterfly* object are shown in Figure 5. Corresponding matched points are denoted with a red circle and a green rectangle on the original, unrotated, and the rotated images, respectively.

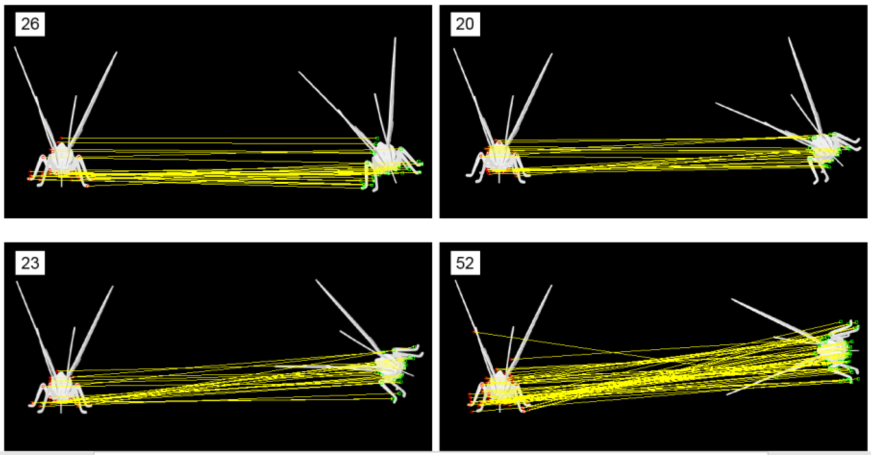

Figure 5: Matching of SURF features for the rotated butterfly *object. Rotation angles around y-axis are 22.5 (top left), 45 (top right), 67.5 (bottom left) and 90 (bottom right) degrees*

In-plane rotations obviously present no problem to the algorithm when trying to match the corresponding features. However, the number of correct matches – indicated by the number of yellow lines and given in the top-left corner of each of the four images in Fig. 5 – is again decisively affected by the level and number of details associated with each image. This is clearly demonstrated in Table 2 where the number of matched features is given for all four objects and three rotation directions.
The task of matching features between the unrotated object and the object that has been rotated with respect to either x- or z-axes was evidently a too difficult one for most of the objects and rotation angles and directions (Table 1). This is in agreement with the findings of the previous studies where it was reported that the SURF algorithm was not robust to the more pronounced out-of-plane object shifts (Matlab, 2016).

Table 1: Number of feature matches for four objects and three rotation directions

	Butterfly	*Warrior*	*Airplane*	*Cup*
Rotation around y-axis				
22.5	26	7	15	4
45	20	9	10	3
67.5	23	19	7	3
90	52	40	33	6
Rotation around x-axis				
22.5	1	5	0	3
45	1	0	0	0
67.5	1	1	0	0
90	0	2	0	0
Rotation around z-axis				
22.5	1	1	1	3
45	2	1	0	0
67.5	2	0	0	0
90	1	0	0	0

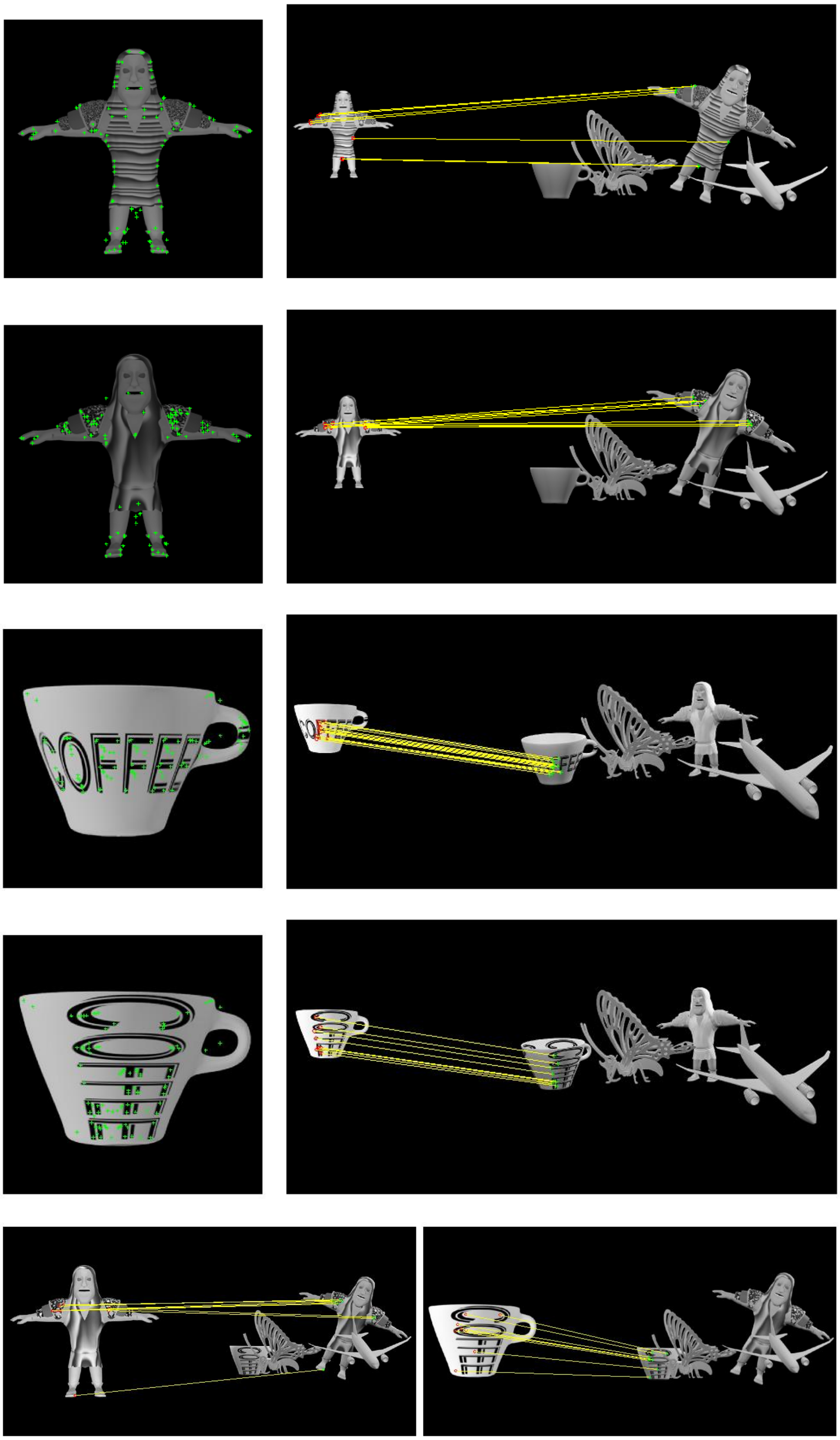

Figure 6: Some examples of successful feature matching and object detection (see text for explanation)

In the second part of the study, our goal was to detect a particular object in a cluttered scene, given a reference image of that object. To simulate more realistic scenarios and to improve chances of correct feature- and object detection, textures were added to individual objects. Figure 6 shows some feature matching and object detection attempts. It can be seen that, in general, textured patterns (horizontal or vertical stripes or text) significantly increase the object detection rate and make it possible to successfully find the object in the scene even if the object has been subject to rotation around x-axes for 8 degrees and around y-axes (*warrior*) or z-axes (*cup*) for as much as 22.5 degrees with respect to the reference image. As demonstrated by the two bottom-most images, successful textured object detection is possible even in the presence of substantial occlusion of the object of interest by other objects in the scene. A more detailed discussion on the results will be given in the presentation.

5. CONCLUSIONS

In this preliminary study we examined the suitability of SURF algorithm to find corresponding points between an isolated and unrotated 3D generated object and the one that has undergone changes in rotation around x-, y- or z- axes. In addition, our goal was to investigate the effectiveness of the algorithm in detecting an object of interest that was located in a more complex scene, possibly rotated and/or scaled. The former task was accomplished successfully as long as the object underwent an in-plane, but not out-of-plane rotations. When the object of interest was augmented with a textured pattern, the method yielded positive results even when the object received smaller out-of-plane rotations and/or was being partially covered by other objects in the scene.

The main benefit of using local invariant features is the fact that they not only make it possible to select interesting locations in the image, but also allow for a new, compact, image representation where image objects or areas of interest can be identified and described without the need for segmentation. In our future work we intend to examine other state of the art local feature-based techniques and their suitability for solving various computer graphics problems.

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INTEGRATION OF AUGMENTED REALITY INTO THE CAD MODELING AND ENGINEERING DRAWING TRAINING OF DESIGNERS

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Abstract: *The graphic designers, and product designers especially, in the modern job market are expected to have some engineering abilities and skills. Those include comprehension of technical documentation and at least rudimentary skills to produce understandable technical drawings. Usual process of training for engineering drawing in the first steps includes training in using a specific set of descriptive geometry procedures. Those procedures allow an imaginary object to be represented on a two-dimensional surface in such a way that it may modeled in 3d space, real or virtual, in true scale and shape and viewed from any position in space. This enables the designers to turn research ideas into technical plans for prototypes and production using computer-aided design (CAD). Recently augmented reality has become able to provide integration variety of multimedia formats in order to enrich education experience. Augmented reality is not new technology, but only with recent development of mobile technologies it become able to be used to its full potential in education. This paper aims to present possibilities for integration of augmented reality technology into the cad modeling and engineering drawing training of designers. This can lead to far better comprehension and easier learning process.*

Key words: Augmented reality, education, cad modeling, engineering drawing

1. INTRODUCTION

The graphic designers, and product designers especially, in the modern job market are expected to have some engineering abilities and skills. Those include comprehension of technical documentation and at least rudimentary skills to produce understandable technical drawings. Traditional education and training for engineering drawing in the first steps includes training in using a specific set of descriptive geometry procedures, this has well-proven benefits. Those procedures allow an imaginary object to be represented on a two-dimensional surface in such a way that it may modeled in 3d space, real or virtual, in true scale and shape and viewed from any position in space. This enables the designers to turn research ideas into technical plans for prototypes and production using computer-aided design (CAD). Students can explore a 3D visualization of the teaching material, thus enabling them to understand more effectively through interactivity with multimedia content (Liarokapis et al, 2004). Educational process must be simple in order to provide users with clear and comprehensible information and to increase the level of understanding the subject. Apart from these issues, the digitization of the teaching material must be done carefully so that all information will be accurately and clearly presented to the users. This digitization or 'content preparation' is usually an off-line process and consists of many different operations, depending on the target application.
Recently augmented reality has become able to provide integration variety of multimedia formats in order to enrich education experience and ensure easy and efficient interaction between the students and the teaching material. So far numerous educational systems based on augmented reality have been developed for different fields (Liarokapis et al, 2002). This paper aims to present possibilities for integration of augmented reality technology into the cad modeling and engineering drawing training of designers. Enabling them to explore teaching material through augmentation and concentrate and study presented procedures, which in turn will lead to far better skill and knowledge adoption.

1.1 Augmented reality technology

Augmented reality technology as a concept has its roots in TV technology where layer of information, text or images, is layered over the video footage. The current form of augmented reality originates from 1990's, it was patented at the beginning of 2000's by the Xerox Corporation (Harrington et al, 2002). Every day usage of this technology to its full potential in interactive applications is still considered a

novelty. Advancements of the hardware performance in mobile devices made possible capturing the real world images in sufficient quality, processing them, simultaneously processing the virtual content and combining them into augmented reality displayed on the device’s screen. Augmented reality basically overlays computer-generated virtual elements onto the real-world images, thus enhancing their informative or entertainment value. Most important characteristic of this concept is that the overlay content is context-sensitive, which means that information displayed is triggered by the real world object in real time. This technology is widely available through different education contents, games, etc. mostly intended for the mobile devices. (Azuma, 1997; Azuma et al, 2001).
There are different approaches to the augmented reality system design. Design rout first and foremost depends on the intended use of the final application, considering field of use, intended user group, devices and environment. All of these factors influence the decision on the technologies to be utilized. According to tracking technique, display technology and interaction techniques, augmented reality technology can be classified:

1. Tracking techniques
    a. Sensor-based techniques
    b. Vision-based techniques
    c. Hybrid techniques
2. Display technology
    a. See-through displays
    b. Projection-based displays
    c. Handheld displays
3. Interaction techniques
    a. Tangible AR interface
    b. Collaborative AR interface

For education field Vision-based tracking technique is especially interesting having in mind that augmented reality is usually used as an upgrade to printed learning materials. These techniques can be further divided into Marker tracking technique where the corresponding image descriptors are provided beforehand and stored into the database and Marker-less (Non-marker) tracking technique where application recognizes images that were not provided to the application beforehand.
Most of the applications in the use today are using marker-based technique, as Marker-less technique is much more difficult to implement because the recognition algorithm should independently identify patterns, colors or some other "features" that may exist in camera frames (Tang et al, 2003). Examples for these two techniques are shown in figure 1.

a)

b)

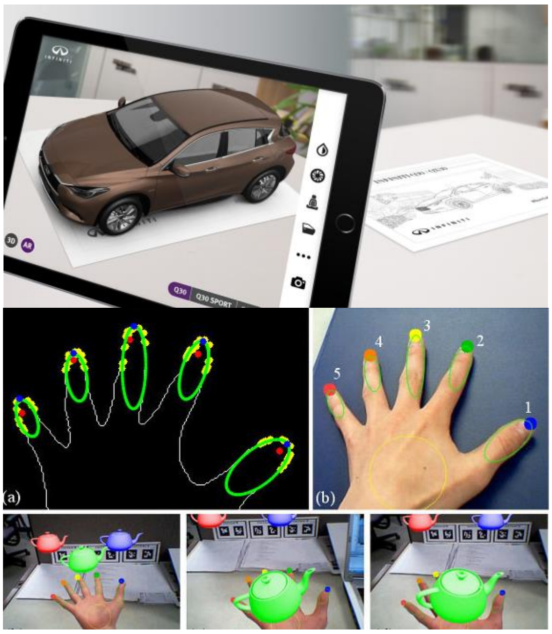
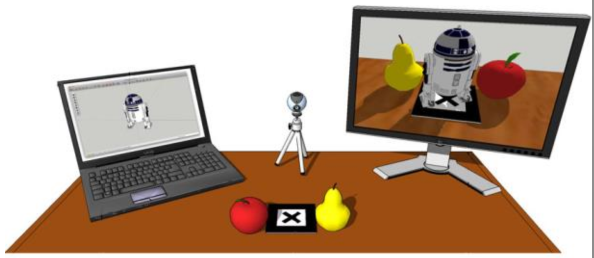


Figure 1. AR tracking a) Marker tracking, b) Marker-less tracking

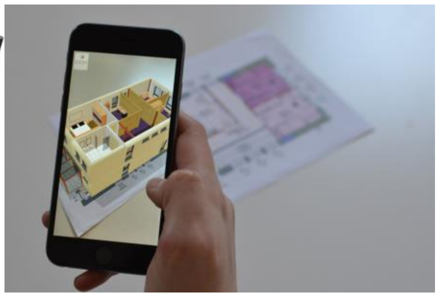
Figure 1a represents marker based tracking where the virtual object is placed upon a recognized image (infiniti.co.uk). Much more difficult to achieve is marker-less tracking shown in figure 1b as the software needs to recognize shape of the human hand and the position of the fingers in order to place virtual content and enable its interactivity with the hand movement (ilab.cs.ucsb.edu).
Sensor-based tracking offers utilization of some specific technologies such as optical, magnetic, inertial, acoustic, ultrasonic sensors. Hybrid tracking techniques combine the best characteristics of previously mentioned techniques (Yang et al, 2008).

1.2 Augmented reality hardware

Driving force behind explosion of augmented reality applications and move from the laboratories to the everyday use is advancement of hardware, mainly of mobile devices. Minimal device requirements image capturing ability, processing machine and display.
Simplest setups consist of personal computer equipped with web camera and monitor, figure 2a (sketchupdate.blogspot.rs). In order to ensure mobility and full usability of the technology for education, modern mobile device such as phone or tablet must be equipped with back facing camera and appropriate application installed, figure 2b (architectmagazine.com). Usability can be expanded even further with wearable technology such as Google glass or similar products. Such wearable technology frees users' hands and enables him to perform manual tasks while he is given additional information or instructions, figure 2c (33rdsquare.com).



a)



b)

c)

Figure 2. AR hardware a) Personal computer, b) Phone, c) Wearable hardware

Future development and integration of wearable electronics in to everyday life will provide new horizons for the implementation of the augmented reality in different human activities and pushing human-computer interaction further.
Using other technologies such as Eye-tracking which enables the computer to track momentarily user's point of gaze, or point of attention, can further intensify emersion by providing virtual content only in the areas of user's interest. Furthermore by incorporating an electro-myogram, electro-encephalogram, and electro-oculogram headgear eye movements, facial muscle movements, and brain waves can be translated into computer input, thus enabling other means of controlling the system.

1.3 Augmentation process

The augmentation is produced after a series of transformations, as shown in the process for the creation of AR using marker-based tracking, figure 3. First, the real video image is captured and transformed.

Transformed image is processed in order to determine position of the markers (containing an image pattern that is compared to patterns stored in a database). Next, the algorithm determines pattern orientation as the base for the coordinates frame and calculates the real position of the digital camera in relation to the physical marker. After that, the virtual objects are placed over the markers, and the final image is rendered and sent to the display (Soares et al, 2012).

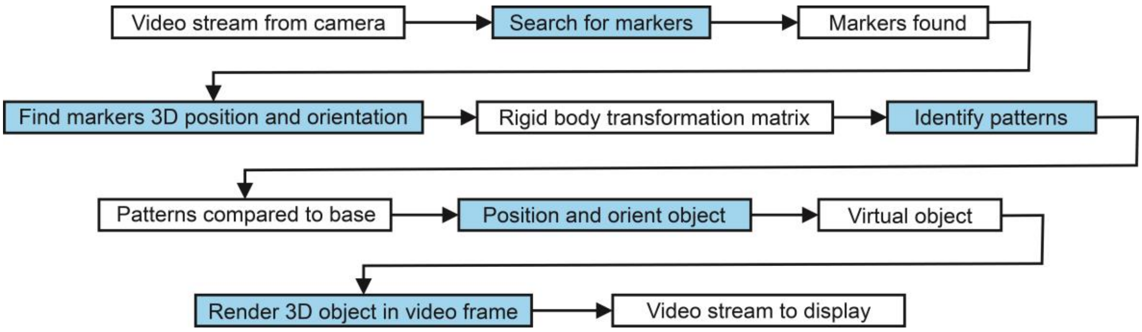


Figure 3. The process for the creation of AR using marker-based tracking

Depending on the application, virtual objects placed over real image can be still images, video content, 2D or 3D graphics. Virtual objects can be also interactive, offering further functionality to the user, such as additional information on the content captured in the real world.

2. METHODS

This paper aims to present the process of creating an Augmented Reality application for CAD modeling and engineering drawing training of designers. Software tools needed for production of such training application based on augmented reality technology can be divided in to the software for teaching material production and augmented reality application production.
3D modeling software, video and raster graphics editing software and screen capture software are usually used to produce teaching material. There are plenty of high quality, 3D modeling tools. Majority of them, whether intended for CAD or polygonal modeling can serve as a good tool for production of the 3D models or training videos. Aside from professional tools there are free software's that poses all the features needed for tasks required in this process. AutoDesk 3DS max 2016 was used for production of the video materials for this application.
Same as in the case of 3d modeling tools there is vide verity of software suitable for after production. Video material rendered and exported from the 3D modeling software almost always needs to be manipulated in after production. Manipulating video quality, video montage or even adding additional elements are usual, especially in production of educational or training videos. Tool contained in Adobe Creative suite 6 Master collection were used for this purpose.
Image and video screen capture is well established technique for production of training material for software users. Techsmith Camtasia used in this case is one of the more versatile solutions, offering after production and possibility of export to many popular formats.
Software needed for augmented reality application production is usually array of different software's depending on the platform used for production and the platform on which final application will be used on. Combination of Unitity 3D, Vuforia, Microsoft Visual studio and Android studio was used to produce the final application.

3. RESULTS

Application that was produced as a case study for integration of augmented reality into the cad modeling and engineering drawing training of designers offers three instructional components: interactive 3D model augmentation and two video augmentations. This application intended for Android platform and can be downloaded from http://www.grid.uns.ac.rs/symposium/download/cadedu.apk. When application is installed and run, interactive 3D model triggered by the image shown in figure 4 offers possibility to the user to manipulate the model and to get much better understanding of the object shape.

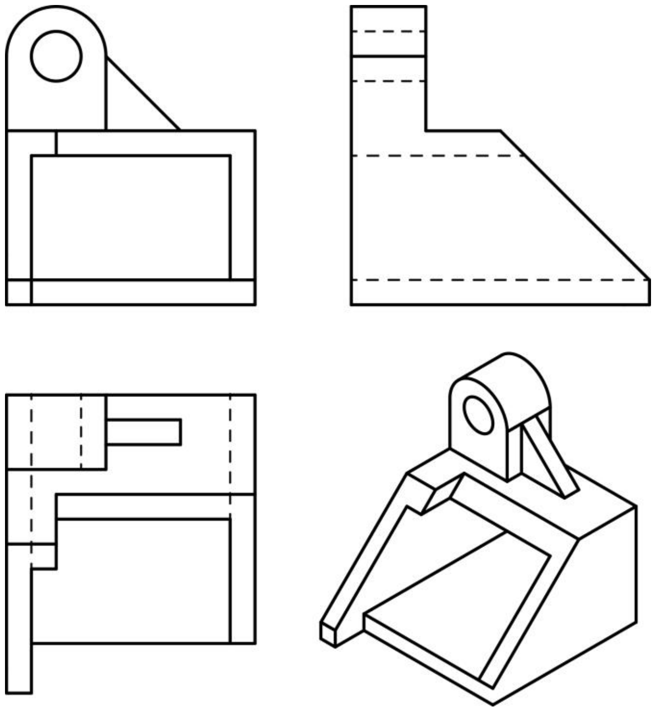


Figure 4. Interactive 3D model trigger

Video augmentation triggered by the image shown in figure 5 explain placement and creation of the orthographic projections. Video is produced using AutoDesk 3DS max and composited using Adobe Creative suite 6 Master collection.

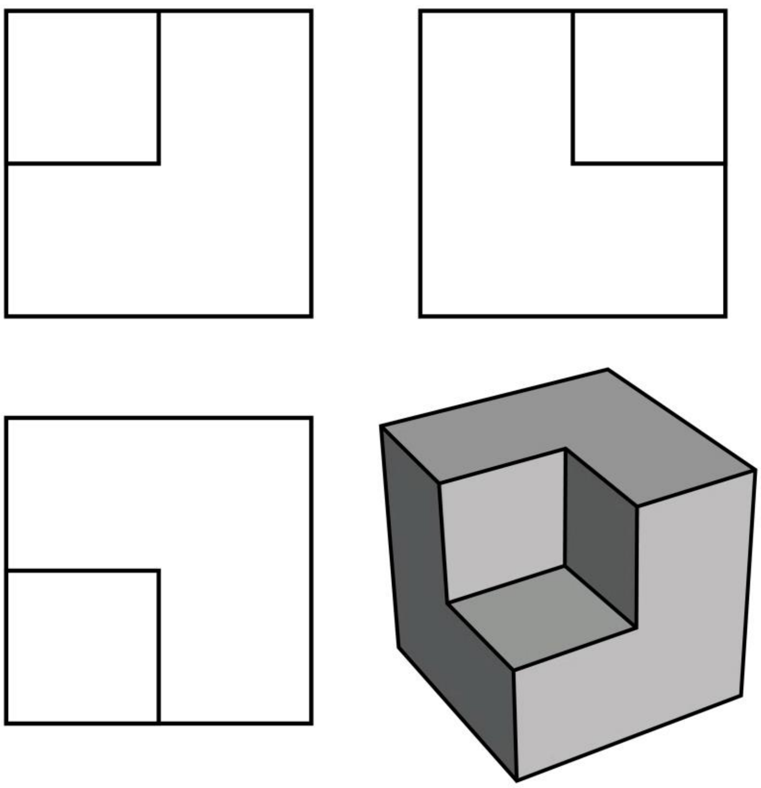


Figure 5. Video augmentation trigger, placement and creation of the orthographic projections

The image shown in figure 6 triggers video material explaining usage of certain tools for creation of CAD model using CATIA v5 software. This video was captured and edited using Techsmith Camtasia.

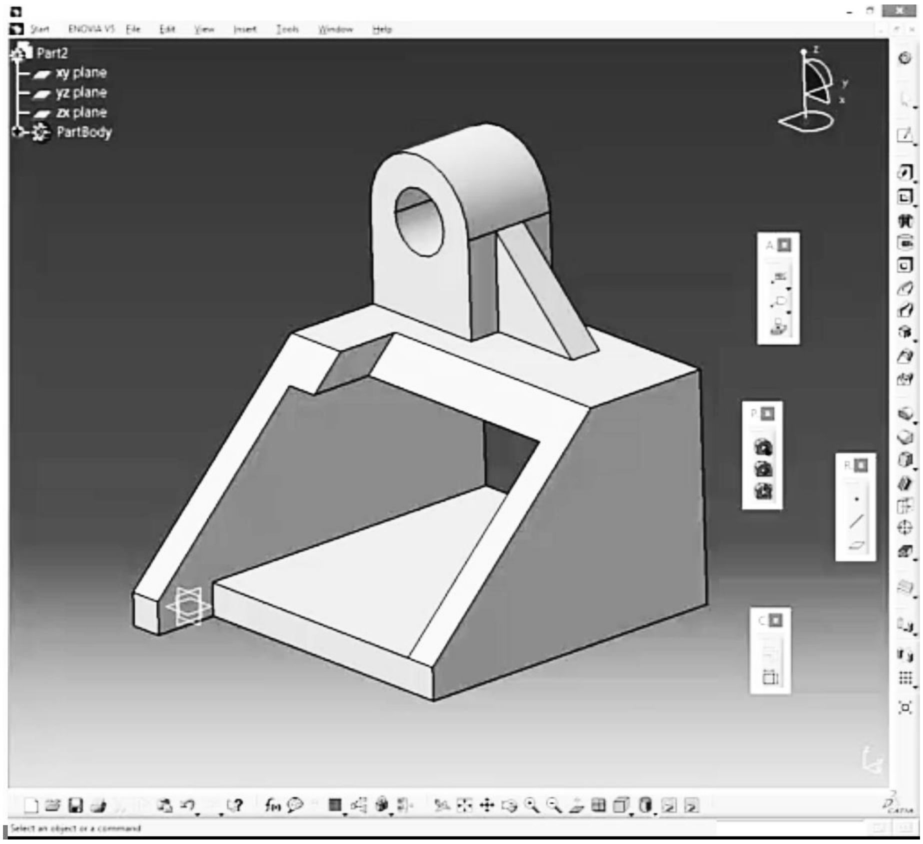


Figure 6. Video augmentation trigger, creation of CAD model using CATIA v5 software

4. CONCLUSIONS

This paper presented the possibility for integration of augmented reality into the cad modeling and engineering drawing training of designers. The basic path of the augmented reality application production is explained. All the results shown are effort of the small group of authors and with evolvement of the experts in each of the fields mentioned results can only be improved.

The future plans include creation of more educational and training material using augmented reality technology, integration with existing teaching materials and optimization of old material to fit better with future trends. Application of this technology in education practice is an imperative. Only the real word usage can answer the questions about advantages and disadvantages of the technology. Enhancing the realism of the integration between real and virtual, using augmented shadows, taking in to account transparencies, etc. is also one of the future goals.

5. ACKNOWLEDGMENTS

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USING AUGMENTED REALITY TECHNOLOGY FOR CONTROLLING STATE OF SMART PACKAGING PRODUCTS

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Abstract: *It is difficult to define exactly what smart packaging is, one significant component of any smart package is its ability to communicate with the person interacting with it. Smart, intelligent or clever packaging is defined as a packaging technique containing an external or internal indicator for the active product history and quality. During distribution, the quality of the food product can deteriorate biologically and chemically as well as physically. Because of the evolution of society and development of new type of foodstuffs, packaging industry must found new possibilities for provision food quality and safety for long time during shelf-life of food. Augmented Reality is an image recognition technology enables you to add digital content and interactive experience over physical touch points like product package, printed ads, etc. Customer unlocks these digital contents through scanning the item with a smartphone camera using Augmented Reality enabled application. This paper shows opportunities of Augmented Reality technology suitable for checking the state of the product in a smart package. The aim is to develop smart labels and mobile application for checking the product state in a smart package.*

Key words: smart packaging, smart inks, intelligent packaging, Augmented Reality, product quality

1. INTRODUCTION

Augmented Reality is the integration of digital information with the user's environment in real time (Rouse, 2015). It refers to a live view of physical real world environment whose elements are merged with augmented computer-generated images creating a Mixed Reality (Furht, 2011). The term “Augmented Reality” was coined by Caudell and Mizell in 1992, as superimposing digital information on the visual field of a user with real-world registration (Caudell et al, 1992). In 1994, Milgram and Kishino introduced the concept of “Mixed Reality”, with Augmented Reality closer to the real side of the “Virtuality Continuum” (Milgram et al, 1994) (Figure 1).

Figure 1: Virtuality Continuum

The Virtuality Continuum (Figure 1) spans the space between reality (Real environment), where everything is physical, and virtual reality (Virtual environment), where virtual and synthesized computer graphics replace the physical surroundings.
Besides adding objects to a real environment, Augmented Reality also has the potential to remove them. Current work has focused on adding virtual objects to a real environment. However, graphic overlays might also be used to remove or hide parts of the real environment from a user.

2. AUGMENTED REALITY TECHNOLOGIES

AR-technology has huge possibilities and only technology and imagination sets the limit on what can be achieved with it. Augmented Reality technology can be used in many fields such as: commercial, games, navigation, tourism, medicine, military, maintenance, etc. (Azuma, 1997) (Sielhorst et al, 2004) (Jung et al, 2008) (Reitmayr et al, 2004) (Platonov et al, 2006). In recent years, a wide variety of Augmented Reality technologies and applications have been developed (Van Krevelen et al, 2010) (Camigniani et al, 2011).

2.1 Augmented Reality Devices

The main devices for Augmented Reality are displays, input devices, tracking, and computers. Display system varies from optical see-through, video see-through to direct projection. There are three major types of displays used in Augmented Reality: head mounted displays (HMD), handheld displays and spatial displays. HMD is a display device worn on the head or as part of a helmet and that places both images of the real and virtual environment over the user's view of the world. Handheld displays employ small computing devices with a display that the user can hold in their hands. There are currently three distinct classes of commercially available handheld displays that are being used for Augmented Reality system: smart-phones, PDAs and Tablet PCs (Wagner et al, 2006).

There are many types of input devices for Augmented Reality systems. In the case of smart-phones, the phone itself can be used as a pointing device. Tracking devices consists of digital cameras and/or other optical sensors, GPS, accelerometers, solid state compasses, wireless sensors, etc.

2.2 Augmented Reality Interfaces

One of the most important aspects of Augmented Reality is to create appropriate techniques for intuitive interaction between the user and the virtual content of Augmented Reality applications. There are four main ways of interaction in Augmented Reality applications: tangible Augmented Reality interfaces, collaborative Augmented Reality interfaces, hybrid Augmented Reality interfaces, and the emerging multimodal interfaces.

3.3 Augmented Reality Systems

Augmented Reality systems can be divided into five categories: fixed indoor systems, fixed outdoor systems, mobile indoor systems, mobile outdoor systems, and mobile indoor and outdoor systems. Mobile system is defined as a system that allows the user for movement that are not constrained to one room and thus allow the user to move through the use of a wireless system.

3. AUGMENTED REALITY MOBILE SYSTEMS

Augmented Reality mobile systems include mobile phones applications as well as wireless systems such as MIT's sixth sense (Mistry et al, 2009) and eye-q (Costanza et al, 2006). Augmented Reality mobile systems involve the use of wearable mobile interfaces for the user to interact with digital information overlapped on physical objects or surfaces in a natural and socially acceptable way. Mobile phones for Augmented Reality present both advantages and drawbacks. Indeed, most mobile devices nowadays are equipped with cameras making mobile phones one of the most convenient platforms on which to implement Augmented Reality. In addition, most cell phones provide accelerometers, magnetometers and GPS from which Augmented Reality can benefit.

4. SMART PACKAGING

Smart packaging provides enhanced functionality that can be divided into two submarkets: active packaging, which provides functionality such as moisture control, and intelligent packaging, which incorporates features that indicate status or communicate product changes and other information (UBM Canon , 2016).

Literature offers several definitions of active, intelligent and smart packaging. In this paper, our work is based on the following definition.

Active packaging is packaging, which has an extra function in addition to that of providing a protective barrier against external influence. It can control, and even react to, phenomena taking place inside the package. Intelligent packaging monitors to give information on the quality and state of the packed product. Smart, intelligent or clever packaging is defined as a packaging technique containing an external or internal indicator for the active product history and quality (Bente et al, 2000).

5. SMART INKS FOR SMART LABEL PRINTING

In recent years smart inks, lacquers and labels are used for the printing, packaging, security (brand protection, traceability, tamper-evidence), medical sterilization, heat and radiation curing, food retorting,

coding and marking, etc. Different types of smart inks that are already produced and whose implementation is most often associated with the processing of graphic products through special effects were considered during the development of augmented activated smart label (Chameleon®Inks & Coatings, 2015).
Smart inks can respond to the following sources of stimulation (Siltech Limited, 2016):

- Gamma Radiation
- UV Radiation
- Heat
- Steam
- Ethylene Oxide
- Infrared Radiation
- etc.

The remainder of this section are examples of smart inks that are beneficial for the development of novel smart packaging augmented activated labels for state identification of product shelf life.

5.1 Fadable Inks

Fadable ink is able to disappear in a defined time period. The fading time is determined by the oxygen diffusion rate through the polyacrylate protective layer of ink and temperature. Different polyacrylates have different rate of air diffusion coefficient that is correlated with the glass transition temperature of polyacrylates.

5.2 Termochromic Inks

These type of inks change colour gradually in response to fluctuations in temperatures. There are both irreversible and reversible types (Chameleon®Inks & Coatings , 2015). Reversible Inks can be heat or cold activated. Heat activated inks change from a colored state at room temperature to a translucent colorless state when heated and can reveal messages or pictures beneath. They revert to their colored state on cooling (Figure 2).

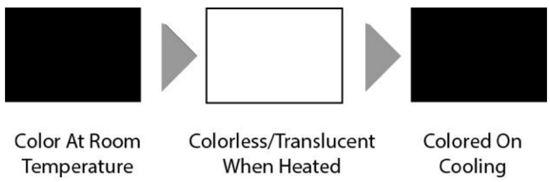

Figure 2: Heat activated reversible inks

Reversible cold activated inks (Figure 3) are colorless at room temperature and become colored or reveal a message when chilled, becoming colorless again when warmed (Chameleon®Inks & Coatings , 2015).

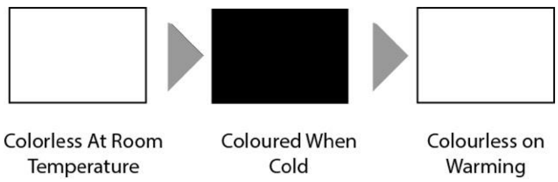

Figure 3: Cold activated reversible inks

Reversible inks are available in many colors such as Black, Red, Blue, Green, Orange and Magenta and in varying temperatures between -10 and 65°C. Producers of these inks hold a few standards. However, most products can be developed to customers' needs.
Uses of these products fall into three areas: cold, body and hot and are used to enhance labels, give warnings, the advice of correct consumption temperature, show proof of authenticity or simply act as an interactive game mechanism on cards and coasters.

Thermochromic Irreversibles are inks that change color permanently when activated by increases in temperature from a colorless to a colored state. The reaction is irreversible. These inks are often used to show permanent proof. They can be produced as screen or flexo-printing inks (Chameleon®Inks & Coatings, 2015).

5.3 Photochromic Inks

Photochromic inks change color when exposed to ultraviolet light usually from the sun or a black light. The inks are effectively colorless indoors and turn into vibrant color outdoors (Chameleon®Inks & Coatings , 2015).

When brought back inside, the inks become clear again. The inks become intensely colored after only 15 seconds in direct sunshine and return to clear after about 5 minutes indoors (Figure 4).

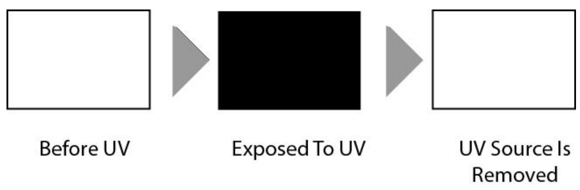

Figure 4: Photo chromatic colour tone change, after UV light exposure and moving away from the source of UV light

Photochromic inks have many features. When they are not exposed to UV Light, they are near invisible. These inks have fast reversible transition - Intense color in 15 seconds returns to clear after 5 minutes indoors. Sixteen standard colors including process colors are available. These inks can be printed on paper substrates, textiles, glassware, ceramics, plastics, etc. (Chameleon®Inks & Coatings , 2015).

5.4 Hydrochromic Inks

Hydrochromic inks react to the presence of water. There are reversible and irreversible types of hydrochromic inks on the market. Irreversible can be produced in two types of ink. The first changes from a color to white when exposed to water and remains so when dry again. The second dissolves and washes off the surface revealing a message below. These irreversible inks are usually available in Blue and Black (Figure 5) (Chameleon®Inks & Coatings , 2015).

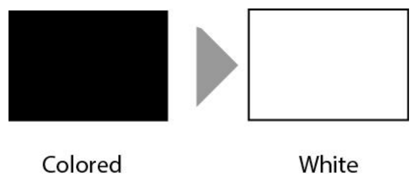

Figure 5: Colour tone change of Irreversible hydrochromic ink

Reversible ink is white in appearance but become translucent when exposed to water and then reverts to a white state when dry. This reversible ink is available only in white color (Figure 6) (Chameleon®Inks & Coatings , 2015).

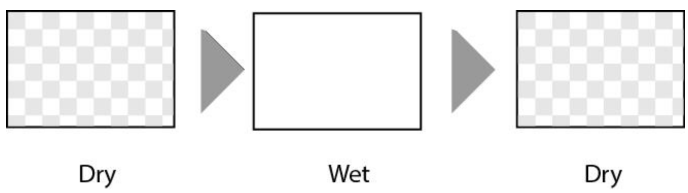

Figure 6: Colour tone change of Reversible hydrochromic ink

6. PROBLEM DESCRIPTION

The objective of this work was to design a smart labels and iPhone Augmented Reality application which analyzes the state of the tone of inks on smart labels and provides information on the state (freshness) of the product in real time and specific store. It would be able to determine what product with smart label the user is pointing the iPhone camera at, after which relevant information should be displayed and in some cases let the user interact with that object via the phone.

7. METHODS AND TOOLS

When deciding how to solve the task there were several key points that had to be considered, which is important for any Augmented Reality system and especially for this one since image recognition was to be done on a mobile phone.

1) Speed
2) Invariance and Robustness
3) Usability

According to (Jing et al, 2006) the key points to having a good overlay of virtual objects on the real world is speed and accuracy. When dealing with a mobile phone there is the issue of limited CPU power and smaller memory capacity. It was therefore important that the application to be created would not require too much CPU power, draining the battery, and would not use too much memory. Knowing that the image recognition method would consume the most CPU power the main focus was to find a well performing method.
Invariance and robustness mean that the image recognition process has to be able to handle rotation, different scales, illumination, blurriness, etc. These were very important factors that had to be considered since the application was to be developed for an iPhone, where the mobile phone will be held by a person in different lighting conditions.
Usability include the application having both speed and invariance and robustness, but also involves which information to display, how it should be displayed and how to interact with it. The main goal in making this application was to make use of Augmented Reality technology, therefore packaging and smart label would be the main focus of interaction.
After analyzing Augmented Reality libraries and key points speed, invariance, robustness and usability, SDK library Qualcomm Vuforia (Vuforia, 2016) has been chosen. The Vuforia platform uses superior, stable and technically efficient computer vision-based image recognition and offers the widest set of features and capabilities, giving developers the freedom to extend their visions without technical limitations. With support for iOS, Android, and Unity 3D, the Vuforia platform allows writing a single native app that can reach the most users across the widest range of smartphones and tablets. For developing app on a mobile phone cross platform Unity 3D has been used, the most popular development platform for creating 2D and 3D multiplatform games and interactive experiences, with SDK Vuforia Unity package 6.0.112 (Developer Vuforia, 2016). Mac OS 10.11.06 has been used for operating system and Unity 3D version 5.3.5 (Unity, 2016) for developing. XCode-a 7.3.1 (Apple, 2016) has been used for building and testing final app on iPhone 6 Plus device. XCode is an integrated development environment (IDE) containing a suite of software development tools developed by Apple for developing software for macOS, iOS, WatchOS and tvOS.
Test package and smart label have been designed with Adobe Illustrator CS6. Test label was not printed with smart inks, it was printed in digital technique only for testing application functionality.Test smart label was printed with digital printing technique on Xerox Docu Color 252 printed, surface for label was Ritrama semigloss 80 g/m^2. Test package was printed on the Nevia 300 g/m^2 surface with digital printing technique on same machine Xerox Docu Color 252. Package has been chosen from EngView Package and Display Designer 6 library a box prototype was created on Aristo Mat 1317 cutting machine. Test label was not printed with smart inks, it is printed in digital technique only for testing application functionality.

8. RESULTS

8.1 Vuforia Aplication Architecture

The following section describes the main components in an application based on Vuforia's SDK. These components are camera, Image Converter, Tracker, Video Background Renderer, Application Code, Target Resources (Figure 7).

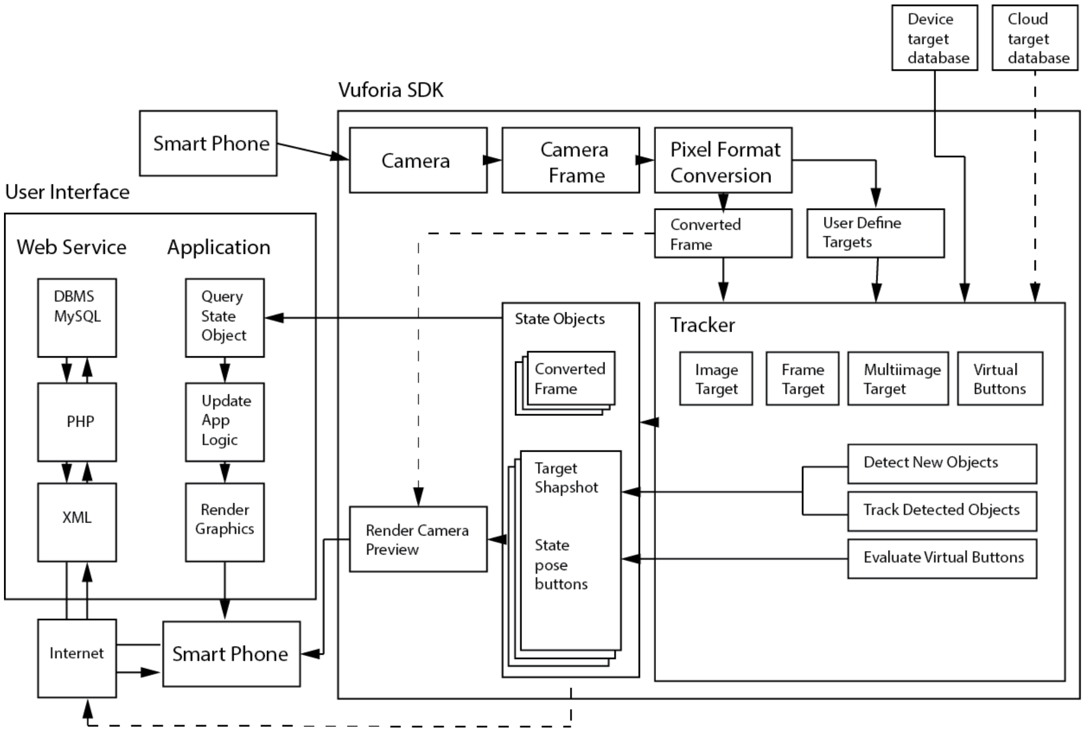

Figure 7: Vuforia Aplication Architecture

The camera singleton ensures that every preview frame is captured and passed efficiently to the tracker. The developer only has to tell the camera singleton when capture should start and stop. The camera frame is automatically delivered in a device dependent image format and size. The pixel format converter singleton converts between the camera format to a format suitable for OpenGL for Embedded Systems rendering and for tracking (e.g. luminance). This conversion also includes down-sampling to have the camera image in different resolutions available in the converted frame stack. The tracker singleton contains the computer vision algorithms that detect and track real world objects in camera video frames. Based on the camera image, different algorithms take care of detecting new targets or markers, and evaluating virtual buttons. The results are stored in a state object that is used by the video background renderer and can be accessed from application code. A multi target consists of multiple image targets that have a spatial relationship. If the result contains multiple image targets, product image and smart label image, Web Service checks target combinations in database and downloads related data to show product state on user interface. The tracker can load multiple datasets, but only one can be active at a time. The video background renderer singleton renders the camera image stored in the state object. The performance of the background video rendering is optimized for specific devices. Application developers must initialize all the above components and perform three key steps in the application code. For each processed frame, the state object is updated and the applications render method is called. The application developer must: query the state object for newly detected targets, markers or updated states of these elements; update the application logic with the new input data; render the augmented graphics overlay. Target resources are created using the on-line Target Management System. The downloaded dataset contains an XML, eXtensible Markup Language, configuration file that allows the developer to configure certain trackable features and a binary file that contains the trackable database. These assets are compiled by the application developer into the app installer package and used at run-time by the Vuforia SDK.

8.2 Smart Label Design Concept

Based on the analysis of existing types of special inks and the possibilities of Augmented Reality tracking, concept for novel smart packaging labels and mobile application for protection, information and identification of product shelf life have been formed.
Different products have different tolerance to temperature, weather or other conditions.
A new kind of smart labels are universal for all product types, but also it can be personalized for a specific group of products. In the case of frozen products important parameters are critical temperature and elapsed storage time, while in the case of other example pharmaceutical products important parameter can be information about product contact with water. It is possible to use the universal label, or personalized label and the fresh check results will be the same.
Novel smart label is in code form, it contains fields printed with different types of smart and convential inks (Figure 8). Smart label Code form enables security feature of Augmented Reality fresh check app.

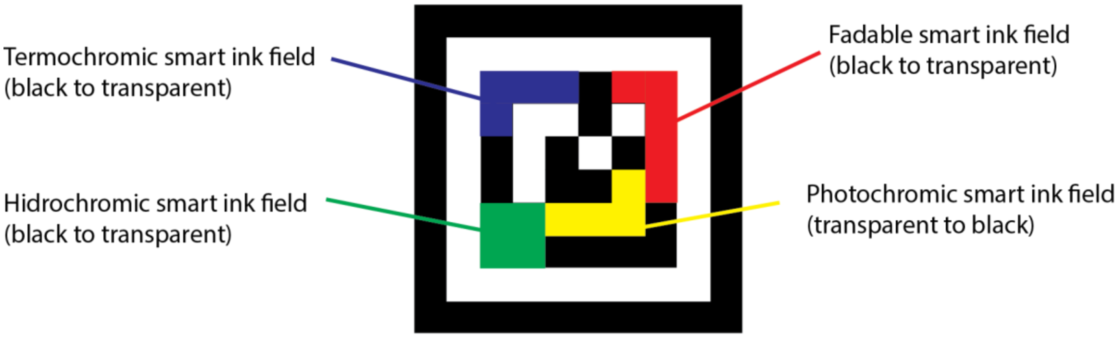

Figure 8: Smart label with fields printed with smart inks

It is clear that there is a large number of combinations of the code after activation of the two or more smart inks. In order to understand the logic of code changes on the smart label, possible variants of code after just one sources of stimulation have been shown on Figure 9.

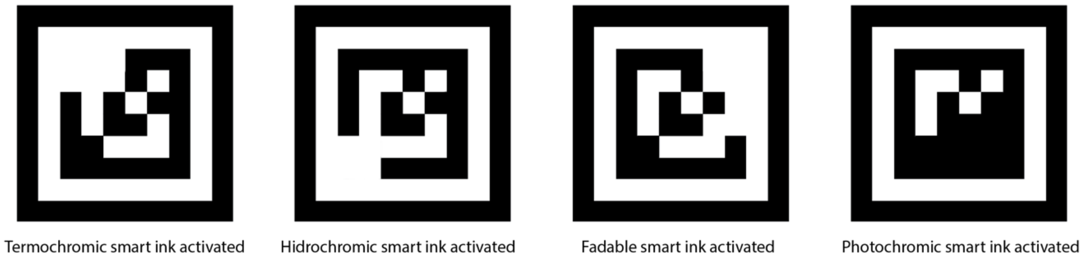

Figure 9: Smart label code variants after one smart ink activation

8.3 Application Algorithm

Application algorithm starts with smart phone camera which captures the scene with smart packaging with smart label. Tracker recognize and tracks package and smart label target. Information about recognized targets via Internet have been sent to a Web service and locally to the application. For specific combination of product-smart label target web service checks state od product freshness and send that information to the smart phone display. During this time app generates 3D scene with buttons for interaction with the same coordinating system as real scene. Augmented Reality with state of the product in the real time have been achieved (Figure 10).

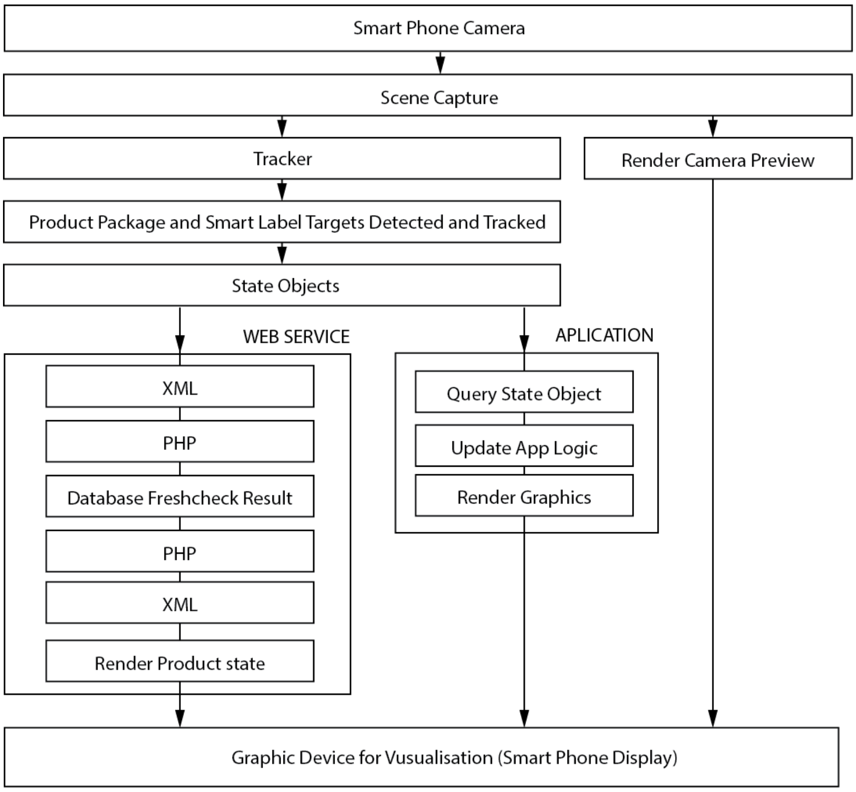

Figure 10: Augmented Reality food freshness check application algorithm

8.4 Smart Package Design

In order to test the application test packaging have been created using EngView Package Designer 6 application library. Graphic design is made in Adobe Illustrator CS6. Design of the test package is shown on Figure 11.

Figure 11: Test packaging for Augmented Reality app

8.5 Application Creating

Image recognition Augmented Reality apps built with the Vuforia SDK must have a known target dataset that can be used to match targets captured with camera device. Qualcomm's TMS offers a convenient web-based tool for Vuforia SDK developers to create this known dataset from input images. To access to the on-line TMS it is necessary to follow this link https://developer.vuforia.com /targetmanager. Registration is

required. After registration it is also necessary to create the License Key in License Manager, then to create database in Target Manager. Then to add image targets to this database and download the dataset. This dataset is then packaged and distributed with the application. Unity package was chosen in this case due to Unity3D is the development IDE.
Downloaded package contains the dataset configuration XML file, that allows configuring certain trackable features, and a binary file, holding the trackable database. If a multi target is created using the web tool, it will automatically include the appropriate definitions into the XML.
Then create new 3D Unity project. Vuforia SDK and dataset have been imported. Add an image target ARCamera from the Asets/Vuforia/Prefabs folder, and delete default camera. Target image and ARCamera positions are set to zero so they are in the middle of the scene. ARCamera have to be sat to face in the Target image. Then it is necessary to add the License Key found in the Developers Portals License Manager page to a App Licence Key in the ARCamera. In the Image Target Inspector, set dataset and image target. In the ARCamera inspector, dataset have to be loaded and activated. Then add a 3D object and User Interface and place it on the image target. 3D object has to be a child element to the target Image. Then it is possible to test it using web camera.

8.6 Interface elements and design

User Interface for Augmented Reality have been developed in 3Ds Max, and then imported to Unity. The idea was to show product inside the packaging and all useful information like product state and nutrition facts (Figure 12).
Application icon and Splash Screen design is shown on Figure 13.

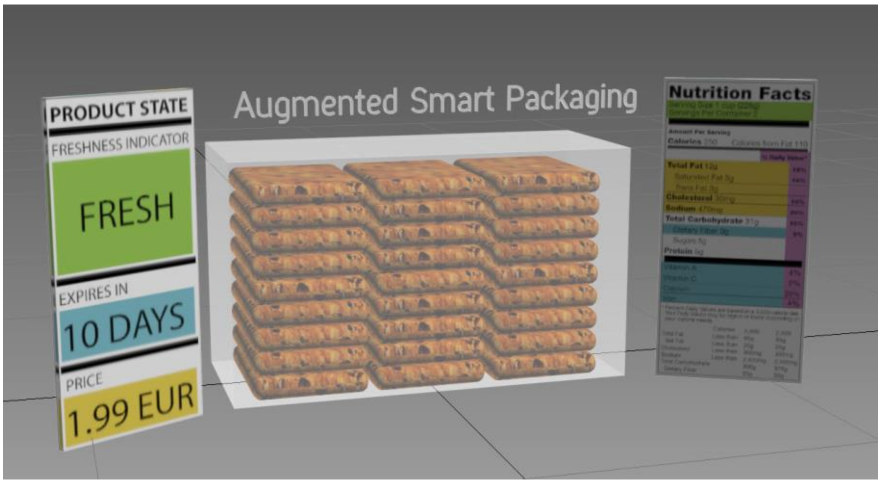

Figure 12: Interface Elements in 3Ds Max

Figure 13: Application icon and splash screen

8.7 Generating Application

Application have been built for an iPhone 6 Plus devices using a xCode 7.3.1 with default settings.

9. DISCUSSION

Smart label and Augmented Reality application a simple solution to control the product state. Current technological advances ensure the implementation of such a control system. Universal smart label achieves low-cost production of labels. It is possible to use screen printing as well as flexo printing technique, which provides fast output production speeds for high circulation. In the future we expect the fall in prices of smart inks and greater development of Augmented Reality. Offered solution of the system falls into the category of mobile indoor and outdoor systems. This system belongs to the group Augmented Reality tangible interfaces for handheld displays. Advances of powerful CPU, camera, accelerometer, GPS, and solid state compass are present in all mobile phones today, making them the best handheld platform for this Augmented Reality system. However, their small display size is less than ideal for 3D user interfaces, but it is expected that in the future this system will be able to adapt and head mounted displays (HMD) and spatial displays.

10. CONCLUSIONS

The final application is a working Augmented Reality application; it fully meets all the requirements for an Augmented Reality application. It is based on multiimage Augmented Reality system technique, the Augmented Reality application service for smartphones was designed and implemented to effectively convey the information of product state. As a result, the service was able to show the product state (freshness) depended on digitally printed label for simulation. In future research, we will try to connect smart label and packaging targets, and to provide a variety of information in a very accurate and fast way. Therefore, unlike the conventional advertising applications which simply introduce and explain products by triggering users' interests, this application is expected to be used in an area of smart packaging, by making interaction between users and package. In the future, it is necessary to upgrade application with the GPS features of the smart phone to personalize information depending on the phones GPS location. GPS integration can also help users to find where is the nearest store with desirable product using developed database of products on Web Service.

11. ACKNOWLEDGEMENTS

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THE DEVELOPMENT OF THE KNOWLEDGE BASE OF CONTEMPORARY GRAPHIC LABORATORY

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Abstract: *The paper presents the research of the process of creating the concept of the modern graphic laboratory in terms of equipment which it is supposed to contain. In addition to the theoretical bases, the aim is to improve understanding of the printing production process through linking theoretical and practical knowledge. The design concept was carried out through an interactive visualization of equipment catalog of the GRID center using Photoshop and InVisionApp. This research represents the part of the projects for the development of the knowledge base for distance learning.*

Keywords: Graphic laboratory, Graphic production, Knowledge base, Interactive equipment catalog

1. INTRODUCTION

Distance learning can be defined as any educational or learning process or system specifically designed to be carried out remotely by using electronic communication which allows immediate revisions and distribution. In addition, it is delivered using standard Internet technology and it does not preclude traditional learning processes (Rosenberg, 2001). The main function of distance learning is to overcome physical distances in order to transfer knowledge. The implementation of distance learning dates back to 1840s, when Isaac Pitman, stenography teacher, applied this system giving tasks to his disciples to prescribe short messages from the Bible, which they would send him back by post. In this way, Pitman has maintained communication with his students throughout the country, and educated them successfully. This way of learning, compared to traditional methods, proved to be a high quality, pragmatic and cost-effective. At first, distance learning functioned through the use of the postal system, which allowed education to people who could not attend classes in traditional schools (Link group, nd).

The first stage of development of distance learning is called Correspondence Learning, and it is primarily used by women since they were excluded from the program of institutional education, then the workers, but also by those who live too far from training centers. The University of London was the first who opened the possibility of distance learning in 1859. This trend continued and followed by other universities such as the University of South Africa (1946), the Open University in London (1969), as well as the Fern Universitat in Hagen, Germany (1974). In the twentieth century, radio, television and the Internet have been used to stimulate distance education (Moore and Kearsley, 2005).

Today, colleges and universities have increasingly accepted online education, and the number of students enrolled in distance programs is rapidly rising. Distance learning implies the existence of lectures and exercises on the Internet, CD or DVD, electronic books, simulations, text messaging, podcasting, blogs, forum, testing via the Internet etc. Elements of the distance learning process are (Link group, nd):

- The participants in the learning process (suppliers and recipients of educational content),
- Educational content,
- Communication and interaction (among the participants of the process) and
- Technology (methods of presenting educational content and communication among participants).

It is important to emphasize that people learn more effectively when they interact with other people participating in similar endeavors. Also, that the use of the multimedia content is very useful in the process of acquiring knowledge, as it provides a much more complete information and gives a stronger impression, allows better adoption of the matter and encourages curiosity and will to learn. Also, an important element is the inclusion of performance support components designed to enhance performance (Link group, nd); (Rosenberg, 2001).

1.1 The types of distance learning

There are two different types of distance learning - synchronous and asynchronous. The simultaneous participation of all students and lecturers is the main characteristic of a synchronous learning system. The main advantage of this system is that the interaction is performed immediately - in "real-time". Examples of the synchronous learning include interactive telecourses, teleconferencing, and web conferencing, polling, application sharing and Internet chats. On the other hand, the asynchronous system does not require the simultaneous participation of students and lecturers, and they do not have to be gathered in the same place at the same time. Instead, students themselves choose the time of teaching and interaction with teaching materials and lecturers, in accordance with their own time and schedule. In comparison to the synchronous system of distance learning, the asynchronous system is more flexible. However, experience shows that the time constraints are necessary to make learning and participation of students in the learning process successful and to maintain motivation for learning which may decrease over time. Examples of asynchronous learning include email, blog, discussion forum, audio courses, video courses, correspondence courses and website based courses. There are three elements that are essential to achieving successful distance education program (California Distance Learning Project, 2011):

- The design of learning materials,
- Technology and
- Ongoing support.

The superiority of e-learning does not come from the fact that technology is used to transfer data, but from the manner in which it uses the available media. In other words, it is the design of teaching that determines the level of success of these programs, and not the use of various technologies, or absence of them. The design is the key that will make learning experience boring or inspiring, exhausting or stimulating, meaningful or meaningless (Allen, 2003).

1.2 The impact of new technologies on the development of distance learning

The emergence of new media has led to major changes in communication. These changes are also reflected in education and led to the creation of new forms of learning which are very different from traditional methods. However, it is important to emphasize that the goal of comparing new and traditional forms of learning is not to assess which of them is better, but to show that the basic idea of distance learning is the possibility of creating and maintaining a productive environment in the case when direct communication or presence are not possible (Haythornthwaite and Andrews, 2011).

Computers and networked technologies that enable online education are not just a replacement of the media that were used in the implementation of traditional learning so far. Instead, these technologies, imbued with innovative teaching methods, enable teachers and students to teach and learn in a more efficient way (Wang and Reeves, 2007).

The emergence of Web 2.0 technology is the first technological innovation which has brought new challenges when it comes to the idea of the creation and distribution of knowledge. Through the technology of social networks, the global network is used in different ways. The exchange of data on the network becomes the platform for the development of social software that allows groups of users to socialize and collaborate in order to create new ways of communicating and learning. E-learning involves the use of some or all of the following technologies (Pachler and Daly, 2011):

- Desktop and laptop computers
- Software
- Interactive whiteboards
- Digital cameras
- Mobile and wireless devices, including mobile phones
- Electronic communication tools, including email, forums, chat facilities and video conferencing
- Virtual Learning Environments (VLEs)
- Learning activity management systems

E-learning includes a range of activities from additional learning, through the combined learning (combination of traditional and online learning) to the learning that is fully realized as online learning. Today, e-learning is not only linked to the term distance learning, but is a part of a selection of an

appropriate, and therefore better, way for effective learning. However, the term technology-enhanced learning is gaining an advantage, because it highlights the way technology gives the value of learning by enabling easier integration with information and other participants in the learning process. This enables continuous access to learning material, greater choice in terms of time, place and pace of learning, alternative ways of studying: distance learning, combining traditional and distance learning, exchange of knowledge from different locations, rapid feedback, active learning regarding the use of interactive technology and multimedia content, the development of skills for life and work in the virtual age (Pachler and Daly, 2011).
Recently, distancing from the desktop computer as a point of interaction with technology has introduced a new dimension when it comes to e-learning. "Sensor technologies" have led to the fact that computers are practically embedded into devices that are used daily. These devices bring the concept of omnipresence of computer in everyday life, and thereby create a significant shift when it comes to the interaction of the individual and technology. Data no longer depend on the device. The impact of mobile phones, as well as the increased number of video and interactive content, suggest that the expectations of users, in terms of everyday use of these devices, have increased. This is a result of aim to create an easier way for the use of information. In the field of education intuitive interface allows a better understanding of complex content (Pachler, Daly, 2011).

1.3 The potential and benefits of using technology in education

The teaching strategies based on educational technology can be described as ethical practices that facilitate learning and improve capacity, productivity, and performance. In education, technology manifests itself through the use of computers. This technology is essential for both the suppliers and recipients of educational content (Minnegerode, 2014).
Some of the potential and benefits of using technology in education are (Pachler and Daly, 2011):

- The same content can be presented using different types of media, including text, 2D and 3D, graphics, sound, image sequences and simulation,
- Different views and approaches to the same topic,
- Combining different media into multimedia presentations,
- Connecting multimedia components in hypermedia applications for learning,
- Reuse and adjustment of existing contents to new courses and curricula,
- Easier management of copyright for multimedia educational content,
- Interactive activities give students the opportunity to experiment and create a constructive approach to solving a particular problem and
- Students can write their references and notes on the material.

Information is becoming more accessible and transmittable. Important skills for students include the ability to use technology to access, filter, analyze and organize multidimensional information sources. Interactive technologies contribute stimulating environments that encourage student participation in the learning process and also aid teachers with creating new learning environments. Also, the structure and use of technology can promote higher-level thinking skills, and use of hypermedia and telecommunications can affect thinking skills (Barron et al, 2002).

1.4 Tools for distance learning

Distance learning is the product of the combination of different learning tools. Types of tools that are used can be organized in descriptive categories, and they can be combined resulting in creating a variety of hybrid forms. The tools that are most commonly used are presented in Table 1 (California Distance Learning Project, 2011); (Allen, 2003).

Table 1: Tools for distance learning (California Distance Learning Project, 2011)

Type	Characteristic	Notable Features
Audiotape	Audio learning tool, very mobile and inexpensive when combined with print materials.	Useful in language learning and practice as well as literature. Linear format.
Videotape in VHS and DVD formats	Visual and audio tool; the checkout approach with print materials is very popular in California.	A multi-sensory tool with a linear delivery format.
Laptop computer checkout	A versatile approach to providing a wide range of learning activities from skill and drill to simulations.	Hardware is expensive and being replaced by less expensive Internet delivery.
Mobile van / lab	Resources took to the learners, useful for work site learning and reaching parents at elementary schools. Van learning.	Historically useful way to distribute videos, audiotapes, DVDs, and other learning tools, but it can be expensive to operate
Radio course	Low cost way to reach ESL learners. Ideally, it should be used by more learning providers.	The radio course must include ways for learners to interact with the instructor. A phone call in during or after air time could be integrated into the programming.
Telecourse	Delivery over television, usually a cable public access channel or school owned channel.	The telecourse must include ways for learners to interact with the instructor. A phone call in is popular. Print materials accompany on-air instruction.
Videoconference – Two-way interactive video	Electronic communications among people at separate locations. Can be audio, audio graphic, video or computer-based.	Often uses proprietary software and consequently expensive. Internet models and broadband communications are making it more affordable and accessible.
Email	Asynchronous text files and attachments.	Good tool to stimulate learning, writing, and communications skills.
Internet	Instructional delivery over the Internet, either learning modules or entire courses.	Instructional learning systems permit teachers to create, manage, communicate with, and test students online

2. METHODS

2.1 Phases of creating interactive content

Content that is used for e-learning must be accurately prepared and shown to be effective. Teaching techniques should be used in a creative way in order to create an experience that motivates and encourages engagement. Phases of creating interactive content, the so-called ADDIE model, are shown in Figure 1 (FAO, 2011).

The trial version of the application (Figure 2) was implemented using Photoshop and online application InVisionApp. This way, participants were able to access the content and explore possibilities of the application whereby coding and designing of the real application using HTML, CSS and JavaScript were bypassed until all possible deficiencies were determined through feedback from the users and then removed.

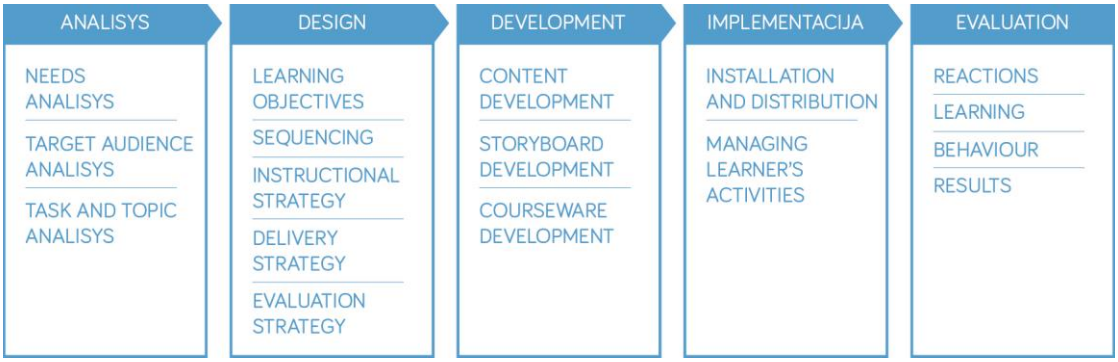

Figure 1: The ADDIE model for e-learning (FAO, 2011)

Figure 2: Sections of the trial version of the application: menu (up left), theory basics (up right), page about machine (down left) and zoom page (down right)

3. RESULTS

Content that is used for e-learning must be accurately prepared and shown to be effective. Teaching techniques should be used in a creative way in order to create an experience that motivates and encourages engagement. During the creation of interactive content for distance learning, it is important to collect feedback from potential users. For this reason, the first version of the application for distance learning was subjected to analysis through interviewing of several participants.
The survey was realized using free Internet platform- Typeform. Completing the survey online reduces printing costs and simplifies the analysis of the collected data. The survey consisted 17 questions that can

be classified into three groups: questions regarding distance learning, questions regarding design and functionality of the application itself and questions regarding personal views of participants regarding the use of this and similar applications. 65 participants in total completed the survey.
Results shown in Figure 3 show that a survey was completed mostly by respondents aged 25-29 years (52.05%). As shown in Figure 4, most of the respondents is familiar with the term distance learning (64.62%), but the number of respondents who are not familiar with this term, or are not sure what the term means is not negligible.

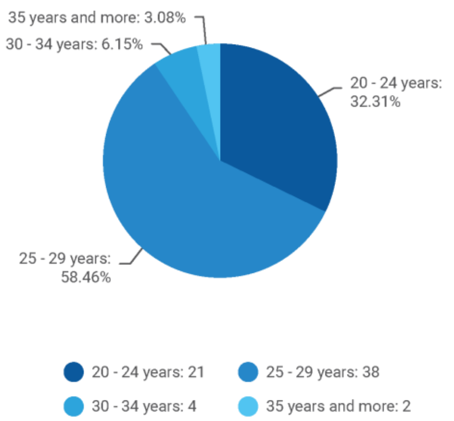

Figure 3: Age of the respondents

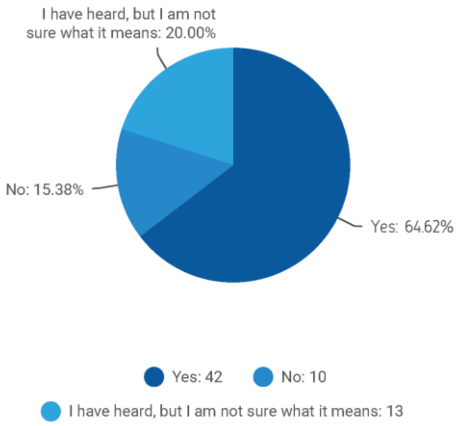

Figure 4: Results for the question: "Are you familiar with the term distance learning?"

Given the fact that that there are two types of distance learning - synchronous and asynchronous, one of the most important questions was the question "Which of these two types of distance learning would you prefer to choose". Figure 5 shows that the majority of respondents chose the asynchronous system.

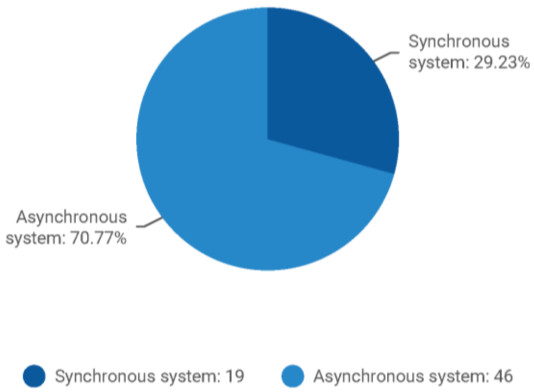

Figure 5: Results for the question: "Which of these two types of distance learning would you prefer to choose?"

The main feature and even the point of the concept of distance learning are the possibilities that the information can be accessed anytime, anywhere, using any device. For this reason, respondents were asked to choose the device for which they believe they will use the most if they were part of the program for distance learning. Although it is considered that the use of smartphones will dominate in the future (38% of respondents finished the survey using smartphone), the survey results (Figure 6) showed that most respondents have opted for a desktop or laptop computer (90.77%), and thus have chosen to be tied to a specific location for learning.

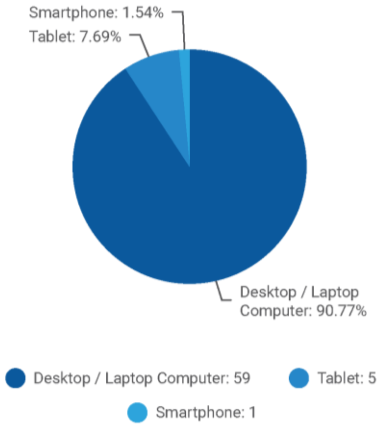

Figure 6: Results for the question: "If you were part of a distance learning program, which of the following devices would you use for learning?"

The next group of questions was focused on the design and functionality of the application itself (the results are shown on figures 8, 9 and 10). The importance of this group of questions was shown through the answer to the question "How important for you is the layout of the webpage when surfing the Internet?" (Figure 7), where the answer 1 had the meaning: "Not at all, the information is all that matters", while the answer 5 had the meaning: "Very important, the information on the webpage is much easier to remember if the website is well organized and designed".

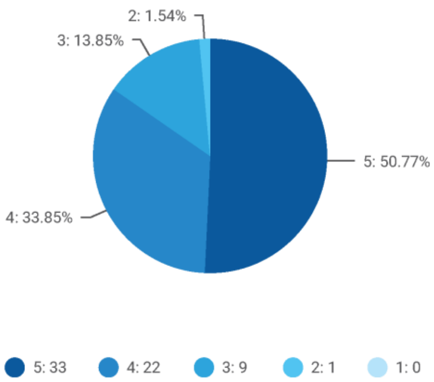

Figure 7: Results for the question: "How important for you is the layout of the webpage when surfing the Internet?"

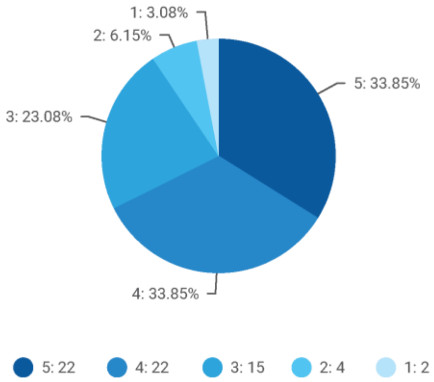

Figure 8: Results for the question: "How would you rate the design of the application?"

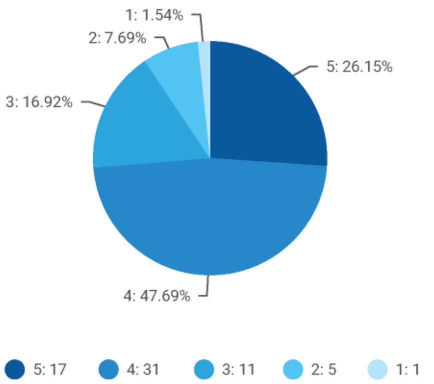

Figure 9: Results for the question: "How would you rate the functionality of the application?"

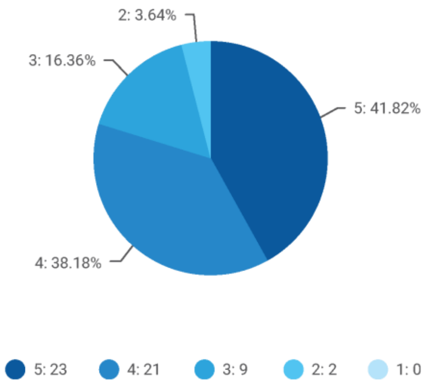

Figure 10: Results for the question: "How would you rate the layout of the application?"

The last group of questions was related to the personal attitude of respondents on the issue of whether the use of these and similar applications can motivate students to learn. The results of this section of questions are shown on the figures 11, 12 and 13.

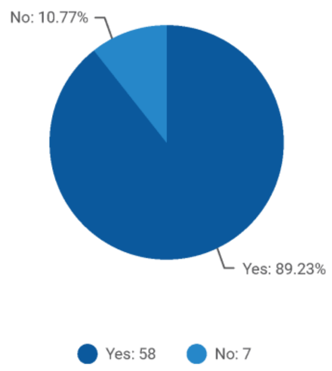

Figure 11: Results for the question: "Do you think that use of this and similar applications would facilitate learning and make it more amusing?”

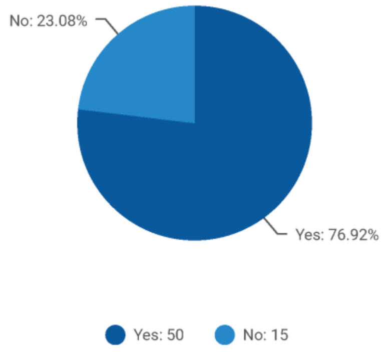

Figure 12: Results for the question: "Do you think that use of these applications would motivate students and increase their will to learn?"

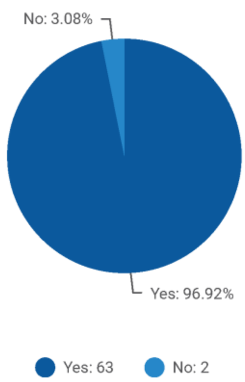

Figure 13: Results for the question: "Do you think that use of these applications could contribute to a better understanding of the material?”

4. DISCUSSION

Survey results have shown that distance learning is a field that has just begun to develop. If the universities implement such programs, students would rather opt for the flexibility of the asynchronous distance learning system, whereby the dominant device used for learning would be desktop or laptop computer. Given the fact that the most respondents react positively to good design and organization of web pages, the assumption that the main focus of the program for distance learning must be aimed at preparation and design of learning material, and that design is what determines the level of success of these programs is confirmed. As the majority of respondents believe that the use of these and similar applications facilitate learning, make it more interesting, motivate students and contribute to a better understanding of the curricula, it can be concluded that designing teaching materials this way is more than welcome. The development and usage of new technologies are increasingly moving students away from traditional learning methods, thus distance learning programs represent near future in the field of education.

5. CONCLUSIONS

Communication suffered major changes due to the emergence of new media. These changes were reflected in the field of education and led to the creation of new forms of learning which are very different from traditional methods. Distance learning is a form of learning that has enabled the creation of a productive environment, where participants are not limited by the geographic location, time nor the physical presence.

The emergence of the Internet and the development of Web 2.0 technologies have created a base for development of social software used for creating new ways of communicating and learning. This enabled the use of multimedia content in order to provide more information, causing a stronger impression on the user and thus better absorption of the curriculum, encouraging curiosity and willingness to learn. In the context of the creation of such content, design plays a major role, because it is the main factor that determines how the user will experience the content - whether as an inspiring and stimulating or boring and pointless.

Given that data does not depend on the device anymore, learning using mobile phones may increase, which is especially facilitated by the development of an intuitive interface for easier understanding of the content. According to that, it is planned to create a version of the application that would be adapted so it can be used on different devices.

After completing the first step in order to form interactive content, further research will be focused on the next phases. That phases are design, development, implementation and evaluation of interactive content by end users, implementation of choice of language and quizzes, all in order to improve and adapt the content to their requirements.

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COMPARISON OF SVG ANIMATION TECHNIQUES FOR WEBPAGES

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Abstract: *The purpose of this paper was utilizing the Scalable Vector Graphics (SVG) and comparing three SVG animation techniques to search for the most appropriate one to include on the web site. The theoretical part is divided into two parts: the first is a description of web animation and its history and in the second, the SVG language is presented, its structure, graphic systems, elements and the SVG animation techniques of elements chosen for comparison. For the experimental part of the paper, the animations were prepared and compared. The SVG animation techniques chosen for comparison were Synchronized Multimedia Integration Language (SMIL), Cascading Style Sheets (CSS) and the GreenSock Animation Platform (GSAP). In results and discussion, we tested the browser support, system load and the efficiency of animations in specific techniques. The comparison and testing showed that at SVG animation, the GSAP technique has the least deficiencies and was therefore chosen as optimal solution for implementation in web pages.*

Key words: animation, Scalable Vector Graphics, Synchronized Multimedia Integration Language, Cascading Style Sheets, GreenSock Animation Platform

1. INTRODUCTION

1.1 Web Animations

Web animation is a simulation of movement (visual illusion of changes of movement, colours, shapes etc.) driven by web technology. It is created by displaying a sequence of images, in which small variations of a defined parameter occur. The development of web animations started with GIF - Graphics Interchange Format animations in 1987. GIF is appropriate for short repeated animation and due to narrow collection of colours, their quality is poor. The GIF "imperfections" have been the reason for the development of new techniques; consequently, the first powerful tool for animating online Flash emerged at the end of 20th century. Flash allows the creation of simple vector animations with the potentials for implementation of interactions. Flash interactions are programmed with ActionScript, i.e. similar programming language to the JavaScript object-oriented language (Bruni, 2016). Due to some technical issues and general non-optimization of Flash solutions, especially for mobile media, the experts proclaimed the end of Flash development and application in Mac operating environment (Jobs, 2010). In 2016 Flash was replaced by Adobe Animate CC (Moss, 2016), which is based on the modern versions of HTML (Hyper Text Markup Language) and CSS (Cascading Style Sheets) programming languages. Besides, Javascript programming language have reinforced its usability for web animations. In the middle of the last decade World Wide Web Consortium started to prepare an enrolment of animations in CSS specifications (Bruni, 2016), which are now available as CSS animation and translations.

1.2 SVG language and its use on the web

SVG - Scalable Vector Graphics is an open source standard (recommended by W3C consortium) for description of two-dimensional graphic applications and images. SVG's use is very popular due to its resolution independency, file size, browsers support, possibilities of manipulations, interactivity and dynamic nature. SVG can be used in printing, on web and in mobile devices as static graphic; however it is optimised for its basic use, i.e. interactivity and dynamics (Rocheleau, 2015). Scalable Vector Graphics (SVG) is the description of an image as an application of the Extensible Markup Language (XML) (W3C, 2011). It is defined with <svg> element, which the description of graphic elements is inserted in. In general, three groups of elements in SVG graphic structure are used:

- **Basic elements -** define basic properties of SVG graphic with the use of the attributes:
  - **xmlns *attribute*** specifies the xml namespace for a document;
  - **viewBox** attribute specifies a given dimensions of a graphic and stretches a graphic to fit a particular container element (definition of x,y and length and width of a graphic);
  - **version** defines a variation of SVG graphic;
  - **width** defines a width of SVG graphic;
  - **height** defines the height of SVG graphic.

- **Grouping elements:** SVG graphic can be simple, however the group of elements allow to build more complex objects:
  - **grouping element <g>:** connects different graphic elements; it can involve also nested group of connected elements. The SVG specification defines that is should be used in the connection with the description <desc> and the title of the element <title>.
  - **element of definition and repeated use <def>:** defines the selected objects with the purpose for the further use.

- **Reference elements:** SVG enables the use of URI references of other objects. The establishment of connections can be obtained with:
  - <use> that enables the connection with the element, anywhere in the graphic;
  - the use of *url* link with CSS property (as shading and filter use).

SVG animations can be generated with various techniques: 1. animation with SVG graphic, i.e. Synchronized Multimedia Integration Language – SMIL; 2. with scripting programming languages, i.e. Cascading Style Sheets – CSS and 3. with the libraries enabling the application of SVG graphics.

SVG animation with *SMIL*

SMIL - Synchronized Multimedia Integration Language is a basic technique of graphics animation on the web. The procedure includes the implementation of SVG graphic into the object, that is going to be animated and the definition of attributes. The attributes are defined with the starting and final values.

SVG animation with CSS (Shenoy 2013)

Animation of SVG elements with CSS is identical as the animation of HTML elements. With the CSS animation, the defined values are changed in dependence of the time. The CSS animation is built with two basic components:

- **@keyframes**: presents a timeline that defines the levels and styles of the animation. The most basic animations include only initial and final values (of a defined animation element), however the variations can be defined also with the definition of more levels between starting and ending point.
- **animation**: here the rules that were defined in timeline are called and their additional properties are established (time, delay, number of repetitions, style of element etc.)

SVG animation *with the library GSAP* (GreenSock, 2014)

Currently, GSAP - GreenSock animation platform is one of the most powerful JavaScript library. GSAP is a collection of tools for animation production with the scripting. It includes different plug-ins in separate scripts for selected animation methods, which can, if necesarry, be connected with HTML document. For animation of elements with GSAP technique, the languages JavaScript and jQuery can be used. GSAP offers many possibilities of animation: banners, interactive pages, stories etc.
The aim of the research was the comparison of three techniques of SVG animation and the definition of the most optimal technique that is adequate for implementation on a web page. With this purpose SMIL - Synchronized Multimedia Integration Language, animation with CSS - Cascading Style Sheets and GSAP GreenSock Animation Platform were chosen and analysed. The study included the analytical comparison of SVG elements animation, time needed for production of SVG graphics, the complexity of structures, browsers support and the study of the efficiency of the three selected techniques. The focus was on the evaluation, which technique is adequate for simple and which for complex animations. In this contribution

only a brief summary of the research work is presented, meanwhile the complete project work can be viewed in the reference (Hojnik 2016).

2. METHODS

The first phase of the experimental was a planning of visual identity of the project, the setting of graphic elements and the definition of how the animations are going to proceed. The variety of animation types were tested:

- motion of element along the path;
- motion of element along x axis;
- application of different type of easing during the motion;
- element's transparency;
- changing of the element's size;
- negative and positive rotation of element;
- animation of element with the click action (interaction);
- changing the colours of elements.

The graphic elements were prepared in Adobe Illutrator (Figure 1 a). For each element or elements group, a unique layer was created that represented a separate part of the graphics with the recognisable name. Consequently, the XML structure was built. Each layer, such as also nested layers, was saved as a group of elements <g> with its identification name. The function of the letter was the connection of the selected elements in the separate groups, similarly as is the function of <div> to mark in HTML programming language. In our project the layer *soncek* (sunshine) was marked as <g id= "soncek"> that connected nested group *sonce* (sun) and its elements. The identification name <path id="zarki"> (*zarki* = rays) for easier recognition was allocated to these elements.
The last phase in Adobe Illustrator was to save the graphics in SVG format. With the purpose to ease the further manipulation in selected animation techniques, SVG was saved in two versions. Besides, SVG Profiles, SVG1.1 type and SVG image location Embed (our illustration did not include bitmap images) were defined. When CSS properties were saved, different variations were defined, namely Style Attributes, where the style of elements was described inside of SVG elements (applicable for the use in SMIL and GSAP techniques), and Style Elements, where the result was the code with CSS style, which is appropriate for animation of elements with CSS techniques.
The next step that should be performed was optimisation. Here it was crucial to completely comprehend the SVG code document in order to avoid unsuitable optimisation and potential cleaning of the important parts of the document. For the optimisation of our document, the tool SVGOM GUI was chosen and implemented (Figure 1 b).

Figure 1: a) Final setting of elements in Adobe Illustrator, b) Preview of SVG code in the programme SVGOM GUI

In this paper, the comparison of the selected techniques is described on the instance of the hot air balloon (the descriptions of other elements is described in details in the reference (Hojnik, 2016).

2.1 SVG animation of hot air balloon performed with SMIL

The perception of adequate movements of hot air balloon was attempted to be implemented in the animation. The focus was to achieve the even speed of uneven movements in all axis directions. This type of animation could be achieved with the motion of element along the path. In our case, the balloon was moving along the curve based on the attributes that were determined for the course of this motion. A part of programming code for the SVG animation of hot air balloon with SMIL is presented in *Programming code 1*.

```
<g id="balloon"> /*skupina elementov  balona v  SVG grafiki
   <g id="Balon" class="balon" > /* skupina elementov risanega balona*/
      <rect id="dno"  width="18.11" height="4.42" x="28.64" y="111.69" fill="#9E9E9E"/>
      <rect id="del" width="25.46" height="4" x="24.35" y="125.13" fill="#A1887F"/>
      <polygon id="kosara" fill="#795548" points="45.59 147.22 28.64 147.4 26.54 129.13 47.93 129.13"/>
      <rect id="palica2" width="2.53" height="9.03" x="30.46" y="116.11" fill="#FFFFFF"/>
      <rect id="palica1" width="2.53" height="9.03" x="42.46" y="116.11" fill="#FFFFFF"/>
      <path id="baloncek" fill="#AD1457" d="M28.64 112S6.24 96.94 6.32 71.28c.05-15.44 14-27.9 33.05-27.88 18.86 0 31.33 12.3
31.5 25.66.3 23.72-24.1 42.94-24.1 42.94H28.63z"/>
   </g>
<path id="pathbalon"  class="path-balon" fill="none" stroke="#795548" stroke-miterlimit="10" d="M234.4 103.56c.1 2.4.58 11.88-
5.07 20.54-9.54 14.63-28.92 15.46-36.43 15.8-21.83.93-23.67-8.86-49.08-13.52-31.25-5.72-46.14 5.85-69.54-6.8-4.93-2.68-9.93-
6.25-13.03-12.33-7.3-14.27 1.7-30.88 2.55-32.4 7.65-13.62 22-16.32 25.37-19.1 12.72-10.52 30.5 7.32 48.9 6.46 23.46-1.08 43.74-
17 58.43-2.5 11.7 11.53 37.1 26.87 37.9 43.86z"/> /* pot balona*/
</g>
```

Programming code 1: A part of programming code for animation of hot air balloon SVG graphic with SMIL.

2.2 SVG animation of hot air balloon performed with CSS

During the animation of SVG graphic with the CSS technique, it was recommended to determine each SVG element with the class selector and recognisable identification name (as in HTML document). In the CSS document the connection with the element is settled through the selector, where the element properties are defined and where the element can be manipulated and animated. For SVG animation with CSS, the class selectors with identification name were involved in elements and their style was assigned in a separate CSS file (*Programming code 2*).

```
<g id="balloon">/*skupina vseh elementov
    <g id="balon" class="balon"> /* skupina elementov, ki sestavlja toplozračni balon
      <rect id="dno" class="dno-balon" width="18.11" height="4.42" x="28.64" y="111.69" />
      <rect id="del" class="del-balon" width="25.46" height="4" x="24.35" y="125.13" />
      <polygon id="kosara" class="kosara-balon" points="45.59,147.22 28.64,147.4 26.54,129.13 47.93,129.13" />
      <rect id="palica2" class="palica-balon"  width="2.53" height="9.03" x="30.46" y="116.11" />
      <rect id="palica1" class="palica-balon"  width="2.53" height="9.03" x="42.46" y="116.11" />
      <path id="baloncek" class="baloncek-balon" d="M28.64 112S6.24 96.94 6.32 71.28c.05-15.44 14-27.9 33.05-27.88 18.86 0
31.33 12.3 31.5 25.66.3 23.72-24.1 42.94-24.1 42.94H28.63z" />
    </g>
    <path id="pathbalon" class="path-balon" d="M234.4 103.56c.1 2.4.58 11.88-5.07 20.54-9.54 14.63-28.92 15.46-36.43 15.8-
21.83.93-23.67-8.86-49.08-13.52-31.25-5.72-46.14 5.85-69.54-6.8-4.93-2.68-9.93-6.25-13.03-12.33-7.3-14.27 1.7-30.88 2.55-32.4
7.65-13.62 22-16.32 25.37-19.1 12.72-10.52 30.5 7.32 48.9 6.46 23.46-1.08 43.74-17 58.43-2.5 11.7 11.53 37.1 26.87 37.9 43.86z"
/>/*pot toplozračnega  balona
  </g>4.2.2.2 Animacija oblakov s CSS
```

Programming code 2: The document of balloon elements in SVG graphic with separated attributes

2.3 SVG animation of hot air balloon performed with GSAP

The last tested technique was GSAP. Our purpose was to achieve the comparable results to other two analysed techniques. For the animation of the objects in the amusment park, the language JavaScript and plug-ins TweenMax.js and MorphSVGPlugin were involved. For the animation of hot air balloon with GSAP technique, the motion along the path was implemented (as within the other two techniques). First, the path *BalonPot* (balloon path) was determined. This path was equal to the transformation of path's data with the help of plug-in MorphSVGPlugin in the series of points of Bézier curve.

The parts of programming codes are presented in *Programming codes 3-6*.

```
balonPot = MorphSVGPlugin.pathDataToBezier("#pathbalon", {align:"#balon"});
```

Programming code 3: Definition of the path of the hot air balloon's animation with GSAP technique

```
var tl1 = new TimelineMax({repeat:-1,});
```

Programming code 4: Timeline for the GSAP technique animation of the hot air balloon

```
.set(balon, {xPercent:-37.9, yPercent:-43.86})
```

Programming code 5: Definition of position of the hot air balloon's animation with GSAP technique

```
.to(balon, 25, {bezier:{values:balonPot, type:"cubic"}, ease:Linear.easeNone, }, 0)
```

Programming code 6: Definition of target values of the hot air balloon's animation with GSAP technique

3. RESULTS

During the comparison and analysis of the animations that were prepared with the selected types of animation techniques (SMIL, CSS, GSAP), additional testing was performed. The techniques were tested in different browsers with the tool for web page testing named CrossBrowser Testing (Figure 2).
Browsers support tests were performed for personal computers and mobile devices separately. The results revealed that for the support of SVG animations the least suitable is Internet Explorer. Within this browser, only SVG animations with GSAP technique are fully supported, meanwhile when the CSS technique is used, the transformation remain unsupported and the implementation of SMIL technique resulted in static images. Chrome revealed as the most optimal browser for SVG animation support. Here, all the analysed techniques successfully passed the testing. Firefox did not support the motion along the path performed with the CSS technique. Namely, when the animation was performed with SMIL technique on mobile devices, the train derailed during the lifting at the end of the path (Figure 3).

Brskalniki	SMIL	CSS	GSAP
IE11 Windows 10	×	○	✓
IE10 Windows 8	×	○	✓
IE 9 Windows 7 64-Bit	×	○	✓
Edge Windows 10	×	○	✓
Google chrome 50 Mac OSX 10.11, Windows 10	✓	✓	✓
Google chrome 49 Mac OSX 10.11, Windows 10	✓	✓	✓
Google chrome 48 Mac OSX 10.11, Windows 10	✓	✓	✓
Google chrome 47 Mac OSX 10.10, Windows 8.1	✓	✓	✓
Mozilla Firefox 46 Mac OSX 10.11, Windows 10	✓	○	✓
Mozilla Firefox 45 Mac OSX 10.11, Windows 10	✓	○	✓
Mozilla Firefox 44 Mac OSX 10.10, Windows 8.1	✓	○	✓
Mozilla Firefox 43 Mac OSX 10.10, Windows 8.1	✓	○	✓
Safari 9 Mac OSX 10.11	✓	○	✓
Safari 8 Mac OSX 10.10	✓	○	✓
Safari 7 Mac OSX 10.9	✓	○	✓
Safari 6 Mac OSX 6.2	✓	○	✓
Opera 36 Mac OSX 10.11, Windows 10	✓	✓	✓
Opera 35 Mac OSX 10.11, Windows 10	✓	✓	✓
Opera 34 Mac OSX 10.10, Windows 8.1	✓	✓	✓
Opera 33 Mac OSX 10.10, Windows 8.1	✓	✓	✓

a)

Brskalniki	SMIL	CSS	GSAP
IE Mobile11 Android Nexus 6P / 6.0	×	○	✓
IE Mobile 10 Android Nexus 9 / 6.0	×	○	✓
Chrome Mobile 49 Android Nexus 6P / 6.0	✓	✓	✓
Chrome Mobile 48 Android Nexus 9 / 6.0	✓	✓	✓
Chrome Mobile 47 Android Galaxy S6 / 5.0, iPhone 6s Plus / 9.0	✓	✓	✓
Chrome Mobile 44 Android Nexus 5 / 4.4, Android Galaxy Note 3 / 4.4, iPhone 6 Plus / 8.3	✓	✓	✓
Firefox mobile 45 Android Nexus 6P / 6.0	○	○	✓
Firefox mobile 44 Android Nexus 6P / 6.0	○	○	✓
Firefox mobile 43 Android Galaxy S6 / 5.0	○	○	✓
Firefox mobile 40 Android Nexus 9 / 5.0	○	○	✓
Safari Mobile 9.0 iPad Pro / 9.3 Simulator, iPad Air 2 / 9.3 Simulator, iPhone 6s Plus / 9.0	✓	○	✓
Safari Mobile 8.0 iPad Pro / 9.3 Simulator, iPad Air 2 / 9.3 Simulator, iPhone 6s Plus / 9.0	✓	○	✓
Safari Mobile 7.0 iPad Air 2 / 8.1 Simulator, iPhone 6 Plus / 8.3	✓	○	✓
Safari Mobile6.0 iPad 4 / 7.1 Simulator, iPhone 5s / 7.1	✓	○	✓
Opera Mobile 35 Android Nexus 9 / 6.0	✓	✓	✓
Opera Mobile 34 Android Nexus 6P / 6.0, Android Galaxy S6 / 5.0	✓	✓	✓
Opera Mobile 30 Android Nexus 9 / 5.0, Android Galaxy Tab S / 4.4	✓	○	✓
Android Browser 5.0 Android Galaxy S6 / 5.0	✓	○	✓
Android Browser 4.4 Android Galaxy Tab S / 4.4	✓	○	✓
Android Browser 4.1 Android 2.3 Simulator	○	×	✓

b)

Legend: ✓ - supported ○ - partly supported × - not supported

Figure 2: The browsers support of the three SVG animation techniques on a.) personal computers and b.) mobile devices

Figure 3: The presentation of the derailment of the train in Firefox browser on mobile phones and tablets

4. DISSCUSION

Especially in case of CSS technique, the research revealed some unexpected findings. Due to actual development of HTML and CSS technologies, more results that are adequate were expected here.
CSS is (besides, HTML and Javascript) indeed very useful and extended technique for the production of web-pages, surprisingly yet its combination with SVG animation resulted in technically and visually insufficient solutions. Here, the browser support is very limited, the description of animation, especially the most complex, is very time-consuming, and CSS technology does not allow the combination of transformations and events. During the measurements of efficiency it was found out that the painting can occur, which can influence on final animation. In our research, also after the application of possible solution that should reduce the painting, this phenomena still caused many problems. Irrespective of all the issues, our opinion states that CSS technique still represents the optimal choice for simple, short animations such as logotypes and info graphic.
The support of SVG animation with SMIL technique was demonstrated as very efficient. Regardless the fact that with this technique the creator is able to solve almost every animation issue, the future predictions for this technique are not favourable. It might be for some limitations that are still present after its application. For instance, when the procedure includes an action of returning element, the animation can become very complex. Besides, our animation work was also disrupted by the time-consuming procedure of defining of more animations to a selected element (especially transformations as motion and rotation). The work became complicated due to the requirement of describing a separate animation and not a group of them. In general, the efficiency of these animations was found to be the worst among the other analysed techniques. After our evaluation, SMIL technique results as adequate for simple SVG animations.
Finally, in our experiments all tested browsers supported GSAP technique. This technique revealed to be very strong tool, able to animate all the planned types of actions and transformations. The efficiency of animations developed with GSAP technique are comparable to animations produced with CSS technique. Furthermore, in our experimental the solutions for improving its implementation range were discovered. In the GSAP workflow, the writing of animation descriptions was very short and optimised. In our opinion and irrespective of the fact that the content of our research included mainly simple animations prepared with GSAP technique, its robust application can be firmly expanded also on very complex animations.

5. CONCLUSIONS

In our research, three SVG animation techniques were experimentally studied and compared: Synchronized Multimedia Integration Language (SMIL), Cascading Style Sheets (CSS) and the GreenSock Animation Platform (GSAP). The analysis included planning and programming of animations, analytical comparison of their efficiency and the testing of browsers support for personal computers and mobile devices. Namely, the results of the research presented that each technique has some advantages and disadvantages and that each animation technique is adequate for some type of animations. Nevertheless, we were the most impressed by GSAP technique that enabled quick and short descriptions of simple and also of complex animations.

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COMPARATIVE QUANTITATIVE ANALYSIS OF WRITING AND READING HABITS ON PAPER AND DIGITAL

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Abstract: *With the appearance and spread of the internet and of the means of mass communication the media market and also the market of printed communication have changed significantly. Digital technology has filtered through people's everyday life. The electronic media have significantly affected the printed media products. Instead of reading printed newspapers, magazines, many have changed over to reading internet news sites and using e-book readers to read books. All this noticeably affected the print run of printed products. These changes also greatly influenced young people's lives, their reading and writing habits changed.*
The aim of this paper is to study the influence of digitalization on today's university and college students' reading, and writing habits in Hungary. We examined how people read on digital screens versus in hard copy as well as how people write using a digital device versus writing by hand with a pen. The methodology applied in this study is quantitative analysis. For the survey we used a questionnaire which had 32 questions. We compered our results with the survey was performed in Serbia. Our results are based on 400 responses. The principal results of this study showed that reading and writing functions are changing with the use of digital technologies but that paper and digital interactions are typical nowadays.

Key words: paper and digital writing, paper and digital reading, reading and multitasking, reading/writing and concentration

1. INTRODUCTION

Due to advance in technology, mass communications as well as their means have changed and improved. This modernization had an impact on the traditional printed products and brought along the innovation of electronic media. People's views changed significantly, nevertheless a new era started with the appearance of the internet news websites. People's reading habits have changed and lots of them get informed about the news through the internet, instead of printed newspapers. Moreover the appearance of e-book reader made it possible to read books on an entirely new kind of surface (Anon. 1, online) (Stranegger, online).
Although the information content of printed media (text, figures, graphics) is stable/static and it cannot be changed quickly, in an interactive way, new technologies make it possible to produce the content tailored to the claims and needs of customers to an increasing degree. The strength of printed media is that they are easy to use nearly anywhere and in any environment – without the use of a special device.
Electronic media include the newest developments of the Internet, the World Wide Web (www) and CD-ROMs. They also cover the traditional forms, like radio and television, and the different forms of recording (recording and storing media), video and audio recording and computer-aided animations connected to them. Electronic media make it possible to integrate audio and video (speech, music and animations) into information documents (e.g. CD-ROM), besides textual, graphic and visual information. This information interaction provides the users with numerous possibilities. However, special devices are necessary to be able to use electronic information, especially during recording, playing and the display of data (Anon. 2, online).
Printed media products are typically produced in medium and large print runs. The products of electronic media are made in small or very small (even one) numbers. A part of printed products, like packaging materials cannot be substituted. The electronic equivalents of other products, like magazines, newspapers, catalogues and books are now available in a large number. The modern electronic media products, a very short time after their appearance, made (and still make) a deep impact on print runs in the printing industry (Kipphan, 2001; Smithers Pira Market Intelligence, online).
The aim of the research is to study the effect of digital technology and electronic media on printed media products. We examined the Hungarian university and college students' reading and writing habits, what

urges them whether to use digital displays or traditional paper to read and write on. We compered our results with the survey was performed in Serbia.

2. METHODS

In this study, a quantitative research method was applied in order to analyze today's young people's (university and college students') attitude and willingness to the traditional way of reading and writing on paper in pen, as against to the modern way, done on electronic devices. In the survey, the students were asked about their habits concerning digital and traditional reading and writing. This study is part of an international research project exploring how people read on digital screens versus in hard copy as well as how people write using a digital device versus writing by hand with a pen (Kaputa, Paulus, 2013; Fortunati, Vincent, 2016; Taipale, 2016).
The questionnaire contained 32 questions altogether, with the following sets of questions:

- Background information
- Reading and writing
- Reading in hard copy or on digital screen
- Text length
- Reading and multitasking
- Reading and concentration
- Writing and concentration
- Additional comments

2.1 Background information

During the survey we received 400 questionnaires that were evaluated. Most of the questionnaires, 273, were filled in on paper and in the online version by 127, by 370 full-time and 30 part-time students. Most of them (66%) were women. The majority were 20-25 years old, the average age being 24.68. Out of the students 360 are doing their BSc, 36 the Master and 4 people the PhD course. We asked them about their reading and writing habits connected to their school work and free time (e.g., novels, magazine articles). They were not asked about their reading for other purposes (e.g. a job, volunteer work, Facebook status updates).
In the survey made in Serbia also 400 valid questionnaires were evaluated, which were filled in by university and college students born between 1980 and 1996 (all on paper), 279 boys and 121 girls, of whom 319 were taking part in BsC, 72 in MsC and 9 in PhD training during the time of the survey.
In both countries, the survey was completed between 1st January and 1st September 2015.
Most young people (93% of all Hungarian responders, i.e. 347 people) have smart phones, laptops are owned by 83% (332) the third most popular device is the desktop computer (43%). Tablets are had by barely one third (105), while the rest of the devices (hybrid laptops, e-book readers, non-smart phones, etc.) are owned by 18% of all responders. In the „Other" category mainly smart tvs and iPods were mentioned (Figure 1.).

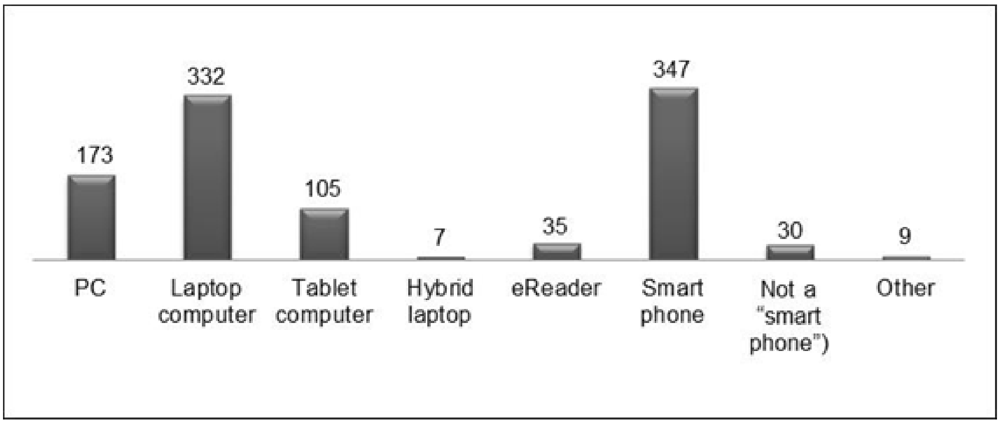


Figure 1: Digital device having (number of Hungarian responders)

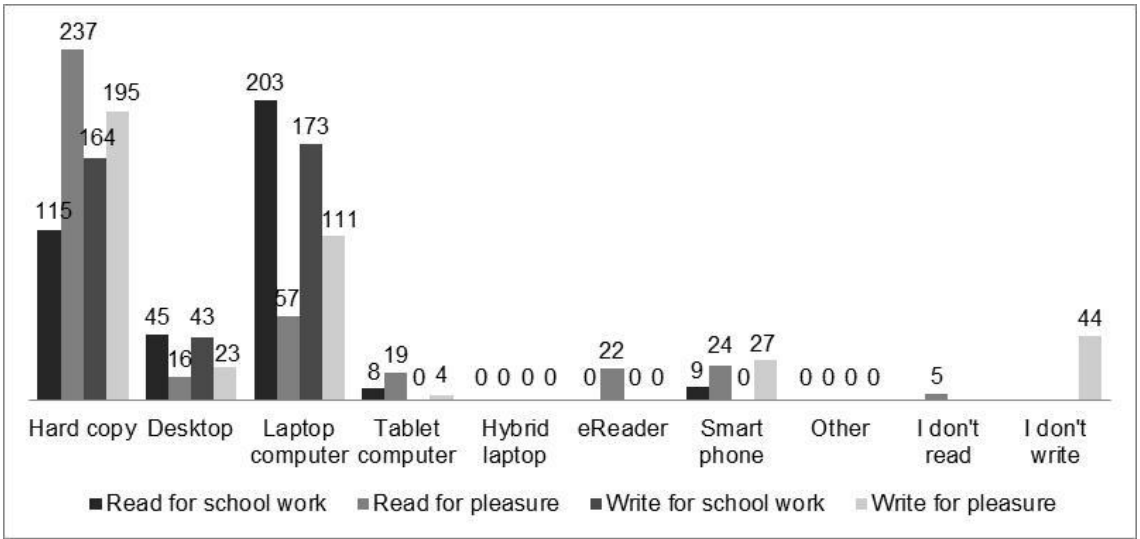
In case of Serbian students the use of digital devices is slightly different. Also most of them use smart phones (86%, 344 people) and laptops (89%, 357 people), but desktop computers are used in a bigger proportion (61%, 244 people). A little fewer students have tablets, 71 people.

3. RESULTS END DISCUSSION

3.1 Reading and writing

In their school work when they reading most of those interviewed use laptops (203, 51%), while paper is used by 115 and desktop computers only by 45 students. The rest of the responders, i.e. 17, prefer tablets and mobile phones. When reading as a free time activity, preference was given to paper, 237 (59%) students read on this surface most often, laptops were ticked by 57 (14%), and mobile phones by only 24. Desktop computers, tablets and e-book readers are used by about 15% of the responders. There were also some who don't read books for pleasure (5).

When using devices for writing we got similar results. For school work, 43% of responders (173) use laptops, 39% (164) write on paper, and 11% (43) on a desktop computer. The responders do not write school tasks on other devices. In their free time, 195 (49%) students write on paper and laptops were ticked by 111 (28%). Mobile phones and desktop computers are used by 50, tablets by 4 students when they write something in their free time. 44 (11%) responders do not write anything at all in their free time (Figure 2.).



NOTE for the questionnaire:
Check only one answer
"Hard copy" means a printed word, including material you have printed yourself.

Figure 2: Hard copy or digital device using for school work and for pleasure (number of Hungarian students)

The Serbian students interviewed, when reading for school tasks – contrary to Hungarian ones – use printed materials in a greater proportion (62,5%, 250 people) and only 28.5 (114) use laptops and 5.5% (22) desktop computers. When reading in their spare time, 202 students read in hard copy, in a smaller proportion on an electric device, 31.5 % (126) on laptops, 6% (24) on desktop computers and 2.25% (29) on smart phones. 1% (4) don't read anything for pleasure.

When writing for school tasks, similar results were obtained in case of those using paper (49.25%, 197) and laptops (41%, 167). 8.5% (34) do their tasks on desktop computers. When writing in their free time, for pleasure, more students prefer paper (48.75%, 195), as in case of Hungarian students. 107 young people (26.75%) use laptops and 37 (9.25%) don't write anything for pleasure.

3.2 Reading in hard copy or on digital screen

The next set of questions asked the students to estimate about how much time they read in hard copy (i.e. using a printed book, an academic journal, or a paper copy they have printed out from online) or on a digital screen (i.e. desktop or laptop computer, a tablet, an eReader, or a mobile phone).

Nearly one third of those Hungarian interviewed (127) read for 3-4 hours a week for school work, the number is only 82 (21%) for 5-6 hours a week, and for 7 or more hours about 19% (76) of the responders. In their free time, 26% (103) of those interviewed spend 3-4 hours reading book, 5-6 hours were ticked by 18.5% (74) and 7-8 hours by 7.5% (30). The number of those students who spend 9 or more hours reading a book was 46 altogether. 142 students (35. 5%) spend 2 hours or less a week reading for pleasure (Figure 3).

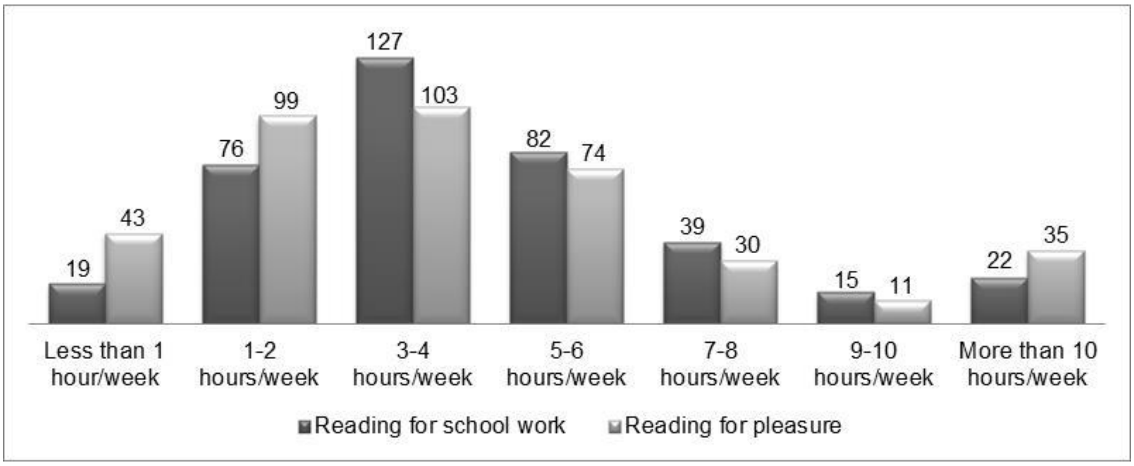


Figure 3: Amount of reading for school work and for pleasure (number of Hungarian students)

The Serbian students' answers differ a lot from the above. 30.25% (121) of Serbian students interviewed spend more than 10 hours reading for school tasks. 49 students (12.25%) read 7-8 hours, 58 (14.5%) 5-6 hours, 77 (19.25%) 3-4 hours per week. Only 12 people interviewed read less than 1 hour (3%). The number of hours spent reading in their free time is similar to that of Hungarian students. 20.75% (83) of those interviewed spend 3-4 hours, 21.75% (87) 1-2 hours, and 10% (40) 7-8 hours reading in their free time.

Less than 1 hour in a week is spent by 46 (11.5%) students reading for pleasure.

3.3 Text length

The next set of questions asked the students about how the length of text influences whether they prefer to read on a screen or whether they would rather read in hard copy.

The text length research showed that when students read short texts for school work, the amount of reading on a digital display is nearly the same as reading on paper. But for 29.5% (118 students) it was all the same what surface they read on.

However, texts of more than 3 pages are read by most responders on paper (280, 70%).

When reading for pleasure, device selection is very similar when the text is short, i.e. 3 pages, the maximum. However, in case of long texts the proportion is different. Only 64 (16%) student said they read texts of more than 3 pages on a digital display, while 291 (73%) prefer reading on paper, and it's all the same for 40 people (Figure 4).

When Serbian students read for their studies, they prefer printed forms both in case of short (3 pages maximum) and long texts. In case of short texts this number is 194 (48.5%). 108 young people (27%) read on digital display, and to 98 people it doesn't matter on what kind of surface they read short texts for school tasks. If the text is long (more than 3 pages), most students (88%, 352) marked reading on paper, and 22 the electronic version.

When they read short texts in their free time, the proportion of hard copy, digital display and the no matter which answer is nearly the same (29.5%, 35.75% and 32.5%). When reading longer texts, 286 young people prefer paper, 53 a digital display and it is all the same for 50. Similar results were obtained in the Hungarian survey.

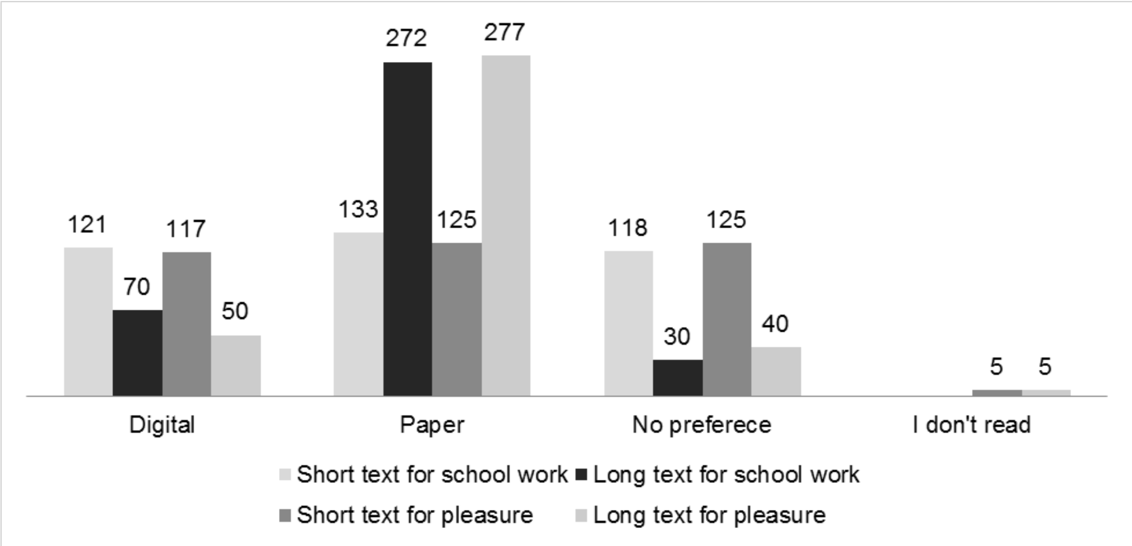


Figure 4: Text length (number of the Hungarian respondents)

3.4 Reading and multitask

Sometimes when people are reading, they find themselves engaging in other activities at the same time (multitasking). We asked the students about their multitasking habits when they are reading in hard copy and when they are reading on a digital screen.

When reading a printed text, about 20,2% (81) of the responders aren't doing anything else, but 45,5% (182) are doing some other activities, although rarely. Only 6 of all the responders said, they're always doing something else, too, when reading. Those who read on a digital display more often do some other activities besides reading. Only 25 students said, they aren't doing anything else when reading. More than half of the students often do some other activities while reading on a digital platform (Figure 5).

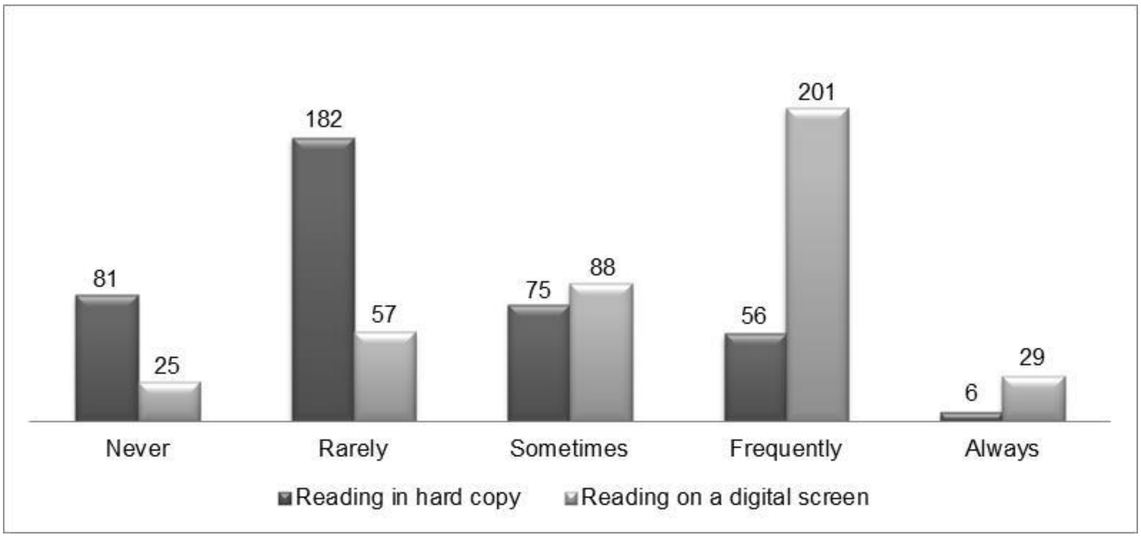


Figure 5: Reading and multitasking (number of Hungarian students)

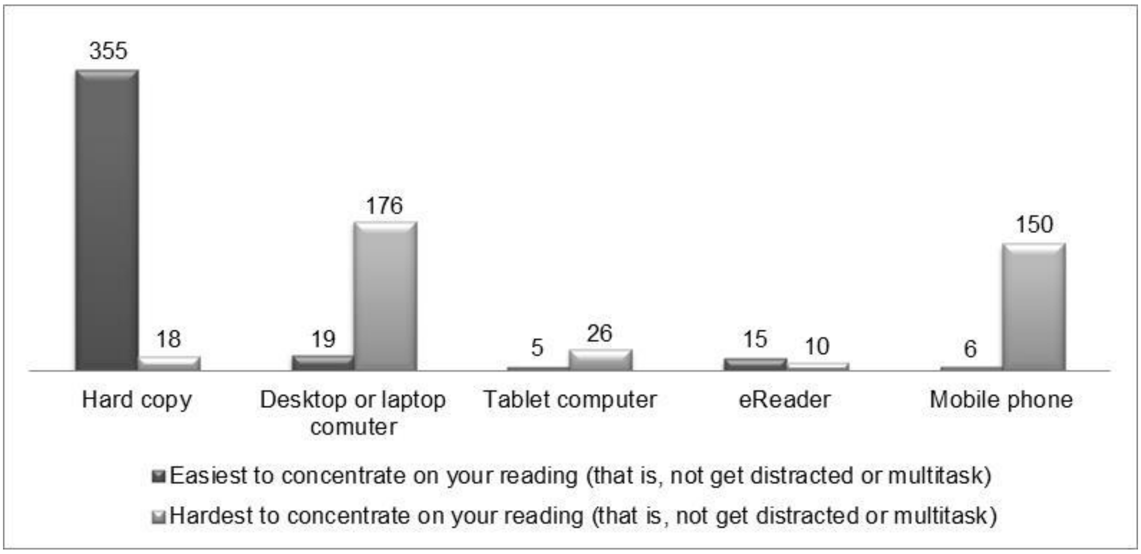
While reading on paper, about 20% (80) of those interviewed are doing something on their mobile phones. 53 students are doing some other activity on a computer and 53 are talking to someone in person. 80 people find other activities, which are most often listening to music, eating and drinking. Many people read when they travel or watch tv, smoke or walk.

When reading on a digital screen, most of the students (60%) and most often are doing some other activity on a desktop computer (included in this category is the use of a tablet, a laptop and a desktop computer). While reading, 50 of them are using their mobile phones. 27 students generally talk to someone. 44 students do other things, too, like listening to music, eating and drinking, watching

television and listening to the radio. Just a few people gave doing some sport or work as an answer to this question.
The results of the survey completed among Serbian students are different from the above. Only 28 young people don't do any other activities when reading a printed material, 170 rarely, 99 often and only 12 always does something else when reading in hard copy. Most of them (126) talk on their mobiles while reading. When reading on a digital screen, 23 never, 69 rarely, 18 sometimes, 139 often and 41 students always does something else, too. Most of them (208) also does something else on the computer, 78 students talk on their mobiles and 33 talk to someone in person.

3.5 Reading and concentration

Most students can concentrate on reading the most easily on paper, almost 90% (355). 19 (5%) students can concentrate the best on a computer or a laptop. Concentration is the hardest on a digital device. About 44% of the students (176) can concentrate on what they are reading on a laptop or a computer the hardest. While reading on paper 26 can concentrate hard, and this number is 10 for e-readers (Figure 6.)



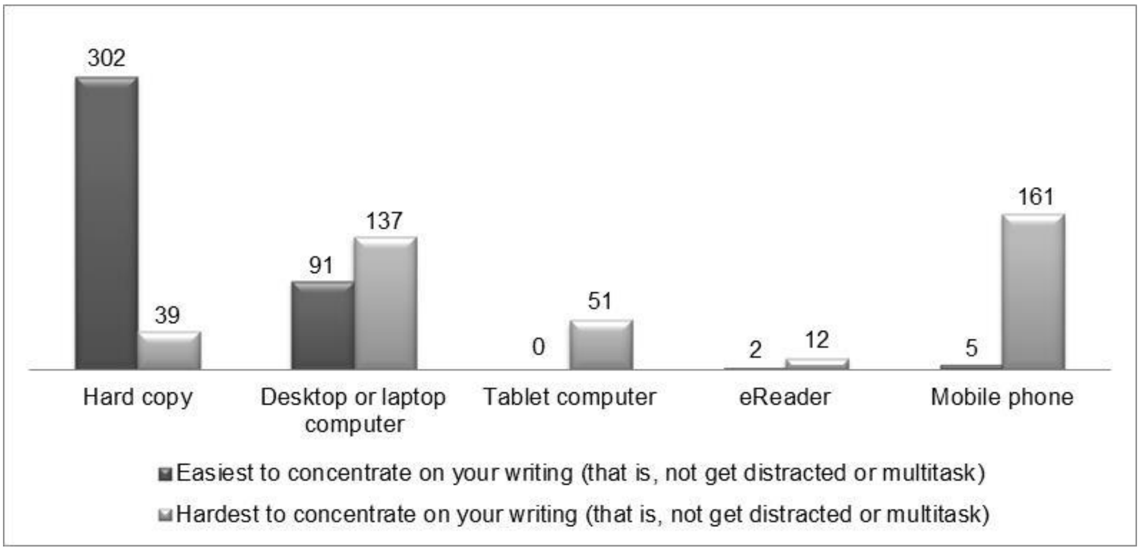
NOTE for the questionnaire: Think about the different platforms on which you might read.

Figure 6: Reading and concentration (number of Hungarian students)

Similar results were obtained about the Serbian young people. 373 of them can concentrate better when they are reading on paper. The hardest to concentrate on mobile phones is for 193 students and on a computer for 177. To concentrate on paper is hard for only 12 students.

3.6 Writing and concentration

The students can concentrate most easily when writing on paper. 306 (76.5%) of them chose this option. 81 (20%) students can best concentrate when writing on a computer or a laptop. Only 7 can focus on writing on an e-book reader or a mobile phone without distraction. The hardest for them to concentrate is when writing on a mobile phone (161, 40%). About one third of the responders (129) can concentrate hard on a computer or a laptop (Figure 7.)
The Serbian survey showed similar results. Serbian young people can concentrate most easily on paper (283), and on a desktop computer (112). It is the hardest to concentrate on mobiles (207). And for 29 students it is hard to concentrate on paper.



NOTE for the questionnaire: Think about the different platforms on which you might read.

Figure 7: Writing and concentration (number of Hungarian students)

3.7 Additional comments

We asked the students taking part in the survey to give a short-text opinion, to share the viewpoints with us why they choose paper or a digital display when reading/writing.
Some of the answers are as follows.
„It's much easier to learn from a book. It's simpler to scroll back, find 1-2 important things and I can take it anywhere, as it doesn't need electricity."
„I like the hold of a book, I can see how much there is to the end."
"For me a book is worth more in a printed version than in a digital form."
„It's more comfortable and cozier to read a printed book."
„ I can simply underline the essence and I can see it better where I am in it."
„Paper is more „mobile", I can learn/read anywhere, while a digital display makes me stoop and I get eye pain."
"Easy to survey, it's simpler to handle, the pages can be turned, it's easier to learn this way."
„Paper is not tied to a place, it doesn't irritate my eyes."
„It's easier to survey it in a printed form, can be remembered better. The digital display vibrates, it disturbs me."
„Paper, because I like scribbling on it, highlighting the essence."
„If it's available in a digital form, I choose that. It's a pity to cut down trees for so little use."
„Digital display: it's simpler to get the material, store it and carry it."
„Printing is expensive I would have to carry lots of paper with me."
„E-book: Sometimes it's hard/expensive to get foreign language books."
„ In my free time I browse on the Internet."
„When travelling I don't want to take extra weight (books) with me."
„Most books can be downloaded for free in a digital form."
„Everything else that I do in my free time is nearer: music, email, facebook, internet."
„I always have my phone with me."
„Easier transportability (E-book reader)

4. CONCLUSIONS

In the survey we asked university/college students about their reading and writing habits. The results of the questionnaires were analyzed and conclusions were drawn regarding the basis of motives which make Hungarian young people prefer reading/writing on paper or on digital devices, during their studies and in their free time.
From the results of the study it's clearly visible that handwriting means an emotional link to Hungarian students, even if they prefer digital communication. Writing on paper is considered more flexible in

practice than the digital version. In their free time, Hungarian students write in hand more willingly, and they choose a digital device for school work. When writing on paper it's also easier to concentrate, they are thinking during the process, which is beneficial for the complete sentence.
Whether they read a text on paper or on a digital display depends on the typology and the length of the text. According to the survey, too, there is a correlation between device selection and text length. When reading on a digital display, the reading of shorter texts is preferred, while they are more willing to read longer texts on paper. Students also like the physical nature of paper, it's tactile, pages can be turned and it's easier to take it anywhere. While they are learning, they like scribbling on the paper and highlighting the essence.
When reading for pleasure, Hungarian young people use both paper and the digital devices with pleasure. A decisive argument for paper was that it's more comfortable to read a printed material and it doesn't fatigue the eyes. They mentioned that they like the feeling of holding a book in their hands, they like the atmosphere. In case of books, the stability of value and the love of traditional things were also mentioned, and that they prefer reading on paper, because it grabs the attention better and there are no disturbing circumstances. It's also a fact that reading on paper is possible anywhere and in any posture. An important advantage for students is the portability of books, although electronic devices are now manufactured so that they can also be taken anywhere. When using paper and printed books we are not tied to electricity and internet access.
Hungarian students agree that reading on a computer screen can make their heads/eyes ache. At the same time, large proportion of school textbooks in only available in an electronic form.
The digital display was chosen by those who think it's more comfortable and quicker to learn from a digital surface. A tablet doesn't take up much space still a huge number of data can be stored on it. There are also young ones who choose the digital solution because of newer information.
Those who read on digital surfaces in their free time explained this mainly because it's more comfortable and they usually read different articles on the internet. There were ones among the students who prefer reading an e-book, because they regard it cheaper than traditional books. Many think that a digital device takes up little space, so it's more practical and we can take it with us more easily.
Compared to the survey carried out among Serbian young people, most results were similar. However, there was a difference when analyzing the use of digital devices. While 43% of Hungarian young people use a desktop computer for their school tasks and in their free time, for Serbian students this percentage is 61%. Moreover, a greater part of Serbian young people read printed material (paper) when doing their school tasks, in case of both short and long texts. The biggest difference can be seen when analyzing the time spent reading. Most Hungarian young people read 3-4 hours a week for their school tasks. 30.25% of Serbian students spend more than 10 hours a week reading and learning, as opposed to 5.5% of Hungarian students.

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Human perception and graphic industry

INTRODUCTION TO MOTION GRAPHIC DESIGN

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Abstract: *The aim of this paper is examination of a relatively young field called Motion Graphics or Motion Design or Motion Graphic Design. The article will inform about the history, industry, aesthetics and education in this field. Roots of this specific practice can be found in abstract films made by Futurists at the beginning of the twentieth century. There are not many theoretical works on this subject, not many books, and articles neither. Nevertheless, motion graphics is gaining much attention in the design industry, mainly because of the evolution of the mobile devices, and displays in general. The motion, as a phenomenon, is receiving more attention than a static picture – consequently in the education of graphic designers it becomes necessary to implement studying of motion graphics. In essence, the traditional graphic designer needs to learn how to use and integrate the elements of time and sound, with other graphic design principles. Therefore, this paper seeks to contribute to the scarse knowledge providing an overview of main aspects of motion design practice, which is omnipresent today and can be found in filmmaking industry, television, public spaces, the internet, videogames and other interactive media, etc.*

Key words: motion graphics, motion design, motion graphic design

1. INTRODUCTION

In this brief overview, facts about Motion graphic design will be presented. Motion graphic design is also referred to as Motion graphics or just Motion design. In contemporary surroundings and through mass media we are constantly exposed to works of motion graphic designers. For example, the most simple format is an animated GIF, which is omnipresent in internet advertising. However, we also find this type of motion graphics in movie titles or video-game intros, tv channels openers, basically almost every screen that we can find in public places, on websites etc. As we think about a work of graphic designer as something meant to be printed, the work of motion graphic designer is meant to be displayed on the screen. Considering more and more screens are around us every day, the work of a graphic designer becomes something which doesn't use the full potentials and possibilities of the screen. The work of a graphic designer is usually printed, and it can be defined as "static" (not animated), and the screen need design that is kinetic, that involves a movement, a motion. In order to introduce the field of motion graphic design to a reader, we will talk about its history, aesthetics, industry and education.

2. FIRST MOTIONS: HISTORICAL OVERVIEW

Our eyes can retain an image of everything that we see for a very short period of time. After that, an image disappears. Due to this phenomenon, known as a *persistence of vision*, we can experience an illusion of motion while watching a succession of different images. For every single image, that partakes in an illusion of motion, in the language of animation we use the term *frame*. Regardless of what technique used, analog or digital, this is the basic principle of creating an illusion of motion.
Attempts to create an illusion of motion date back to 17th century. In the 19th century, cinematic inventions flourished across Europe and America. Real breakthrough happened in the first decades of 20th century. Film and animated characters were born, experiments were made with new animation processes (e.g. cell animation), stop action photography developed, a combination of live footage and hand-drawn elements was used, etc. In fine art we have also a contribution of the abstract avant-garde films or *pure cinema*. Works of filmmaker Viking Eggeling, close to Dada and Constructivism, are among the first experiments with *absolute film* and *visual music*. In the year 1924, Eggeling made his most important work, the *Symphonie diagonale* (see figure 1).

Figure 1: frame from "Symphonie diagonale" by Viking Eggeling, 1924.

Finally, after the Second World war, first works of motion graphic design find their place in the film industry, in a form called *title design*. According to Krasner "Since the 1950s, when legendary Saul Bass revolutionized the practice of film title design, the movie industry has integrated the language of traditional graphic design with the dynamic visual language of cinema" (Krasner, 2013). After '60's, an evolution of digital technology takes place and makes a strong influence on the further development of the motion graphic design practices.

Since then, using powerful computer technology, motion design was in charge of making moving graphics for tv programs, film, video games, websites, mobile platforms and for the variety of other communication media. Especially online videos are driving the motion graphics production to new heights. Online video is becoming the most popular type of content, not only in the field of leisure (music videos, funny videos, movie trailers, etc.) but more and more in a marketing environment. Generally, one-quarter of internet users watch video content on a daily basis. Digital video advertising is a form of advertising that will surely occupy much more space on the internet. From 2012 to 2014 video material that was used for the purposes of advertising increased dramatically (Anon, 2016). In fifteen countries that took part in a survey done in June 2014, a percentage of internet users who watch online video content on any device varied from 71% to 95.9% (ibid).

Other statistical data are staggering, too. For example:

- so-called "social video" (video made for watching and sharing on social networks) generates 1200% more shares than other posts that use text and images combined
- more than 60% of consumers get a poor perception of a company that publishes poor quality video
- showing video on website homepage can increase conversions by at least 20%
- video drives a 157% increase in organic traffic from search engines (Miller, 2016)

A majority of organizations take advantage of this form of sharing their online videos, in order to connect with their audiences.

3. AESTHETIC IN MOTION

If we think about the means of expression as one of the most important aspects in defining any creative practice, in a case of motion graphics we will take into account a motion itself as a mean of expression. Roughly speaking, motion design is an animated graphic design. Although, there are authors that would disagree with this point of view. For example, Schlittler (2015) considers that "there are plenty examples of effective moving graphics where motion has been achieved by means other than animation". Major aspects of good graphic design – such as understanding of composition, form, color, typography and other visual elements – are also essential in motion graphic design. The main difference is the addition of motion, which involves another complementary aspect – the right timing, or sequencing. The aesthetic potential of motion is easy to understand and recognize. Motion can be the bearer of a meaning, it can add a character to an animated element of design. Path of an animated element, its speed, and acceleration, can tell a lot to a viewer. Seeing that motion can be energetic, calm, springy or heavy, to name just a few, emotional connection with the viewer is almost instantly established. The above-mentioned element of timing is crucial in achieving the right dynamic of everything that happens in the final work. It is crucial for holding the viewer's attention, creating tension, or provoking a feeling of expectation. While an emotional connection is important for engaging the viewer, even more important is the fact that in this process, complex idea display, or presentation content is easier to understand. For this reason, animation is one of the most powerful forms of communication.

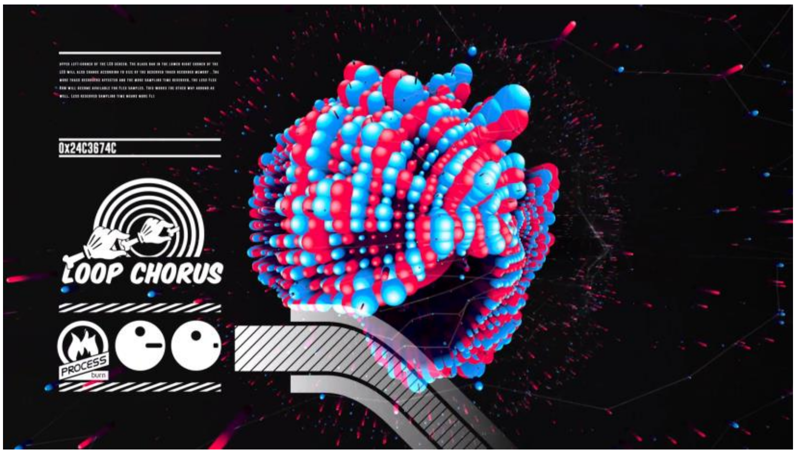

Figure 2: frame from TV show opening for SKY One HD's TOPDJ, 2014.
(copyright: FullScream motion graphics agency; directed by: Ced Pakusevskij and Elisabetta Giovi)

4. MOTION GRAPHICS IN INDUSTRY

Due to the fact that a number of video content is constantly increasing on the Internet, it is expected that production of motion graphics will be slightly increased in the years to come. Motion design is gaining much attention in the design industry, mainly because of the evolution of the mobile devices, and screens in general. According to various sources almost 60% of internet traffic is driven by video content. It is expected that this percentage increases to almost 80%. For example, the U.S. Bureau of Labor Statistics estimates 7% job growth through the year 2022 (on the website of U.S. Bureau of Labor Statistics, under the category named *Multimedia artists and Animators*, information about median pay and typical entry-level education can be found, also the number of jobs in a specific year, the job outlook for next 10 years, changes that will occur in the same period, etc.). All of this resources imply that video content will be the future of online marketing, especially because motion design videos are important assets of marketing campaigns. Apart from producing online videos, most often motion graphic designers are employed in television studios, film industry, the publishing industry, web design agencies, marketing and advertising agencies, manufacturing industries etc.

4.1 From a motion graphic designer to an art director

Before making a career in motion design, multimedia artists and animators usually spend a lot of time in graphic design studios. To find a job as a motion graphic designer, it is much more important to have a strong portfolio or showreel (also called demo-reel) than a university degree, or course certificate. Moving up from a position of motion graphic designer to a position of an art director is a common way of advancement in this profession. At the beginning, motion graphic designers take part in a production of commercials, movie trailers, broadcast titles, mobile device, web ads, music videos etc. It is necessary for them to pass through every stage of the creative workflow like – conceptualization, character design, rotoscoping, keying, compositing, storyboard drawing, making animatics, to name just a few. Many of this

stages are borrowed from filmmaking industry. Because of the complexity of projects, it is highly recommended to be a team worker and easily collaborative with colleagues, although more than half of multimedia artists and animators are self-employed or freelancers.
Reaching a position of an Art Director requires at least a bachelor's degree (fields of animation, multimedia, visual effects, etc.). Usually, beginner motion graphic designer needs to work at least 3-5 years, or longer. Many years of experience and a very good portfolio are also necessary. Art director responsibilities range from reviewing "work in progress" and supervising project sketches and storyboards, to discussing ideas, communication with the clients, and conducting a general look of the project, or a feel. Other skills include negotiating, time management, dealing with budgetary constraints, foreign languages etc.

5. EDUCATION

Studying Graphic design include subjects like Computer graphics, Digital editing, Design history, Web design, Color theory, Advertising concepts and many others. Education required, for those who will be qualified to work in the field of motion graphic design, includes many skills known to educated graphic designers, with the addition of subjects like 3D modeling and animation, 2D Animation, Classical Animation, Character animation, Visual effects, Compositing, Storyboards, Interactive design and Programming, for example. Special attention should be pointed out to an audio element like music and sound effects. In essence, the traditional graphic designer needs to learn how to use and integrate the elements of time and sound, with other graphic design principles. In comparison to graphic design tools, some new tools (program applications) tools that allow rendering an animated, or video, content is necessary. It is interesting to say that many animators, multimedia artists, and motion graphic designers have earned a bachelor's degree in some field of fine arts. According to data from 2012. found on website O*Net OnLine (www.onetonline.org), 62% of multimedia artists and animators have earned bachelor's degrees, and 19% had associate's degrees. Such a degree could provide a position of an effects specialist for video games, movies and television, as well as for the entertainment industry in general.

6. CONCLUSIONS

In an attempt to give an overview of motion graphic design, as a relatively young design practice, it was essential to review many aspects. Like any other creative practice it includes many technical skills, and, we could say that it emerged from an artistic response to new, mostly digital, technology. Adopting analog cinema techniques in the beginning, through electronic techniques used in television, motion graphic design was finally settled down in the digital surroundings. Following new trends, new generations of graphic designers gain an advantage on the market if they include motion design in their service offerings, mostly because of the fact that it represents a novel, and ever growing, communication media.

7. ACKNOWLEDGMENTS

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Original scientific paper

STUDENT RESPONSES TO INTERACTIVE LEARNING TROUGH VARIOUS MULTIMEDIA CONTENT

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Abstract: *The paper explores the responses of students to learning through interactive multimedia content, through practical application, investigating its advantages and disadvantages, with special focus on the field of graphic engineering and design.*
The experiment, through the usage of teaching tool containing different levels of interactive animation, explores the levels of information at which students are satisfied with the interaction which contributes to easier and faster acquisition of knowledge. The experiment has been conducted using three tools, which differ in the level of interaction and the type of containing data. Tools include an interactive animation, videos and images in conjunction with audio, respectively. As a result, statistically processed student answers are expected to give indication of which one of these multimedia contents provide the best results in the process of knowledge transfer and learning.

Key words: multimedia learning, simulation, interaction, students responses on e-learning tools

1. INTRODUCTION

New methods of learning are becoming more and more present, driven by the demand for the prequalification of the work force, in a simpler and faster way. The development of techniques and technology enables the advancement of learning techniques. Considering that the main goal of successful education is a trained student who can perform autonomously in the areas of technology and operation on various machines, as well as other areas, it becomes necessary to train the student for practical work as efficiently and quickly as possible. In graphic engineering, the students need to be introduced to a great number of printing machines and devices, as well as different computer software. With this and similar educational curricula, interactive learning technology can be introduced, which could, among other things, efficiently present to the students machine work procedures, its inner structure and functions, without any danger both to the students and the machine that they are being enabled to work with.
Authors that did research on interactive learning list various advantages and disadvantages that interactive learning offers to the students (Bates, 2001; McDonald et al.; Byrne, 1996). The numerous advantages listed in these papers are undisputed, but the greatest disadvantage is the students' inconsistency in the application of this type of learning method, or, simply, the students giving up on the lessons presented in this way. This paper tries to present the opinions of the students on this type of learning method, through their evaluation of the said method by various criteria.
Furthermore, the paper is a part of an experiment which has been going on for a number of years, and is currently still in progress, and includes different generations of students at the Department of Graphic Engineering and Design. As interactive learning represents relatively new approach in the field of science, which means that not all of its aspects have been researched. The goal of the said perennial experiment is to explore the role of the method of knowledge transfer through interactive approach, in order to apply this new method of learning as an upgrade of the existing traditional learning methods, and to give the students the opportunity to acquire new knowledge more efficiently and quickly, as well as to upgrade their existing knowledge.
The methods used in this research are well known in this scientific field and include subjective experiment methods through questionnaire and statistical analysis of answers.
The reasons for introducing interactive learning are numerous. The advantages listed by Zhang et al. (2006), from the point of view of influence on the participants, are:

- providing the participants with quality participation in the education process;
- time and location flexibility;
- reductions in cost and time for educational institutions;
- encouraging self-regulated rhythm and method of learning, creating a student oriented learning;

- unlimited access to learning material;
- option of adding material and knowledge which are preserved in a more efficient manner.

The great advantage of interactive learning over other methods of learning is the possibility of customization, adapting to the needs of every individual user. Under the term customization Clark and Mayer (2011), in their book *E-Learning and Science of Instruction*, include the modifying of content and instructional methods in relation to the purpose, learning goals and individuality (with special consideration for previous knowledge). With the possibility of customization, everyone has the ability to adjust the materials, repeat the process, follow the process numerous times, or speed it up, all depending on the user's needs.
In 2009, 126 billion dollars were spent on work force training in the USA (ASTD State of Industry Report, 2010). In 2014, every company spent average 1,299 dollars for work force training, which is 1,7% more than in 2013 (ASTD State of Industry Report, 2015). When these numbers are presented, the enormous advantage of e-learning systems becomes clear. Through these systems, in a short time period, students can experience real world working conditions, problems and ways of working through them in virtual environment. This is certainly an excellent method for training and preparing students to be the future efficient and capable work force.
The new concept of education implies the connection between theoretical knowledge and practical skills. In this way, students are enabled to control, design and test the learning material according to their specific needs. Students will be prepared for the future demands they will receive when working with specific software.
E-learning systems for knowledge transfer have their disadvantages, which manifest more as a consequence of cognitive system overload due to multimedia content. It is very important to be aware that cognitive system has its limits in relation to the amount of multimedia content it can follow efficiently, the topic on which more will be said further in the paper.
The monitoring of the new learning methods is infrequent, according to Aleksandrov et al., so much so that it often happens that the learning models are age inappropriate, too complex or inapplicable for all levels of education (Aleksandrov et al. 2013).
Many research papers on the interactive learning take Mayer's cognitive learning theory as their basis, following the assumption that, in order to understand how multimedia combinations affect learning, one should first analyze how and in what ways the said combinations are created. In the area of pedagogic psychology, the widely accepted theory is Mayer's cognitive theory of multimedia learning (Mayer, 2002), as shown on figure 1.

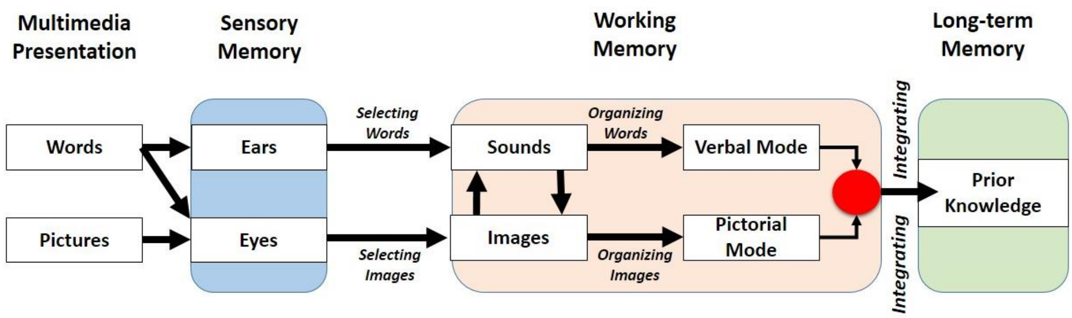

Fig 1: Mayer's cognitive memory of multimedia content learning

Figure 1 presents the cognitive multimedia content learning theory, based on Mayer's three assumptions on the way that human brain works. The picture shows three cognitive processes whose sequence is traced by the presented arrows:

1) Word and image selection – the first step is paying attention to the relevant words and images in the presented material;
2) Organizing words and images – the second step represents mental organization of selected verbal and visual material; and

3) Integration – the last step represents the integration of received visual and verbal representations, both between themselves and with the previously held knowledge.

Kirschner et al. (2011) point to the importance of understanding of the cognitive system, mainly its capacity during the learning process, according to who the architecture of cognitive system, the learning environment, as well as the interaction between both, need to be clearly adjusted and even. The theory of cognitive system overload is based on complex cognitive processes, during which the control of cognitive capacity overload is essential for efficient learning. In order to achieve the said control, the theory of cognitive overload uses available knowledge on the structure of human cognitive system and creates learning techniques based on that data. According to Kirschner et al. (2011), the following elements are listed as being part of the cognitive process structure: effective unlimited long term memory, which interacts with work memory which is very limited in capacity and work ability (time limited).

When considering effective long term memory, the literature speaks about certain patterns of her functioning, in the sense that long term memory uses patterns according to which different elements of different information are preserved and combined into only one element with a specific function (Miller, 1956).

Efficient learning is realized when the information is successfully transferred into work memory and a new pattern is created (pattern creation), new elements from information are included into existing patterns (assimilation), elements that contain lower level patterns are combined with those from the higher level patterns and create a significant number of even more complex patterns (pattern elaboration), and existing patterns in contact with new patterns that do not fit in into the existing ones are adjusted (Kirschner ,Van Merriënboer, 2013).

Cognitive system overload is created when performing a task whose essential nature causes the overload or the way in which the information in the task is presented is the cause. Overload caused by the task's essential nature is caused by the number of interactive elements in the information. The more elements the task has, the more information it has, and the interaction between them is bigger, which means that the cognitive overload is bigger (Kirschner et al., 2011).

Milić et al. come to the conclusion that there is a great tendency of movement towards the e-learning systems. In the conclusion is said that multimedia e-learning systems offer greater potential for better instructor performance and its improvement at a low cost.

In the classrooms, as a standard learning environment, verbal model (spoken and printed material) of teaching still has the traditionally greatest significance in the teaching process in relation to the visual teaching model. Verbal model consists of spoken material (discussions of classes) and printed material (books or presentation slides). Visual model consists of images and graphics (photographs, illustrations, graphs and tables), as well as dynamic graphics (animations and video). The advantages of computer graphics and visual explanations on the World Wide Web lead to the increase in interest for exploitation of potential offered by these methods in knowledge transfer (Milić et al.).

2. EXPERIMENT METHODOLOGY

The experiment included giving the students that had used the e-learning system to obtain knowledge on the functioning of the chosen graphic system questionnaires. After the finished lesson and answers to the questions related to the lesson itself, the students were given the choice of grading the presented material and the way in which the material was presented. Experiment was performed on the Faculty for Technical Sciences, on the Department for Graphic Engineering and Design, in Novi Sad, and it included total of 82 students. Students were divided into three groups. The groups consisted of students that were presented with the learning material in different ways. The first group had the material presented with interactive animations and audio, the second had the material presented with video and audio, and the third group had the material presented with images and audio. The students are from the fourth year of studies at the Department for Graphic Engineering and Design. The students were randomly divided into the three groups:

1. Animation and audio (26 examinees): they were presented with an interactive animation which was accompanied by appropriate audio content describing the processes that were happening in the animation. Animation is interactive, meaning that the students have the ability to replay the processes they desire.

2. Video and audio (28 examinees): they watched the video material accompanied with an audio explanation, the students had the ability to replay the video, but they could not replay the specific segments, meaning that the level of interaction was smaller.

3. Images followed by audio explanation (28 examinees): the learning material was presented in the form of a sequence of images accompanied by audio explanation.

The experiment was divided into three phases. First, the students were tested for previous knowledge about the graphic system that was being learned about. For this test, students had five minutes. The next phase was the presentation of the version of multimedia learning material according to the given group, in the scope of ten minutes. The final phase consisted of a test divided into three parts: knowledge test, visual test and knowledge transfer test. The students had ten minutes to do the test. After the test, the students received a questionnaire *(IBM Computer System Usability Questionnaire)*, in which they graded their satisfaction with the presented version of the learning material and the way in which the knowledge was transferred (Table 1).

Table 1: The questionnaire the students filled out after the lesson

<table>
<tr><td rowspan="8">Information quality</td><td colspan="7">1. The amount of presented information is adequate</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="7">2. The content of learning unit is easy to understand</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="7">3. The presentation and selection of information enable easy memorizing</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="7">4. Sequence and organization of information is adequate</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td rowspan="10">Interface quality</td><td colspan="7">5. Interface of learning unit is pleasant</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="7">6. Interface of learning unit is easy to use</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="7">7. Interface of learning unit enables efficient memorizing</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="7">8. Interface of learning unit makes learning easier</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="7">9. Generally, I am satisfied with e-version of learning unit</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
</table>

3. RESULTS OF THE SURVEY

Answers to questions that were statistically analyzed are presented as follows.

The existence of statistically significant difference between the three examinee groups was analyzed by single factor variance analysis (ANOVA). Statistically significant difference exists on the questionnaire item number 5; “Interface of learning unit is pleasant” ($F=5,39$, $p=0,006$) and questionnaire item number 6; “Grade the ease of interaction with the interface of the presented learning material.” (3,20, $p=0,046$). When the mean values are looked at (M), it can be seen that for the questionnaire item number 5, group: animation and video, has a mean value $M=6$, while group: audio has a lower score ($M=5$). Questionnaire item number 6 was graded highest (greatest correlation) by the examinees from the group video ($M=6,85$), somewhat lower grade was given by the group animation ($M=6,65$), and the lowest grade was given by the group image and audio ($M=6,17$).

Further analysis was based on the existence of connection between the answers related to the quality of information and quality of interface. Existence of connection between these two groups of questions can lead to the conclusion that the improvement of the interface will affect the quality of presented information.

Table 2: Difference between the three student groups in their answers to the questionnaire

Questions		1	2	3	4	5	6	7	8	9	Sum
Version 1 Animation	N	26	26	26	26	26	26	26	26	26	26
	M	6,0769	6,5385	6,2308	6,6538	6,0769	6,6538	6,3846	6,0769	6,3462	57,0385
	SD	,89098	,64689	,71036	,62880	,97665	,68948	,75243	,84489	,56159	4,44955
Version 2 Video	N	28	28	28	28	28	28	28	28	28	28
	M	6,2143	6,5000	6,2857	6,5357	6,0000	6,8571	6,0357	6,0000	6,3571	56,7857
	SD	,73822	,69389	,80999	,63725	1,38778	,59094	1,13797	1,15470	,91142	5,52675
Version 3 Images	N	28	28	28	28	28	28	28	28	28	28
	M	5,9286	6,2500	6,0357	6,3214	5,0000	6,1786	5,8214	6,0000	5,9286	53,4643
	SD	1,24510	1,20570	1,26146	1,09048	1,61015	1,51666	1,30678	1,33333	1,08623	9,25556
Total	N	82	82	82	82	82	82	82	82	82	82
	M	6,0732	6,4268	6,1829	6,5000	5,6829	6,5610	6,0732	6,0244	6,2073	55,7317
	SD	,97854	,88931	,95747	,82027	1,43051	1,05523	1,10867	1,12190	,89908	6,89614
F		,591	,850	,519	1,152	5,392	3,208	1,798	,041	2,100	2,386
p		,556	,431	,597	,321	**,006**	**,046**	,172	,960	,129	,099

N-number of examinees, M-arithmetic mean (mean value of the sample), SD-standard deviation (average standard deviation of the sample), F-variance analysis, p-statistical significance

Table 3: Connection between the questions on the quality of information and quality of interface

		Question 5	Question 6	Question 7	Question 8	Question 9
Question 1	r	,497**	,582**	,481**	,434*	,728**
	p	,007	,001	,010	,021	,000
	N	28	28	28	28	28
Question 2	r	,538**	,453*	,745**	,640**	,722**
	p	,003	,016	,000	,000	,000
	N	28	28	28	28	28
Question 3	r	,469*	,392*	,639**	,535**	,690**
	p	,012	,039	,000	,003	,000
	N	28	28	28	28	28
Question 4	r	,270	,495**	,813**	,708**	,593**
	p	,165	,007	,000	,000	,001
	N	28	28	28	28	28

r-pearson's correlation coefficient, p-statistical significance, N-number of examinees

There is a statistical connection between the quality of information and quality of interface. The strength of connection is high, which means that the connection between the quality of information and the quality of interface is high. The only questions that do not have statistically significant correlations are items 1 and 8.

Table 4: Descriptive indicators for the group Animation, questionnaire

	N	Min	Max	M	SD
Question 1	26	4,00	7,00	6,0769	,89098
Question 2	26	5,00	7,00	6,5385	,64689
Question 3	26	5,00	7,00	6,2308	,71036
Question 4	26	5,00	7,00	6,6538	,62880
Question 5	26	4,00	7,00	6,0769	,97665
Question 6	26	4,00	7,00	6,6538	,68948
Question 7	26	5,00	7,00	6,3846	,75243
Question 8	26	4,00	7,00	6,0769	,84489
Question 9	26	5,00	7,00	6,3462	,56159
Sum	26	49,00	63,00	57,0385	4,44955

N-number of examinees, M-arithmetic mean (mean value of the sample), SD-standard deviation (average standard deviation of the sample), F-variance analysis, p-statistical significance

Table 5: Descriptive indicators for the group Video, questionnaire

	N	Min	Max	M	SD
Question 1	28	5,00	7,00	6,2143	,73822
Question 2	28	5,00	7,00	6,5000	,69389
Question 3	28	5,00	7,00	6,2857	,80999
Question 4	28	5,00	7,00	6,5357	,63725
Question 5	28	3,00	7,00	6,0000	1,38778
Question 6	28	4,00	7,00	6,8571	,59094
Question 7	28	3,00	7,00	6,0357	1,13797
Question 8	28	3,00	7,00	6,0000	1,15470
Question 9	28	4,00	7,00	6,3571	,91142
Sum	28	45,00	63,00	56,7857	5,52675

N-number of examinees, M-arithmetic mean (mean value of the sample), SD-standard deviation (average standard deviation of the sample), F-variance analysis, p-statistical significance

Table 6: Descriptive indicators for the group Images and Audio, questionnaire

	N	Min	Max	M	SD
Question 1	28	3,00	7,00	5,9286	1,24510
Question 2	28	3,00	7,00	6,2500	1,20570
Question 3	28	1,00	7,00	6,0357	1,26146
Question 4	28	2,00	7,00	6,3214	1,09048
Question 5	28	1,00	7,00	5,0000	1,61015
Question 6	28	1,00	7,00	6,1786	1,51666
Question 7	28	1,00	7,00	5,8214	1,30678
Question 8	28	2,00	7,00	6,0000	1,33333
Question 9	28	3,00	7,00	5,9286	1,08623
Sum	28	20,00	63,00	53,4643	9,25556

N-number of examinees, M-arithmetic mean (mean value of the sample), SD-standard deviation (average standard deviation of the sample), F-variance analysis, p-statistical significance

Based on the tables 4, 5 and 6 it can be concluded that the highest questionnaire grade was given by the first group (Animation), then the second group (Video), and the lowest by the third group (Images and

Audio). If we look at the grades for questionnaire items 8 and 9, ("Grade how much the interface makes the learning process easier", "Give a universal grade of the e-version of the learning material"), from the maximum 7 points, the first group had 6,0769 and 6,3462, the second group had 6 and 6,3571, while the third group had somewhat lower grades of 6 and 5,9286.

4. CONCLUSIONS

The significance of application of virtual interactive systems in the process of education is growing every day. In many educational processes on all levels textbooks are being replaced by computers and tablets. The possibility of presentation and transfer of experience of working on various real life systems into virtual environment represents the future of educating students and learners in different areas, especially in those where it is needed to obtain knowledge of expensive dynamic systems to which the learners rarely have access to.

Cognitive complexity of the teaching aid plays a significant role in the quality of the transfer of long term knowledge, and it is especially influenced by the quantity of information presented by the system, as well as the level of learners' previous knowledge on the material presented by the teaching aid. Drawing in of the learners into the virtual environment facilitates increased concentration during the process of learning and, by its very nature, longer lasting record in the user's memory. Danger to the quality of learning is represented by a large quantity of information that can be found in the teaching aid, so that it needs to be reduced to an optimal level which will prevent large cognitive overload and keep the learner's attention and the desire to follow through with the process of learning.

Examinees in the experiment who had better additional ability to control the animation, or, in other words, certain level of interaction, had better experience in the use of the teaching aid than the examinees that were passive observers of the video material, even though the quantity of information was identical. Examinees that used only the image portion of the teaching aid experienced larger cognitive overload since they had to fill in the dynamic movements of the observed system by themselves, which resulted in them being less satisfied with the teaching aid. Examinees that watched the video had smaller cognitive overload since the system dynamics was completely obvious to them through the form of the video and they could focus on the learning. This lead to their greater satisfaction with the learning process which was less of a problem for them, represented in their questionnaire grades.

The experiment also showed a statistically significant correlation between the interface and the quantity of information in the teaching aid. The examinees that watched the video did not have to fill in the missing frames by themselves in order to understand the system dynamics and were more satisfied with the presented information.

In further research the variable of previous knowledge will be changed, so that it will provide additional information on the level in which the animation becomes more significant or on the level in which the animation represents increased obstruction when it repeats the already known information or the information that could be obtained through the knowledge transfer. These experiments should give a clear insight if interactive teaching aid should be used on all knowledge levels or if they lose their advantages at a certain level.

5. ACKNOWLEDGMENTS

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ANALYSIS OF HEARING LOSS AS AN OCCUPATIONAL ILLNESS IN PRINTING INDUSTRY AND ITS EFFECTS ON THE WORKER

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Abstract: *Noise is defined as unwanted and annoying sound and it causes psychological and physical problems. Industrialization growing every day and cities becoming metropolis make noise an important pollution and they have caused hearing losses to increase. Hearing loss is a health problem not seen with eyes. The most common occupational illness in the world is hearing loss. Unfortunately, it is also true for our country. Occupational illnesses are temporary or permanent illnesses, physical or psychological disabilities the insured worker has because of a repeated reason due to the work he does or because of the execution conditions of the work, according to the 14th clause of the Law no. 5510. According to the Occupational Health and Safety Law numbered 6331, it is an illness, which occurs as a result of exposure to occupational risks. According to these definitions, hearing loss caused by noise is considered as an occupational illness. It has been remarked that the number of hearing losses because of occupational exposure has exceeded 200.000 in Turkey.*
Noise level increases as mechanization increases in industry. In printing industry, noise occurs especially at printing and postpress production. In case the worker is exposed to noise originating from printing, cutting, sticking, sewing, blending and crushing-folding machines in the work environment of his, different physical and psychological negative effects occur together with hearing loss. According to the 22nd clause of the Worker's Health and Work Safety Code, noise level should not exceed 80 decibels in places where hard and dangerous work is not done. The level of the noise can be 95 decibels at most in places where work, which requires noisier working, is done. However, in this case, suitable protective devices like helmets, earpieces and earplugs should be given to the workers. Noise at this level creates effects, which cause important health problems such as increase in blood pressure, speeding in pulsations and respiration, sudden reflexes and anger.
According to the legislations about environmental noise measurements in occupational health and safety, noise measurements were done in the "guillotine cutting machine", "offset printing machine" and the "cutting machine" in the workplace environment where production is made with offset printing. The measurement results were evaluated according to the related laws and the precautions to be taken were indicated. In order to reduce the noise and be protected from the harmful effects of the noise, which is not reduced in printing businesses, collective protection measures (isolation, engineering, substitution, reducing the work time etc.), using personal protective equipment and training the workers and the employees are necessary.

Keywords: Occupational health and safety, Occupational illness, Noise, Hearing loss

1. INTRODUCTION

In our era of change and development, we have to pay attention to factors affecting our lives negatively. As in every industry, various health problems may occur in the printing industry as well unless necessary attention is paid to health. Improving the quality of working life for workers who spend a significant part of their lives working and eliminating occupational risks and hazards from the working environment will make workers more efficient and thus contribute to economy of the industry and the country.
It is possible to classify factors affecting workers' health in printing industry as biological, ergonomic, chemical, psychological, socio-cultural and physical. The most health-threatening factor for workers in industrial area is noise (Ferrite and Santana, 2005). Noise-induced hearing loss is one of the most common physical factors in the working environment and it affects the health negatively (Ulgen et al, 2002; Nandi and Dhatrak, 2008). Today, it is impossible to find an area of industry with a noise-free environment (Mirmohammadi et al, 2008; Zare et al, 2007), which is an issue of concern for workers (Prasanna et al, 2008). In practice, the measurement unit of noise (sound) is decibel (dB). Decibel is a physics term and a logarithmic expression. As a logarithmic expression; 20 µPa is equivalent to 0 dB and 200 Pa is equivalent to 140 dB. 0 dB is referred to as the hearing threshold, whereas 140 dB is referred to as the pain threshold.

The two main characteristics of sound are frequency and intensity. Frequency is the number of vibrations per unit time and its measurement unit is Hz. Not all vibrations are heard by the ear. The human ear hears sounds with frequencies from 20 to 20,000 Hz. In terms of sound pressure, the human ear is sensitive to sound intensities between 20 micropascals (μPa) and 200 pascals (Pa). The most sensitive frequency range of the human ear is 1,000 - 4,000 Hz. The unit of sound pressure level is decibel and it is represented with dB. The unit of sound level may be dBA, dBB or dBC depending on the weight curve used. dBA is a sound assessment unit which particularly emphasizes medium and high frequencies, to which the human ear is the most sensitive.

1.1 Hearing Loss and Its Symptoms

Hearing is the most important tool in terms of communication and facilitates perception. It is possible to experience problems with hearing due to congenital or acquired disorders. Hearing loss develops slowly. Its development slows down or stops when the person depart from the noisy environment. This condition can be noticed in later stages. Lack of hearing is the quantitative decrease in sensory sensitivity. Reduction in ability to distinguish sounds and a qualitative deterioration in distinguishing acoustic signals are seen (Berk et al, n.d.). Hearing loss observed in adults causes anti-socialization, exclusion and serious economic losses (Smith, 2004) and it is listed as the fifteenth most serious health problem in the world due to its strong effect on individuals (Nelson et al, 2005; Rao et al, 2015).
The need for turning the volume of the TV more than adequate, having problems understanding speech at the level of whispering, having difficulties perceiving speech and other sounds from the environment, asking others to speak slowly, clearly and loudly and avoiding conversation and certain social environment, thus becoming anti-social may be listed as symptoms of hearing loss (Sentürk, 2015). Symptoms of hearing loss are seen in Figure 1.

Figure 1: Symptoms of hearing loss

1.2 Records of International Labor Organization

1. Everyday, about 1 million work accidents and occupational diseases occur throughout the world.
2. Each year, 2.3 million people pass away due to work accidents and occupational diseases. Accordingly, 6300 workers around the world lose their lives everyday.
3. The monetary equivalent of work accidents and occupational diseases is 4% of gross product of the entire world, which is about 1.25 trillion dollars.
4. Considering the situation in Turkey, 14 out of every 1000 workers experienced a work accident in 2014.
5. In 2013, the number of reported work accidents was 191.389, which increased by about 15% and reached 221.366 in 2014.
6. In 2014, 1421 work accidents resulted in permanent disability (loss of body function over 10%)

and unfortunately, 1626 work accidents resulted in loss of life.

7. Everyday, 600 work accidents occur in Turkey, 4-5 workers lose their lives and 4-5 workers become disabled as a result of work accidents.
8. The cost of work accidents and occupational diseases to Turkey is about 10 billion dollars annually (Ceylan, 2011; Gokce, 2013).

1.3 Effects of Noise on Health

Noise pollution is a type of non-fatal physical factor, yet it affects sensory organs directly (Mihailovic et al, 2011). It was found as a result of studies on noise that sounds between 30-60 dBA caused psychological discomfort, sounds between 60-90 dBA caused psychological and neurovegetative disorders, sounds between 90-120 dBA caused otologic disorders as well as psychological and neurovegetative disorders and sounds over 120 dBA caused tympanic membrane perforation.

Effects of noise are usually examined under four groups:

a) Physical effects are temporary or permanent hearing losses. These effects may be associated with several factors. These can briefly listed as sound intensity, distribution of sound frequency, time of exposure, personal sensitivity, age and sex of person (Grujić et al, 2011).

b) Physiological effects are changes in the activity of the body. Cardiovascular disorders such as increased blood pressure, circulatory disorders, increased breath rate, arrhythmia, sudden reflexes and sweating are observed as a result of exposure to excessive noise (Tomei et al, 2000; Virkkunen et al, 2005).

c) Psychological effects include behavioral disorders, depression, difficulty in communication, zonesthesia and overall debility (Rabinowitz and Rees, 2005; Dobbie et al, 2002).

d) Performance effects include decreased work efficiency, lack of concentration, restricted movement and inability to communicate (Bilgili et al, 2011; Stansfeld and Matheson, 2003)

Noise exposure time is a quite important factor in hearing loss. A person exposed to intense noise for a prolonged period of time is likely to suffer hearing loss to a great extent. Without doubt, the most important effect of noise is hearing loss experienced by people. Table 1 shows examples of noise levels encountered in working environment or daily life.

Table 1: Noise levels in different places and locations

Noise Level	Place and Location
0	Hearing threshold
8	Human breathing
20	A quiet forest / whispering
40	A quiet room
50	An office in the city
60	Conversation
82	Factory noise
85	**Paper cutting guillotine, Offset Printing Machine**
110	Air hammer
140	100 m from a jet engine Pain threshold, damaging level

1.4 Noise in Printing Industry

Used to consist of small- and medium-sized firms, the printing industry has seen the rise of large industrial organizations with a turnover of a few billion dollars over the last 30 years. As well as very positive economic contributions, this situation has lead to some negativities as well. The printing industry is one of the sectors with the highest industrial noise. The primary factors that cause this noise level are paper-cardboard cutting machines and printing machines (Norton, 1994).

This is especially evident in occupational health problems. The use of heavy metals and hazardous chemicals in the production process has decreased in the printing industry, whereas especially printing and post-printing processes involve noise. It is inevitable that workers' health is affected negatively as a result of prolonged exposure to noise in the working environment caused by printing, cutting, bonding, sewing, blending, folding and even packing machines (Smith, 2004).

2. METHODS

Considering the fact that different noise levels might be present in different parts of the working environment in a printing firms, measurements were performed in cutting, bonding, bindery and printing departments of ten preselected printing firms in order to determine the noise level of these environments (Table 2). An attempt was made to determine whether a worker would experience a hearing loss due to the resulting noise level in the environment without operating one of these machines. Following these measurements, noise levels of machines in the same firms were measured and noise levels which operators of these machines were exposed to were determined (Table 3).
Extech SL355 Personal Noise Dosimeter, Cesva SC310 Sound Level Meter and Spectral Analyser and Casella CEL 35x Noise Dosimeter were used for measurement. All measurements were performed in accordance with the SLM (Sound Level Meter) method. (The microphone is placed or attached to a distance of 0.1 and 0.4 meter from the external auditory canal entrance on the side with the highest exposure. The microphone is placed on the central plane of the worker's head at the same level with eyes and parallel to the axis of worker's sight and these positions are maintained and tracked throughout the worker's movement. During the measurement, the person conducting the experiment must stay behind the worker positioning his or her body sideways. In the absence of the operator, the measurement is performed at a height of 0.80 m ± 0.05 m from the seating platform for a seated operator and at a height of 1.55 m ± 0.075 m from the ground for a standing operator.)
Also, a worker who had been working in one of these firms for at least ten years and had never used personal protective equipment was selected from each firm and the audiogram test (hearing test) was applied. Audiogram charts of a worker who did not have hearing loss and a worker who had noise-associated hearing loss were drawn up according to test results (Figure 2).

3. RESULTS

Table 2: Noise level measurement results of selected working areas of ten printing firms included in the study

Place of measurement	Personal Exposure (Lex) 8 hours (dBA)	Lowest Exposure Action Value (dBA)	Highest Exposure Action Value (dBA)
Cutting	83,97	80	85
Bonding	85,26	80	85
Bindery	79,65	80	85
Printing	83,12	80	85

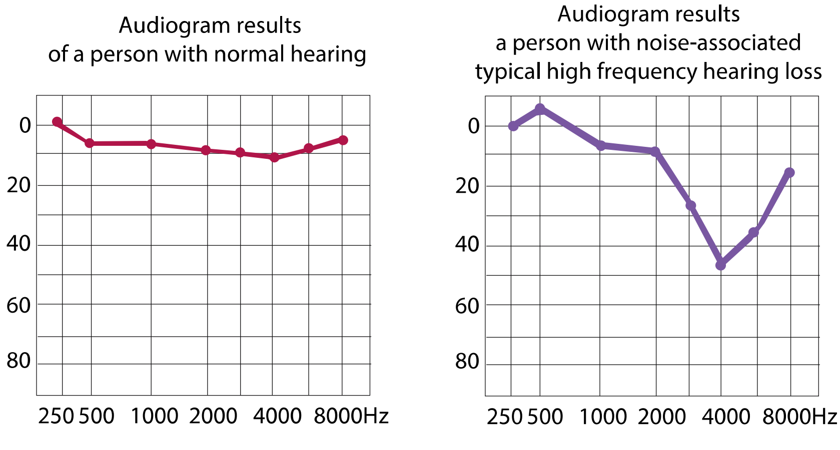

Figure 2: Audiogram (hearing test) results of a person with normal hearing and a person with noise-associated typical high frequency hearing loss

Table 3: Noise level measurement results of selected machines of ten printing firms included in the study (Leq: Equivalent Noise Level, average, Lmax: Maximum Noise Level, Lmin: Minimum Noise Level, Std Dev: Standart Deviation)

Machines	Paper cutting guillotine				Sheed-fed offset printing machine				Web Offset printing machine				Letterpress printing machine			
	Leq. Average	Lmax	Lmin	Std Dev	Leq. Average	Lmax	Lmin	Std Dev	Leq. Average	Lmax	Lmin	Std Dev	Leq. Average	Lmax	Lmin	Std Dev
1	86,4	89,3	84,7	1,03	85,3	84,1	87,3	1.30	89,3	92,4	88,3	0,96	84,6	86,1	82,3	0,87
2	88,3	90,8	86,5	1,12	87,6	90,1	84,6	1,15	93,4	95,7	90,3	1,34	86,8	88,4	84,7	0,90
3	85,4	87,5	84,0	0,91	84,7	87,3	82,5	1,12	92,5	95,8	90,1	1,12	85,3	86,7	84,6	0,67
4	86,2	89,1	84,3	1,13	85,1	88,4	83,4	1,02	93,4	96,5	89,9	1,20	85,4	88,1	83,4	1,08
5	87,1	85,5	89,6	1,07	86,4	89,8	83,4	1,36	91,3	94,7	89,3	0,87	85,0	87,1	84,8	0,82
6	84,2	83,1	87,1	0,85	85,3	87,4	84,5	0,78	89,4	93,5	87,5	0,88	84,5	86,3	83,6	0,45
7	84,5	82,7	88,3	1,32	85,5	87,6	83,4	1,03	92,5	95,3	90,4	1,10	85,6	87,2	84,1	0,67
8	85,8	82,4	89,6	1,45	87,2	89,9	85,4	1,06	93,1	96,2	90,3	1,23	87,2	89,5	86,1	0,50
9	86,1	83,5	90,2	1,76	86,2	88,6	84,1	0,86	92,8	95,6	90,7	0,95	85,4	88,3	83,1	1,34
10	90,2	85,2	93,1	1,88	85,3	88,3	84,2	1,02	92,4	94,3	89,7	1,11	85,8	87,0	84,9	0,32
Average	86,42				85,86				92,01				85,56			
Std.Dev	1,78				0,96				1,53				0,87			

4. DISCUSSION

Creating a healthy and safe environment in workplaces, decreasing the number of work accidents and occupational diseases and determining necessary measures against occupational risks encountered by workers are only possible with creating awareness for occupational health and safety. The purpose of occupational health and safety is to inform workers about their legal rights and responsibilities and legal legislations, ensure that they use personal protective equipment, ensure warning signs are in place, and thus create a safe environment in the workplace.

The noise exposure action and exposure limit values were set out in relevant laws and regulations. It is possible to use weekly noise exposure level instead of daily noise exposure level in terms of exposure limit values and exposure action values in jobs for which it is known with certainty that daily noise exposure level vary from day to day. In these jobs, the weekly noise exposure level determined with adequate measurements cannot exceed the exposure limit value of 87 dBA and appropriate measures are taken to mitigate risks to minimum.

A noise level of 80-85 dBA and above may occur due to machines used in the printing industry, particularly paper-cardboard cutting, folding and bindery machines. Although machines built with improved technologies offer better insulation, workers in the printing industry are usually exposed to harmful levels of noise due to technical inadequacies.

According to the data obtained in this study, it is necessary to make ear protective equipment available in cases where the lowest exposure action value is exceeded. In cases where the highest exposure action value is reached or exceeded, the use of ear protective equipment must be enforced to workers and monitored (Table 2-3). Effective measures aimed at reducing noise are only possible with in-depth knowledge about sound formation. Determination of the difference between sound level in air and background noise or the combination of two is important for taking correct measures.

5. CONCLUSIONS

Noise negatively affects the hearing health and efficiency level of industrial workers. For this reason, the prevention of noise is of critical importance. Noise in printing industry usually occurs as a result of sounds made by machines while running and due to the use of moving tools and equipment in production areas. The prevention of noise at the source, in the environment and for the worker is the main objective. Although sound absorption, reflection panels and covers are expensive applications, they are important measures to prevent the noise at its source and in the environment. Also, the noisy environment must be monitored with regular sound measurements and improvements must be made.

Personal ear protective equipment must be used, working hours of persons exposed to noise must be regulated or the rotation system must be applied to prevent effects of noise on the worker. Also, earlier measures can be taken against possible hearing loss problems by applying audiometric tests to workers more frequently.

Noise reduction methods for machines and facilities can be addressed under two titles. The first is to avoid noise and the second is to prevent sound propagation and dispersion. Emerging technologies and engineering sciences may be used at this point.

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TECHNICAL DESCRIPTION IN ACADEMIC WRITING

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Abstract: *Description can take many forms in academic writing. In scientific and technical writing it usually involves explaining how to do or make something, The paper considers the main properties of rhetorical technique of description for graphic engineering and design which is a part of the subject matter of an ESP course taught at Faculty of Technical Sciences, University of Novi Sad. Scientific and technical rhetoric can be defined as a result of the process of organizing scientific and technical information to produce a desired text for a given type of reader. This process is basically the act of selecting the items of information and then ordering them, i.e. putting them in the most functioning sequence, and indicating the types of relationships existing between the sequential items and between an item and the total context. The paper discusses various rhetorical devices which are used depending on what kinds of information are transmitted to the reader. Thus, it is partition which tells the reader what something consists of; physical description which tells the reader what something looks like; function which describes how the whole and the parts of something work; and process description which tells what steps should be taken to achieve a result. The description of an issue or procedure affects the senses or mind and it is a word-picture of something: an apparatus, a structure, a place, or a condition. Since it is one of the major rhetorical functions of scientific and technical writing it includes two kinds of description: technical and ordinary description The first kind of description is expository in that it attempts to enlarge the understanding. The second kind, ordinary description, aims to provide an experience of the object through imagination and this kind of description is also known as suggestive description. The writer states facts, something objective and beyond dispute.*

Key words: scientific rhetoric, technical description, tertiary education

1. INTRODUCTION

When reading any piece of academic writing, whether it is an essay, a journal article, a dissertation, a thesis or a book, it always contains a number of clearly distinguishable 'types' of writing within it. These types reflect the objectives – or *functions* – one tries to achieve at different stages of work, and they include *definition, description, classification, cause–effect, comparison and contrast*, and *argumentation*. Particularly in longer pieces of writing, such as a research report, most of these functions will feature at some point and the report will therefore consist of a complex network of these types used in combination. Furthermore, one function may form an integral part of another function; for example one may use *classification* or *comparison and contrast* as part of a *description* (Murray & Moore, 2006).
Thus, description in technical academic writing requires clarity of expression and therefore simplicity of language. Technical writing is intent on expressing certain key concepts so that these may be understood as easily as possible by the readers. Writing in a clear, concise manner makes understanding the text easier (Crème & Lea, 2008).

The paper considers the main properties of rhetorical technique of description in writing for graphic engineering and design. It is a part of the subject matter of an ESP course Academic Writing for Graphic Engineering and Design which is taught at Faculty of Technical Sciences, University of Novi Sad. Thus, when talking about press finishing for example, or sequences of events in this procedure, absolute clarity of writing is not only needed in the code discussed; but also in documenting this particular process for the audience. The author needs to attain the same level of clarity of expression in both cases, otherwise readers will turn to other procedures, which are more accessible on the level of understanding and therefore easier to apply or extend (Murray & Moore, 2006). The writer describes when he answers the following questions:

a) What is it like?
b) What are its characteristics?
c) How do the whole and parts of something work?
d) What steps must be taken to achieve the result?
e) What does something consist of?

The description of an issue or procedure affects the senses or mind and it is a word-picture of something: an apparatus, a structure, a place, or a condition; description is one of the major rhetorical functions of scientific and technical writing.
Academic writing includes two kinds of description: *technical description* and *ordinary description*. Technical description gives information about the thing described; ordinary description provides an immediate sense impression of the thing described. The first kind of description is expository in that it attempts to enlarge the understanding. The second kind, ordinary description, aims to provide an experience of the object through imagination and this kind of description is also known as suggestive description (Hyland, 2004).
There is another and very important distinction between technical and suggestive description. In strictly technical description there is no place for interpretation by the writer. The description is concerned only with the facts about the object, facts that can be observed by anyone, for example, when describing an automobile it is suggested that its engine has a 1,595.00 cubic centimetre capacity with an 8.3 centimetre bore and a 7.3 centimetre stroke. The facts are stated; they are something objective and beyond dispute; in other words, the author provides technical description of the engine of an automobile. But when the description reveals that an engine is big, works well, and does not make any noise, it is a suggestive description (Richards & Miller, 2005). Certainly, technical description is in the focus of our attention.

2. RHETORICAL DEVICES IN TECHNICAL DESCRIPTION

Various rhetorical devices are used depending on what kinds of information are transmitted to the reader (Clare & Hamilton, 2003). Thus,

1. *Partition* tells the reader what something consists of
2. *Physical description* tells the reader what something looks like
3. *Function* describes how the whole and the parts of something work
4. *Process description* tells what steps must be taken to achieve a result

Often all these will be found in one piece of writing.

2.1 Partition

Partition, as the process of breaking something into its component or functioning parts, is basic to physical description. There is a tendency to confuse partition and classification. However, they are essentially different in that classification gives information on the items that make up a class while partition takes *one* of those items and breaks it into its parts. Partition is usually, but not always, limited to discussions of physical objects.
Partition defines an object by listing its parts. Paltridge (2004) says that it is exactly the process used by an automobile mechanic in taking a motor apart, by a chemist in breaking down a substance into its components, and by a biophysicist in breaking down the cell into its minute elements. It deals with one object and tells what the main parts of that object are. The parts do not necessarily have anything in common beyond the fact that they belong to the same unit. When dealing with writing for graphic engineering and design here is an example:

Page Layout

The text is set justified on the base line grid in two columns; highlights are italicized; paragraphs start with a 3 mm indent in the first line. A bullet is used as the first-level numbering symbol; a dash (en rule) is used as the second-level numbering symbol. There is empty line spacing before and after a list. The following paragraph is not indented. Besides pure typeface decisions all other aspects of the book were also determined:

- the page format (193 mm ¥ 242 mm),
- the type area with two columns (156mm¥ 200 mm),
- the column width (76 mm).

The figures are preferably single column, double column, or 1.5 column width; the frames are 100% coloured and 0.4 pt thick (for figures without a background), all figures with a background (e.g., photographs) remain frameless; pictures are centred within the frame. Figure captions appear below the figure and are set justified; for 1.5 column widths figures they are next to the figure and unjustified; the distance between the caption lines and the edge of the picture is 3 mm. The figure number stands on its own if the caption text is longer than one line, otherwise it is at the beginning of the line without a following period. The part-figure designations (a, b, c, etc.) are printed black and in bold. They are always placed on their own line. (Kipphan, 2001, p.22).

Thus, partition and classification are often confused, but to make them distinct it should not be forgotten that classification is a means of analyzing or explaining a plural subject. It examines relationships by determining similarities and differences between different members of a class. A class exists as the *idea* of the qualities shared by a number of individual members. But no one member or set of members belonging to the class is necessary for the existence of the class. For example, we can destroy one individual condenser, or several, and the class "condenser", the idea of what constitutes a condenser, is not impaired. Brooks and Warren (2002) say that

A class may, it is true, be said to include the items in that class, but a class, as ordinarily conceived, has no structure in relation to the particular items that fall within it. That is, particular items are not *parts* of the class. (p. 95)

This means that a class is not an analyzable structure, but that an object is, when its components are organized and have a mutually supporting function in determining the nature of the structure.

2.2 Physical description

Physical description is the process of describing the whole of an object or the parts that make up the object, stressing the spatial relationships between the parts. The level of precision in terms of spatial relationships is dependent on the author’s purpose and on the nature of the reader's knowledge and need. Physical description also includes information on size, weight, colour, texture, material, shape, height, width, depth, thickness, etc. If the colour or texture is not mentioned in a complete physical description then they are clearly not important to the discussion and, in fact, may be irrelevant. The reader should also note this negative approach (Luey, 2010).

Physical description may be found in EST (English for Science and Technology) at all levels of writing, written for all kinds of readers: for beginners who are being introduced to a new technical subject or for experts who are being informed about new inventions and ideas. Both beginners and experts are learning something new, and they both, in their minds, have to create mental pictures about those new things, objects, or concepts. The first step in introducing the new concepts is to define, classify, and describe them, physically and in terms of their function as in the following example:

Traditional printing

Offset lithography is the most widely used printing process. It is an indirect printing process which means that an image is transferred, or offset from one surface to another. A printing plate mounted on a cylinder transfers the image to a rubber blanket mounted on another cylinder. The image is then transferred from the blanket cylinder to the substrate as the substrate passes between the blanket cylinder and an impression cylinder. The image on the plate is ‘right reading’ and when the image is transferred to the blanket it becomes ‘wrong reading’. When the image is transferred to the printing surface it becomes right reading again.

The image area and non-image area of the offset plate are on the same plane and work on the principle that oil and water do not mix. The non-image areas of the plate attract a wetting agent (fountain solution) and repel ink made from an oil base. The image areas attract the ink and repel the fountain solution.

The types of printed material than can be produced with offset lithography are numerous and varied. Some of the items include: newspapers, magazines, books, continuous business forms, brochures, posters, greeting cards, business cards, etc. (Kipphan, 2001, p.219).

2.3 Function description

Function description is the process of describing

- how the whole and the parts of something work
- what the purpose of the whole is
- what it is used for
- the way the parts work
- the purpose of each and how they function together to do their job
- how the parts work in relation to one another to achieve the purpose of the whole.

Function description stresses the cause and effect relationship between the parts if a time procedure is involved, and then the time order is also used (Nash, 2004). The technique is illustrated in the following example:

Printing Systems

In addition to the image carrier, each of these printing technologies requires a back pressure element which presses the substrate onto the image carrier to transfer the ink. Gutenberg's press, an adapted wine screw-type press, worked on the principle of "plane to plane", that is, the image carrier and the back pressure element were flat. Middle- and large-sized letterpress machines of the nineteenth and twentieth century worked on the principle of "plane against cylinder", i.e., with a flat image carrier and a back cylinder which rolls on the image carrier. The currently dominant technologies of offset printing, as well as gravure printing and flexography, work entirely on the principle of "cylinder against cylinder" to achieve entirely rotating motion sequences in the printing unit. Only in this way is it possible to achieve the production speeds expected today of 5,000 up to 100,000 impressions per hour. Multi-colour printing presses, where several printing units are located one after the other, are largely constructed on the cylinder/cylinder basis.
Figure 1.2-33 shows a multi-colour *sheet-fed offset press* together with the relevant control and measuring equipment in the print room. Figure 1.2-34 gives an impression of the production process in the press room of a printing company. (Kipphan, 2001, p.31).

2.4 Process description

Process description is the type of function description in which there is a time ordered series of related activities. Process description is used if the order in which a series of steps is made is important. It tells what steps must be taken to achieve a result, and in what order the steps are taken. Time order and cause and effect are essential rhetorical techniques in process description (Kouritzin, et al., 2009). Detailing laboratory experiment is an example of process description.
Written description of a process depends, as does every type of writing, on the intended reader's requirements. If the reader needs to perform the process, it will be necessary for the technical writer to consider every detail. If the reader needs only a general knowledge of the principles involved and does not need to perform or supervise the performance of the process, the writer will not go into specific details which may only confuse the reader, but will instead emphasize the broad principles and give a generalized account of the steps and sequences. Thus, before starting a process description a writer should

a) decide on the purpose,
b) pick the subject,
c) break the process down into steps,
d) check the order of the steps carefully, and then
e) write the process, keeping the audience in mind throughout.
Here is for example an explanation of the process steps of book finishing:

Process steps of book finishing

Figure 7.1-3 shows an example of a manufacturing process for hard-covers for fancy books. In practice we can distinguish between categories such as fancy books, simple edition bindings, school books, children's books, and so on, which reflect the degree of complexity of the book blocks and the extent of surface finishing of book covers. The diagram (Fig. 7.1-3) describes the production process for fancy books from print sheets. All process sections inside a red box are essential for the production of hard-covers and represent simple edition bindings.

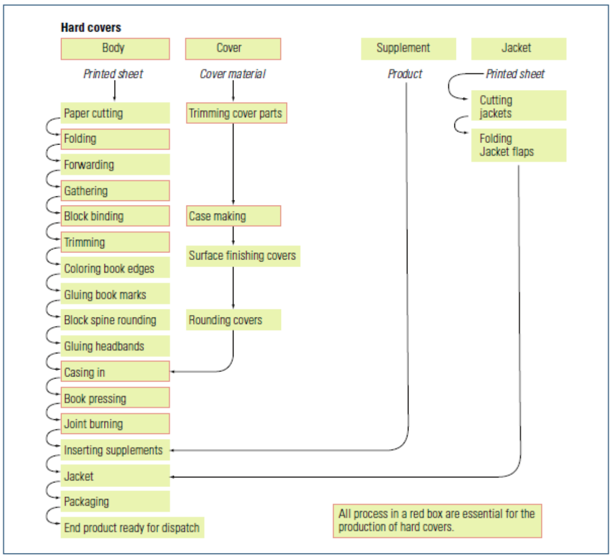

Figure 1: Process steps for the production of fancy books (Kipphan, 2001)

3. CONCLUSIONS

The four kinds of description i.e. partition, physical description, function description and process description, have been discussed separately in order to be differentiated more clearly, but, in fact, they are seldom found in isolation. They are more often mixed with each other, as can be seen from the following example:

Making Paper

Although there are many subtleties which affect the quality of a paper, papermaking in essence is a simple process. Whether using recycled materials or fresh organic matter, the process starts by shredding the material into small strips and soaking them overnight to loosen the fibres. Next, the fibres are boiled for 2-6 hours, being turned every so often. When finished, the fibres are washed with fresh water to remove impurities and then small particles or specks are removed by hand.
The fibres are beaten in a blender or by hand to a creamy pulp. At this stage, dyes can be added to create coloured papers. The pulp is poured into a large tub and the fibres are suspended in the water. The artisan dips a framed screen into the water and with great skill, lifts it to the surface catching the fibres onto the screen. The screens can either be left in the sun to dry, or be transferred to boards, pressed, smoothed and then dried.
Papers made in this tradition are durable, flexible and extremely versatile. They can be used by anyone for gift-wrapping, writing, drawing and painting. They are also used by craft-makers to produce books and binding, stationery and greeting cards, boxes, picture frames and so on. Paper also has many applications in architecture and interior design, such as wallpaper, screens, blinds and lampshades. By using techniques such as moulding and papier-mache one can make almost anything - vases, trays, jewellery, furniture and utilitarian products such as cartons and packaging. In fact, paper is such a versatile medium, its uses are only limited to the imagination... So Dream On!
Although the above paragraph is a mixture of description, one kind of description predominates.
Description can take many forms in academic writing. In scientific and technical writing it usually involves explaining how to do or make something, for example, how to conduct an experiment, how to construct a printing machine, how to operate a machine or how to carry out a manufacturing process. When describing the methodology employed in the course of the research, this type of description is referred to as ‘process’ description because it describes a series of steps that need to be carried out in a particular order. Sequence linking words and phrases are therefore used to connect each step in the process. Being able to think about our writing explicitly in terms of the different functions it is performing at different

stages can help us in two ways. First, it can help categorize or 'label' different sections of writing and serves as an organizational framework according to which we can place those sections in the most logical, readable order. For example, a definition tends to precede a description: the writer most likely wants to define what 'hybrid automotive technology' is before explaining its purpose and how it works. Second, having established the particular function with which one is working at any particular time, this knowledge can serve as a cue for the introduction of the appropriate words and phrases commonly used to help express that function. What follows is an explanation of the functions mentioned earlier, together with some examples of the kind of language typically associated with each of them.

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THE EFFECTIVENESS OF NEWS TICKER GRAPHIC ELEMENTS IN A TELEVISION NEWS PROGRAM

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Abstract: *In this paper, the basic graphic elements of the modern broadcasters are defined through the practical and theoretical process. Two preliminary studies were carried out concerning the crawl usage for the national and international broadcast channel, as well as the examination of the effectiveness of crawl implementation in television news and their influence recipients' memory. We observed differences in ticker design across TV stations, mostly in their aesthetics, the way they appear on the screen and time of their duration. However, in a between–subject design, we did not find significant difference between news ticker text set in positive and negative.*

Key words: ticker, television, video, graphics, typography, infographic

1. INTRODUCTION

Ever since the broadcast of information over TV networks spread out, the need for information design on television screens emerged. The design of additional graphic elements, such as tickers, inscriptions, and other design forms, became more prominent for a majority of present–day broadcasters. Contemporary television information broadcast causes the transfer of a large amount of information, and also their quick presentation, where accuracy is measured in seconds. Essentially, television news programs are trying to compensate for the lack of interaction by presenting to the viewers as much information as possible. This transaction between the internet and television is part of the research of Bolter & Grusin (Bolter et al., 2000) as a way of showing how one media resource is presented in the other. However, they noticed that this transaction is mutual and not linear. In other words, the new media represents a kind of recommendation and reform of the structural aesthetics and content of the old media, while concurrently the old media embraces the aesthetics of the new media and internet. In line with above–mentioned, this paper addresses the comparative analysis of the graphic element's layout on the national and international news broadcast channels. Furthermore, this paper attends to the literature review of the research on news tickers, the speed and effectiveness of their graphic elements.

2. LITERATURE REVIEW

There are numerous reasons for the news ticker expansion. Many believe that the tipping point were the September 11 attacks. Suddenly, there was a soaring demand for information while, at the same time, a great deal of information emerged and was need to be delivered to an audience promptly and accurately. At that moment, several authors shared their views on the crawl application, thus Sella (Sella, 2001) states that traditional information transmission over television screens became unsustainable and that emergence of crawls were the best multimedia alternative. Some early work of Edwardson, Kent & McConnell (Edwardson et al., 1985) imply that using videotext may lead to improved informing of the public because it requires more active behavior on their part and more attention than an audio transmission of news. However, there were no consequent studies that would determine to what extent ticker application influences newer generations of viewers.

2.1 The evolution of the news ticker

The first running text on the television screen appeared around 1984 when the technique of moving letters from one end of the screen to another emerged. Today, this kind of information visualisation on the screen is known as news ticker or crawl, which entered the world of daily news broadcast after the September 11. Every TV station at that time was flooded with the information about the World Trade Center (see Figure 1) and, one by one, TV stations recognised the effects of the crawl. After only 21 seconds of the fall of the north tower, Fox News launched the first news ticker at 10:49 a.m., followed by CNN's ribbon at the bottom of the screen at 11:11 a.m., and MSNBC involvement around 2 p.m. (Stoeffel, 2011). Consequently, emergency news ticker along the bottom of the screen was devised. The crawl was used to grab viewer's attention partially, without interrupting news consumption. After a few months, its popularity decreased. However, it became the tradition many TV stations didn't want to give up so easily, especially when crawls turned out to be an appealing visual tool for younger generations. The continuous technological development, in the field of software application for complex graphic elements design, enabled expansion of numerous crawl solutions, as shown in Figure 2.

Figure 1: News ticker of the FOX TV station on 9/11 2001.

Figure 2: New trends in ticker graphic elements

2.2 News ticker in research

Academic research lacks studies on news ticker application in the media and its impact on the perception of the viewers. Topics, such as the functionality, the importance of the use, the way the crawl is perceived, how it affects viewers, as well as the construction and the style of presentation arise as research questions that need extensive analysis. Blackmon, Kimball & Berhow (Blackmon et al., 2004) used a content analysis on 24-hour news programs from the three biggest TV station (CNN, FOX, and MSNC), defining crawls as a variable. The main purpose of their research was to determine the type of information displayed through news tickers. Their results provide interesting, but not surprising, insights. The news covering war and welfare appeared to be the most common (22% coverage). In the second place were the news on criminal actions (18%), and the next in line were promotion news for the TV station. The least covered topics were science and travels. They concluded that crawls are mostly used for serious topics labelled "Breaking News". Furthermore, the analysis of crawls, as a tool of more comprehensive information display, at these three TV stations implied that news tickers with diverse information were better accepted than the ones with the repetition of the same news. Keefe–Feldman (Keefe-Feldman, 2007) set out to examine whether crawl application in the news broadcast has positive or negative effect on viewer's perception in relation to headline news. The findings of his study indicate a negative correlation between the news tickers and ability of individuals to take in all the information being broadcasted. Particularly, the results of this study comply with the excessive information theory according to which a person faced with abundance of information is not capable of successfully examining specific a piece of information. Furthermore, the results of this study also reveal that previously mentioned TV stations display irrelevant information to the headline news on tickers, impeding news reception additionally.

Blain & Meeds (as cited in Keefe-Feldman, 2007) hypothesize that application of news tickers results in viewer's total obstruction of the ability to memorize the information at hand. The aim of their study was to measure the speed of tickers and detection of the ideal ticker speed for the best advantage of the viewer's attention. Their additional dilemma was whether TV stations should use crawlers all the time or just for the emergency news broadcast. Similar concern developed in Keefe–Feldman's (2007) study; one part of his analysis was concerned with the crawl appearance speed on the screen. His research methodology involved measuring how much time was needed for one letter to reach the other side of the screen. The results indicate that FOX TV station has the fastest crawl. However, this finding should be interpreted with caution because of the fact that the spacing of the crawl at this TV station is narrower, unlike the other two tested stations which have crawls running along the entire bottom of the screen. When font legibility on the TV screen is concerned, the research findings indicate that choice of the typeface, letter case and position on the screen should be taken into consideration (Pušnik, Možina & Podlesek, 2016; Pušnik, Podlesek & Možina, 2016). After reviewing the literature, we defined the focus of our research: examination of the news ticker effectiveness during a broadcast of the news program. The effects we are interested in are the shape of the ticker, the choice of font, speed ratio, and the relationship between the colour of the letters and background. Therefore, we postulated the research question: What is the extent of the influence of graphic elements in news tickers on viewer's attention – do different graphic elements influence memorability of the information on tickers?

3. METHOD

The experiment was conducted in two stages: preliminary studies and main experiment.

3.1 Preliminary study 1

The first preliminary study was concerned with determining and comparing the crawl speed. The measured speed included the time needed for one letter to cross from one end of the screen to another. The sample included three national TV stations (Novosadska, RTS1 and B92). These TV stations were chosen because they broadcast news program with crawls included at the bottom of the screen. The analysis reviled that the duration of all three crawls was approximately the same (see Table 1).

Table 1. The average duration speed of the tickers on selected national TV stations: Novosadska, RTS1 i B92

TV station	Novosadska	RTS1	B92
Average speed of the ticker–a time it takes for one letter to appear from one side of the screen to the other	7,2 sec	7,1 sec	7 sec

3.2 Preliminary study 2

The second preliminary study addressed the comparison of crawl graphic elements. For the purposes of the crawl graphic elements analysis, national and international TV stations were sampled. These TV stations were filtered for informative and entertainment programs that use crawls to emphasise additional information. International TV stations appeared to be using different graphic elements than national ones. International TV stations display graphic elements, such as logo, inscriptions, crawls, and time stamps, at the bottom third of the screen, whereas national TV stations still display logo at the upper part of the screen. Also, there is a trend of designing special graphic elements for particular programs which expands visual vocabulary of a certain station. All of the sampled international TV stations use sans serif fonts. CNBC uses two tickers, one of which is using white background with blue letters while the other one uses blue background and white letters. CNN and Al Jazeera use white letters on a blue, that is, orange background; BBC and SKY use black letters and white, that is, yellow background. FOX uses yellow letters on a black background. These preliminary results lead to a conclusion that all TV stations aim in the same direction– information display on tickers with clear precision using san serif typefaces, contrast between the colour of the letters and background, and position on the screen.

3.3 Procedure

In order to test the effects of crawls design on consumer's memory, between–subjects experimental design was used. Difference between displaying text in positive and negative was tested in regards to viewer's attention and recall.

Figure 3: Screen shot of Adobe Premier software used in stimuli design and editing

Stimuli design was in a form of a news program, edited in Adobe Premier (see Figure 3), using European format DV PAL Widescreen 48kHz, 16:9 (14587), 720x576 with 25 frames/sec. The data acquired in the preliminary tests were used to construct two sets of target videos with the same information content and duration (2 min). The image was adapted to television broadcasting in RGB colour mode. One version of the target crawl was displayed in white letters with black background, as in Figure 4a. The other target crawl was displayed in black letters with white background, as in Figure 3b. The font used was sans serif, and both videos were displayed at the same speed i.e. the time of the crawl duration was 1.44 minute. The crawl contained three different news snippets. Each snippet appeared three times during the news programme. In the experiment 30 participants took part. The first group saw the news ticker in black background with white letters (text in negative), while the second group viewed the ticker in white background with black letters (text in positive). After they finished watching the news program, the participants answered six questions. The first question referred to the main news story, while the other five questions were related only to the information from the crawl. All the participants received the same questions with answers provided, where only one was the correct one.

4. RESULTS AND DISCUSSION

The results were tested using Chi-Squared (x^2) test statistics. The comparative analysis of the correct and imprecise answers reviled that there was no significant statistical difference between the groups of participants (t = 0.538, p = 0.592) (see Table 2). The group of participants that viewed white letters on black background was slightly better in memorising the news information (M = 4.0000, SD = 1.68154) than the one that viewed black letters on the white background (M = 3.7667, SD = 1.67504). However, these results indicate that the target stimuli was equally effective.

a) *b)*

Figure 4. a) News ticker with black background and white letters (text in negative); b) News ticker with white background and black letters (text in positive)

Table 2: Means (M) and Standard Deviation (SD) of participants recall test (questions answered accurately) for both tested videos

	Group	N	M	SD	t	p
Number of answers that were accurate	News crawl–black background	30	4,0000	1,68154	,538	,592
	News crawl–white background	30	3,7667	1,67504		

5. CONCLUSIONS

In this study we examined the effects of different news ticker design on consumer's memory. Based on the results of this research, managerial implications would include more attentiveness to the font size, typeface attributes and legibility, contrast, duration of the crawls, and the length of content displayed. It should be noted that viewers do not pay close attention to tickers and that each individual has a different reading habits. In conclusion, from the sample we tested, the variables in crawls were not salient enough to draw further attention. TV stations may rely on positive effect when using both text in positive and negative in news tickers.

6. ACKNOWLEDGMENTS

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