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LEGIBILITY OF TYPEFACES AND PREFERENCES OF TEXT/BACKGROUND COLOR VARIATIONS IN VIRTUAL ENVIRONMENT

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Abstract: *Text legibility is an important and influential aspect of multimedia, not only on usual multimedia reading devices (displays, tablets, and mobile phones) but also in three-dimensional virtual environments (VE). In VEs, text can be used for many purposes in accordance with the category of experience (gaming, architectural visualization, exhibition, education). Font type used can deteriorate the VE experience if the user has to strain his eyes so that he may correctly read what has been written. The purpose of this research is to examine different fonts in order to determine which properties of a typeface are more suitable for VE. Four different fonts have been tested in 10 font sizes at three viewing distances (5, 10, and 15 meters). Times New Roman as a representative of serif fonts, Helvetica as a non-serif font, Caveat as a representative of handwritten fonts, and Roboto as a font for digital use, initially developed for the Android operating system. Different typographic characteristics of fonts significantly affect readability in VE. Additionally, was explored how the color of the text and the background color influence text readability in 20 combinations. It is known that the relationship between text color and background color affects readability. Since VR is a relatively new medium, we wanted to determine which relationship between colors of text and background is the best and whether it follows some rules present on the web. The colors of the text were black and white, and the colors of the background were black, white and gray, red, green, pastel green, blue, pastel blue, yellow, pastel orange, and pastel pink. Results regarding text color/background color have shown that most participants preferred black text on white background, black text on a gray background, and white text on a pastel orange background. On the contrary, participants rated white text on a yellow background as the least preferable combination, accompanied by white text on a pastel green background.*

Key words: virtual reality, virtual environment, typography, text legibility

1. INTRODUCTION

Text readability and legibility are terms that are often misused and used interchangeably when discussing typography, and for a better understanding of this research, definitions are provided. As Tefki stated in his paper, "*text readability studies are concerned that a given piece of writing reaches and affects its audience in the way that the author intends"* and text legibility encompasses many factors in typography that may affect ease and accuracy of reading, such as typeface, font size, weight, lower/upper cases and changes in spacing (Tefki, 1987). Other definitions state that the meaning of readability is "*how easy written materials can be read and understood*" and that efficient readability is dependent on good legibility (visual properties of the character) of the text (DuBay, 2004; Zamanian & Heydari, 2012; Zuffi et al., 2007). There are many research papers investigating formerly explained terms, and in their paper, Arditi and Cho give a comprehensive list of conducted studies and report their study of legibility where they tested nine different fonts (presented both on computer and paper) and concluded that (on relatively small sample size – 4 participants) no differences of legibility was found between typefaces that differ only in the presence or absence of serifs (Arditi & Cho, 2005). When comparing readability and legibility on paper versus iPad, research results showed that Sans serif Gotham font is more readable and legible on iPad than Minion Pro serif font (Čerepinko et al., 2017). Beside of aforementioned research on text legibility made on classic paper, digital screens, or tablets, a newer media comes into the digital era: virtual reality (VR). VR devices made a comeback in recent years, with improved technical specifications that allow users to experience high resolution stereoscopic content on a relatively light head mounted device. There are many aspects of VR application design to consider, but this paper focuses on typography. Kojić et al. (2020) in their paper compare two VR devices and three text samples in Arial font (short – 2 words, medium – 21 words, and large – 51 words), manipulate font size from 5 – 40 pt and distance of text from 0 mm – 10000 mm. They found significant differences regarding angular size depending on displayed text length. They found no differences regarding VR devices. Also, they tested the contrast ratio between text and background color and the results show that text settings are not significantly different for different text lengths or devices, but in all conditions are at least 7:1, and they had some very high contrast results

(Kojic et al., 2020). Dingler et al. (2018), besides optimal angular size, investigated UI parameters (dark/light background color, serif/sans-serif font and vertical position of the view box). Their results show that angular size of the text should be 41 ± 14 DMMs (DMM – distance independent millimeter is a unit presented by Google in 2017, and it represents unit where 1 dmm as 1mm height at 1m viewing distance). Participants preferred white text on black background (Dingler et al., 2018; Hinojosa, 2018). Another study conducted in 2016 investigated which visual properties a typeface should have, so that the user can better estimate the distance in VR. They used Arial font in three different styles (colored flat text, colored embossed text, and transparent embossed text in wireframe). Results show that two-dimensional and flat text performed better than the other two tested text samples (Vairinhos et al., 2016). Text is not only to be read in VR but also can be written in a form of input. Bowman et al., have in 2002 compared four text input techniques (one of the text input techniques authors developed themselves and named "The Pinch keyboard") but conclude in results that more research is needed to determine which text input technique is optimal for virtual environment (Bowman et al., 2002). Art is also being made with typography, as shown in examples given about experimental typography in VR (Banu Dur, 2021; Niyazi, 2019).

2. METHODOLOGY

This research aims to determine how different fonts impact legibility in a virtual environment, at different viewing distances. Thus, four different typefaces have been chosen as representatives: Times New Roman – serif font, Helvetica – sans serif font, Caveat – handwritten font, and Roboto – font for digital use. Figure 1 below depicts selected fonts.

Figure 1: Selected fonts for virtual reality

After the selection of the fonts, a scene for virtual reality was created in the Unreal Engine 4 (UE4) application. The scene was designed in such a way that it accommodates all four fonts, each in a separate compartment with an additional compartment for testing background-color text-color influence. Also, to equalize the movement on the scene while testing different distances of font readability, each reading distance (5 m, 10 m, 15 m) was key bound to a keyboard number or letter. For example, Times New Roman distance of 5 m was bound to keyboard number 1 (one), a distance of 10 m to keyboard number 2 (two), and a 15 m distance to keyboard number 3 (three). Following the same manner, the other three fonts' distances were bound to different keyboard numbers/letters. This was programmed in order to equalize the standing position for reading for all participants, to avoid participants being able to freely move around and accidentally stand nearer or further away from the text panel. That means that the experimenter clicks a number (or a letter) on a keyboard, and the participant is placed on that location in VR without having to navigate around and search for a position to stand. Figure 2 depicts a part of the VR scene for testing font legibility.

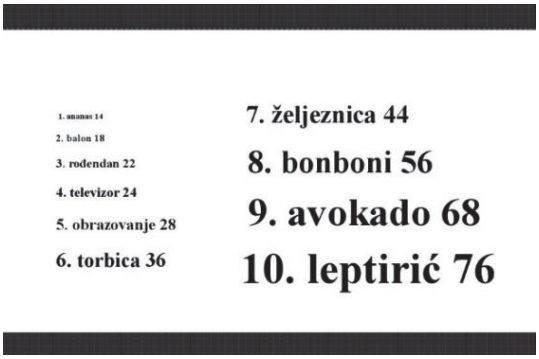

Figure 2: Example screenshot of a testing panel in VR – Times New Roman font

As mentioned earlier in text and depicted in Figure 2, each font tested had its own compartment for testing the legibility, the testing area. The participant standing in the testing area is frontally looking at the panel in front of him. On the panel, the participant sees ten words in different font sizes (14 pt, 18 pt, 22 pt, 24 pt, 28 pt, 36 pt, 44 pt, 56 pt, 68 pt, and 72 pt) firstly on 5 m distance, followed by 10 m distance and finally at 15 m distance. All words were written in the Croatian language. The participant is seeing the same ten words on all three distances, but the used words are different for different fonts tested. The participant is asked to determine which font size is the least comfortable for reading and which one is the most comfortable for reading (at every viewing distance). Finally, the participant is placed in front of the fifth panel, at 15 meters standing distance, to investigate how the background color and text color influence text legibility in 20 combinations. Combinations were as follows; black or white text color on black, white, gray, red, green, pastel green, blue, pastel blue, yellow, pastel orange, and pastel pink background color. Figure 3 depicts tested color combinations in the VR scene. For every color combination, participants were asked to determine visual recognizability, i.e., which color combination suits them better for reading in a virtual environment. Finally, participants were asked to rank three combinations that they considered most favorable for reading in VR and three combinations that they considered to be least favorable for reading in VR.

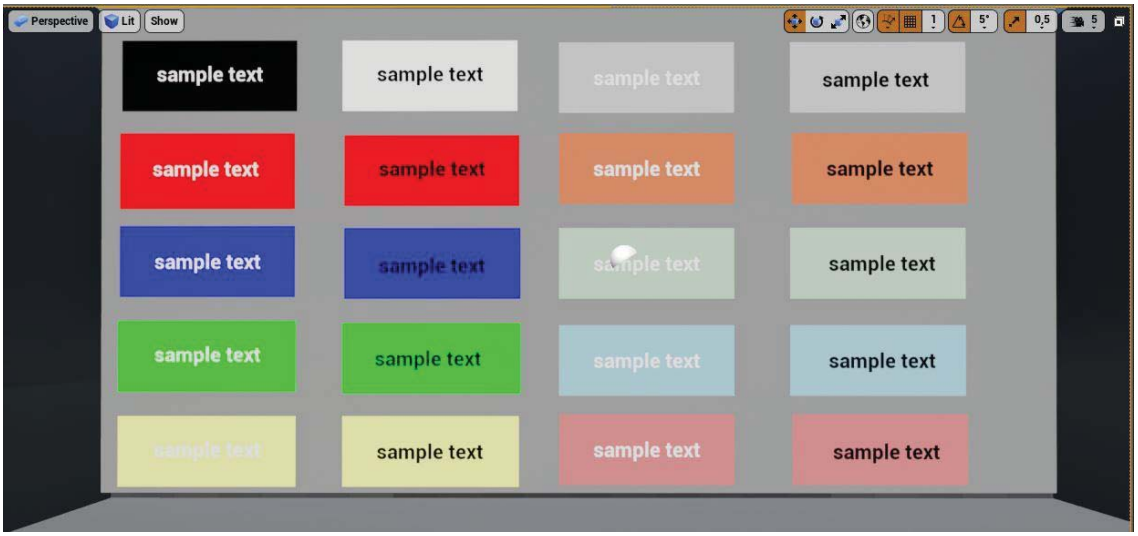

Figure 3: Example screenshot of a testing panel in VR – text color/background color combinations

2.1 Participants and equipment

Research participants were students and employees of the faculty, their participation was voluntary, and they did not receive any financial reimbursement for participation. Participants signed a written consent to agree to be in the study. They were introduced to VR headset and equipment (one at a time), and they could adjust headset settings to fit their comfort (interpupillary distance and head straps). A total of 18 participants were included, aged from 20 – 62 years (avg=29.4, SD=11.88), and in gender distribution, 11 participants were female (61%) and 7 (39%) male. Most participants had no experience with virtual reality 10 (55%) and almost half had some experience 8 (45%). No experts were among the participants. Furthermore, most of the participants' preferred reading medium is a book (11 participants), followed by a mobile phone (3 participants), a classic computer screen (2 participants), a tablet (1 participant), and an e-book (1 participant). Lastly, participants reported if they have normal or corrected eyesight (glasses/lenses); 12 (67%) have normal eyesight, and 6 (33%) have corrected eyesight. The virtual reality headset used was HTC Vive and the application was run on a Dell Alienware laptop.

3. RESULTS AND DISCUSSION

In this section, the results are divided into two parts; the first is designated to font legibility tested in VR and the second to text color and background color preferences in VR.

3.1 Font legibility test in VR results

As mentioned earlier in the text, a total of four fonts were tested for legibility at three viewing distances (5m, 10m, and 15m). A simple analysis was run to determine differences between typeface legibility preferences.

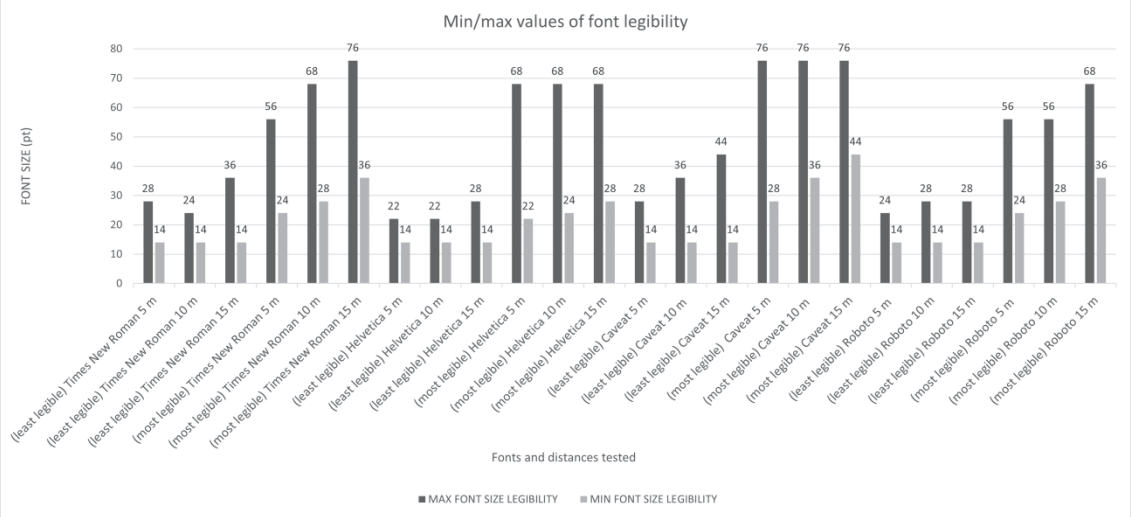

Figure 4: Minimal and maximal values of font legibility for all tested distances and fonts

From the Figure 4 the average font legibility for all tested distances can be observed. For Times New Roman, Helvetica and Roboto tested typefaces, minimal legible font size was 14 pt. For Caveat – (handwritten typeface) minimal font size legibility was 28 pt, then 36 pt and 44 pt, an obvious increase of minimal font size needed for reading in accordance with distance. In addition, a chart with calculated median values is presented in Figure 5 below, for the same data.

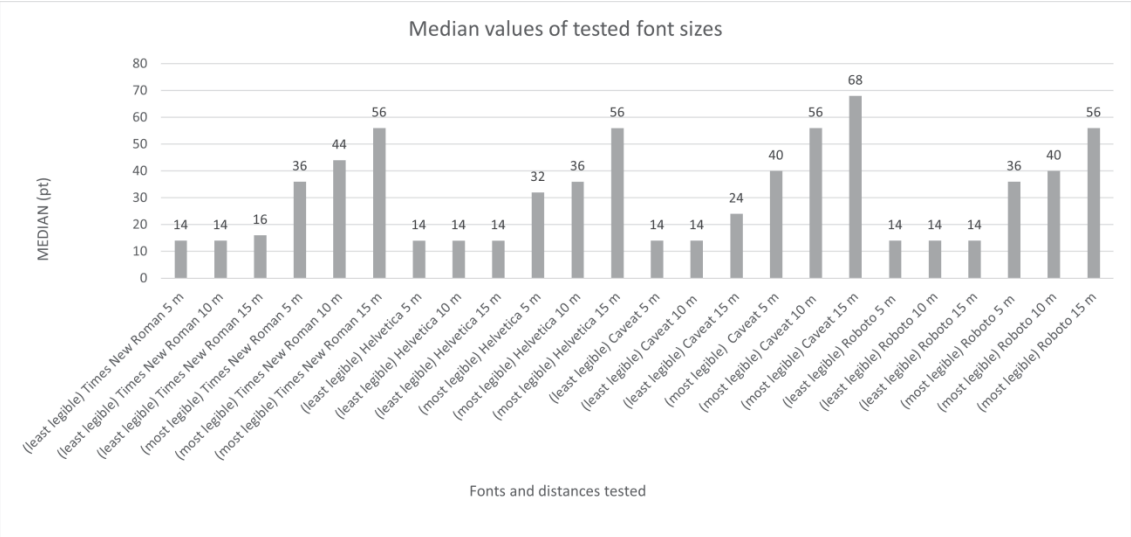

Figure 5: Median values of font legibility for all tested distances and fonts

Median values show that 14 pt font size is least legible for all 5 and 10 m viewing distances, but at 15 m an increase in size is recommended, at least in handwritten and serif typeface. For most legible font size at 15 m distance values are ranged between 56-68 pt. Higher font size is required for handwritten font.

3.2 Text color and background color preferences in VR

Figure 6 below represents results for text color and background color preferences in VR, where participants had to select between 10 color pairs of combinations. It can be observed that black text on a white

background is preferred over vice versa and on several other background colors (gray, pastel blue, green, pastel green, and yellow). Other combinations like red, pastel pink, and pastel orange background do not have a predominant text color option.

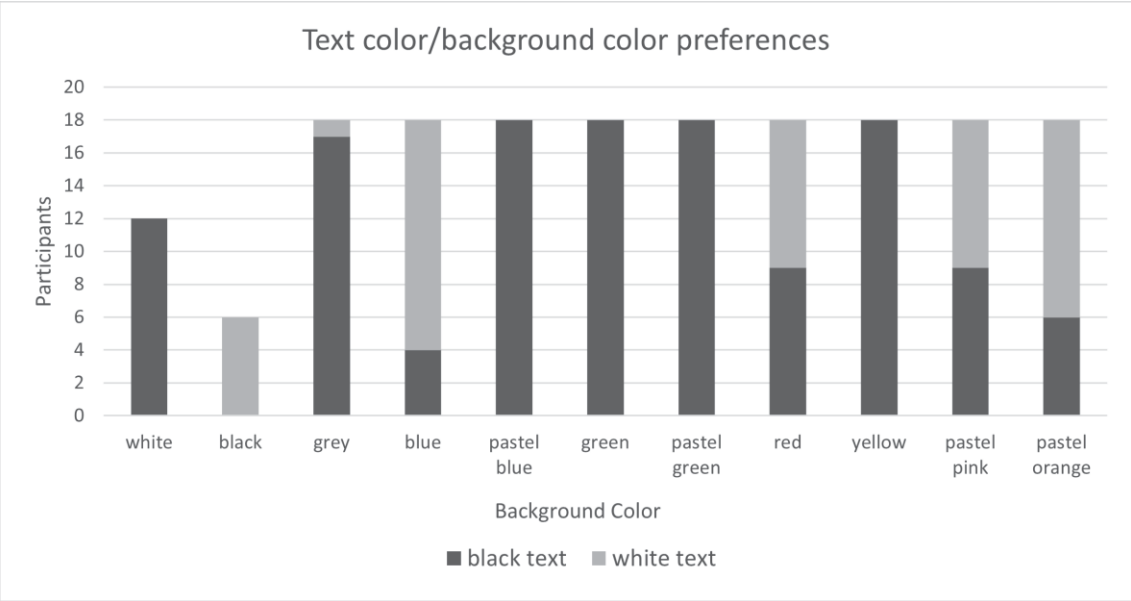

Figure 6: Text color and background color preferences in VR

The last question participants were asked was to determine three combinations that they consider most favorable for reading in VR and three combinations that they consider least favorable for reading in VR.
For better understanding of the results, one extra figure was added through simple scoring of the results. Scoring was set in such a manner that each participant ranking of the most favorable combination was multiplied by 3, second most favorable multiplied by 2 and third most favorable by 1. Least favorable rankings were issued corresponding negative scores, as shown in equation 1 below.

$$SCORE = (nt_1 \times 3) + (nt_2 \times 2) + (nt_3 \times 1) + (nb_1 \times (-3)) + (nb_2 \times (-2)) + \left(nb_3 \times (-1)\right) \quad (1)$$

* nt_1 = number of times in top 1st position = multiplier 3
* nt_2 = number of times in top 2nd position = multiplier 2
* nt_3 = number of times in top 3rd position = multiplier 1
* nb_1 = number of times in bottom 1st position = multiplier -3
* nb_2 = number of times in bottom 2nd position = multiplier -2
* nb_3 = number of times in bottom 3rd position = multiplier -1

Figure 7 below shows results of the scoring of the most/least favorable color combinations. The highest score (top combinations) is black text on white background (which is the highest contrast), then black text on pastel blue background (lesser contrast), followed by black text on gray background (also lesser contrast). Interestingly, we can observe that top four highest scores have combinations with black text followed by four combinations with white text on pastel (also lesser contrast). These results can be explained in such way that participants are accustomed to black text on white background, and because of high contrast. Other preferred combinations are black text on pastel blue background, black text on gray background, white text on black background, and white on pastel orange and pink (lesser contrast combinations). When observing least preferable combinations, as expected, white text on yellow background is top worst. Jimenez et al., in their research also report this result for text legibility for white text on yellow background (Jiménez et al., 2020). Among other least preferable combinations are white text on green, gray and pastel green background, and black text on blue background.
From these results recommendations can be suggested for creating and designing typographic content for VR, even though one has to take into consideration other scene design parameters, such as overall scene illumination, which has impact on general visibility in virtual environment. It may seem logical to

assume that high contrast combination is better than low contrast combination, but it can be observed that white text on pastel color background is among most and least preferable combinations.

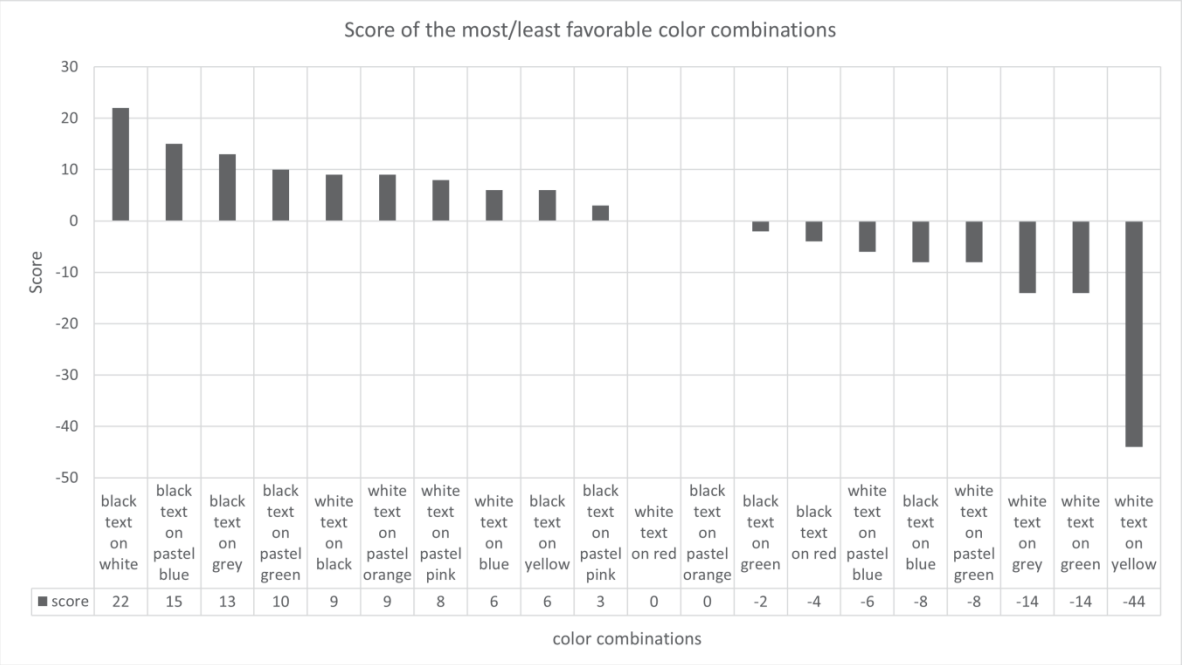

Figure 7: Scoring of the most/least favorable color combinations

4. CONCLUSIONS

This research explored some aspects of typography in VR. In a VR environment, four different typefaces were tested regarding legibility at three viewing distances (5m, 10 m, and 15m). Each typeface was distinct from another (serif, two sans-serif, and handwritten). In addition to text legibility, we tested the influence of text color and background color (also on text legibility). Median values repeat for most of the least legible typefaces (14 pt) for different typefaces. An exception is Caveat font at 15 m distance, 24 pt. For most legible font sizes at different viewing distances, an increase in font size is evident with distance. For all typefaces most legible font at 5m was between 32-40 pt, at 10m between 36-56 pt, and at 15 m 56-68 pt. A scoring formula was used for assessing the most/least favorable combinations for text and background color combinations. The highest score for the most favorable combination gained black text on white background, followed by black text on a pastel blue, gray, and pastel green background. As expected, the least favorable combination was white text on yellow background, then white text on green, gray and pastel green. Further research is needed to better understand legibility, readability, and color preferences in virtual reality, in the aspect of different illuminants or scene designs in VR.

5. ACKNOWLEDGMENTS

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