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ANALYSIS OF EMOTION EXPRESSION ON FRONTAL AND PROFILE FACIAL IMAGES

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Abstract: *Expressions of emotions are often found in facial images. In addition to the neutral facial expression, we know six basic expressions of emotion: joy, anger, sadness, fear, surprise, and disgust. The similarity of some emotion expressions sometimes leads to incorrect recognition or confusion of two emotions. In our study, we tried to find out how these substitutions manifest in the recognition of emotions on frontal and profile face images. The results of the substitutions in emotion recognition were presented with a substitution matrix. The second part of the study focused on confirming these results with the analysis of facial feature observation and fixation duration. In the analysis of facial features, the three main facial features (eyes, mouth, and forehead with nasal) that attract the most attention were considered. Fixation duration was also measured for these facial features. The basis of the research equipment was an eye tracker, which we used to define the areas of interest (AOI) for the analysis. The results of the observational proportions of facial features confirmed a relatively large scale of substitutions of the emotions fear and surprise, anger and disgust, and partial fear and disgust in frontal facial images. In profile facial images, the most frequent incorrect recognition were the emotions happiness and surprise, anger and disgust, fear and disgust, and anger and sadness. Since there is less information about the face in the profile facial image than in the frontal facial images, the results also confirmed a higher proportion of incorrect recognition in the profile face images and thus a more difficult recognition of emotions in the profile face images. The greater extent of incorrect recognition was also confirmed by the fixation duration results. Both results (observation proportions of facial features and fixation duration) were also presented in a graph.*

Key words: frontal facial images, profile facial images emotion expression, internal facial features, fixation duration, eye tracking

1. INTRODUCTION

Every day we deal with situations where we cannot can not always see people's faces in the front view. When recognising faces that cannot be seen in frontal view, most research has been done with profile facial images. In addition to frontal and profile views of faces, faces are usually shown at a 45^{o} angle (mid-profile view), which is called a ¾-view. This represents the face between the frontal and profile views. Research (Blatz, Tarr & Bulthoff, 1999) has shown that when given a choice between faces at different angles, users chose the ¾-view as the most appropriate view that combined information about the frontal and profile views.

Most studies dealt with frontal, ¾ and profile views. Research (Edelman, 1995) has shown that when the objects of observation are highly similar, recognition is largely influenced by. Since faces are a group where the similarity between the elements of the group is very high, the viewing angle also plays an important role in the recognition of faces. In all this research, the designers and face databases also consider the researchers' requests and take pictures of the faces from different angles.

In our study, we used only two groups of facial images: frontal and profile. With these images, we aimed to identify emotions based on facial features. In general, facial features are divided into inner and outer facial features (Moore, 1985). Inner facial features include the eyes, nose, and mouth, while outer facial features include the forehead, cheeks, ears, and chin (Buchan, Pare & Munhall, 2007). Otherwise, facial features can be further subdivided (eyebrows, eyelids, lips). Figure 1 shows the basic classification.

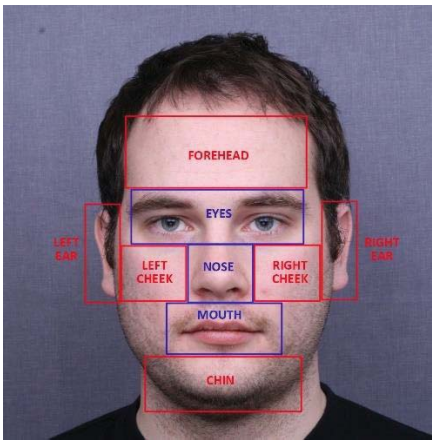


Figure 1: Inner (blue) and outer (red) facial features

When emotions are shown, three parts of the face change the most (eyes, mouth, and forehead). We have therefore based our research on the analysis of the proportions of observing these facial features.

2. METHODS

2.1 Participants

As mentioned above, we conducted two tests, one for frontal facial images and one for profile facial images. For each test we recruited 20 participants among our students. Average age for frontal facial images was 20,3 years (SD = 0,78), and for profile facial images 20,5 years (SD = 0,81). All participants volunteered and had normal vision.

2.2 Stimuli

We took the images from the Stirling/ESRC 3D Face Database (Hancock, n.d.), which contains a good representation of facial images of all emotions in both frontal and profile face images. The dimensions of the images were again adjusted to the set resolution and natural observation conditions (Henderson, Williams, & Falk 2005) and reduced from 800 × 800 px to 480 × 480 px. Three face images were selected for six facial emotions of each gender. Thus, we had 36 (3 × 6 × 2 = 36) frontal face images and 36 profile face images. Subjects in both groups were identical. Figure 2 shows surprise emotion expression of frontal facial image (a) and anger emotion expression of profile facial image (b).

(a) *(b)*

Figure 2: Surprise emotion expression of frontal facial image (a) and anger emotion expression of profile facial image (b) (5)

2.3 Apparatus

All tests were carried out in the Laboratory of Visual Perception and Colorimetry at the Department of Textile, Graphic and Design of the Faculty of Natural Sciences and Engineering at the University of Ljubljana. When setting up the environmental and testing system we followed the standards and recommendations.
We performed the test with the Tobii X-120 eye tracking system. The distance between the test subjects and the screen with the facial images was 60 cm. The setting of the test environment and the test subject is shown in Figure 3.

Figure 3: Testing setup

Analysis were done in Tobii Studio 3.4.8 software. The defaults setting for definition of fixation was 100 ms for 30 px area. That means if eyes stayed in the area 30 pixel for at least 100 ms it was concerned as one fixation (Tobii studio, 2016).

2.4 Procedure

The test was designed based on the real-time response of emotion recognition. In planning the test procedure, we helped each other with similar tests (Guo & Shaw, 2005; Green & Guo, 2018). After the initial instructions and a two-second of dark screen, a facial image showing an emotion expression is displayed for four seconds. The duration of the presentation of the facial image varied between researchers. For some, the image was viewed freely (after the image was shown, the subject quickly clicked the emotion response button); for others, this time ranged from half a second to five seconds. We determined this time based on our previous tests (Iskra & Gabrijelič, 2019), and it was four seconds. It is important that the time be long enough so that we can perform a good analysis of the proportions of observation of the areas of interest which were based on previously mentioned facial features. After the facial image was shown, a list of six emotions followed, and the subject answered which emotion was shown. After the response, a new face image was displayed with a mouse click. The procedure of emotion expression recognition test for frontal face images is shown in Figure 4. The procedure for profile face images was the same.

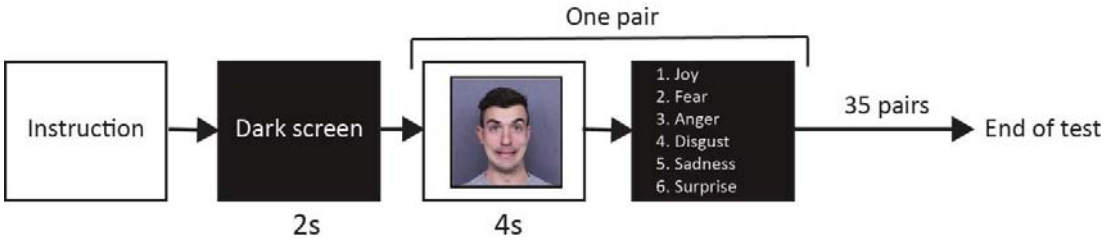
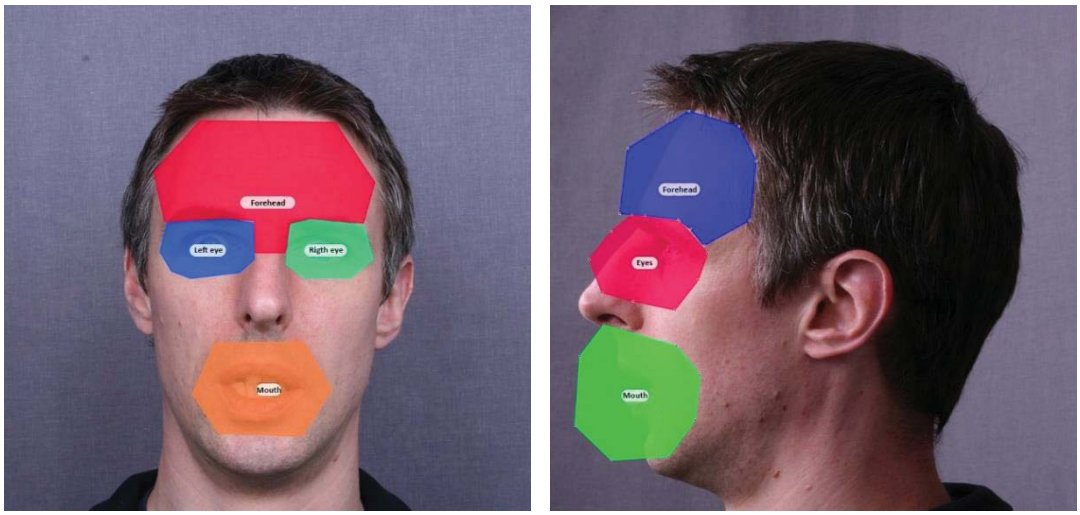


Figure 4: Procedure of emotion expression recognition test

2.5 Analysis of results

In recognizing emotion expressions, participants' responses were recorded manually. As mentioned earlier, we had 20 participants in each test. There were 36 images in each test, so we obtained 720 emotion recognition responses for frontal facial images and the same number for prifile facial images. These results were presented in a substitution matrix, which was also used in by other researchers (Guo & Shaw, 2005; Iskra & Gabrijelič, 2019). One direction of the matrix represents the facial emotion expression presented, and the other direction represents the participants' responses. In this way, false recognitions can be quickly detected (one emotion expression is shown, the test participant recognizes it as a different emotion expression).
In analyzing the observation of facial features, we wanted to find out in what proportion the three parts of the face that change the most when emotions are expressed (eyes, mouth, and forehead) are observed. To obtain these results, we determined the area of interest (AOI) and used the fixation duration setting in the Tobii Studio Pro program. When extracting the data, we were only interested in the total time spent visiting a particular AOI. The creation of these areas was done manually. An example of the AOI for frontal and profile face images is shown in Figure 5.



(a) (b)

Figure 5: AOI for frontal (a) and profile (b) facial images

As mentioned above, the average fixation duration was obtained directly from Tobii Studio Pro and the use of AOI.

3. RESULTS

3.1 Frontal facial images

Table 1 shows the results of emotion expression recognition in frontal facial images. The results of correct recognition are coloured green. These are, of course, the higher results because participants generally recognised the emotion expression correctly. The results of incorrect recognition between 5% and 10% are coloured yellow, and the results above 10% are coloured red.

Table 1: Results of recognition of emotion expression for frontal facial images

		Presented emotion expression					
	Recognition [%]	**disgust**	**anger**	**sadness**	**fear**	**surprise**	**joy**
Participants' response	**disgust**	84,2	6,7	1,7	10,8	2,5	0,0
	anger	7,5	75,0	3,3	3,3	0,0	0,0
	sadness	4,2	2,5	77,5	2,5	0,8	0,0
	fear	0,8	7,5	15,0	63,3	11,7	0,0
	surprise	3,3	8,3	2,5	20,0	85,0	0,0
	joy	0,0	0,0	0,0	0,0	0,0	100,0

The results of the proportion of observation of three facial features for all six emotion expressions are presented in Figure 6. Participants spent about half of the observation time observing the eyes, about a quarter of the time observing the mouth, and a small proportion of the total time observing the forehead.

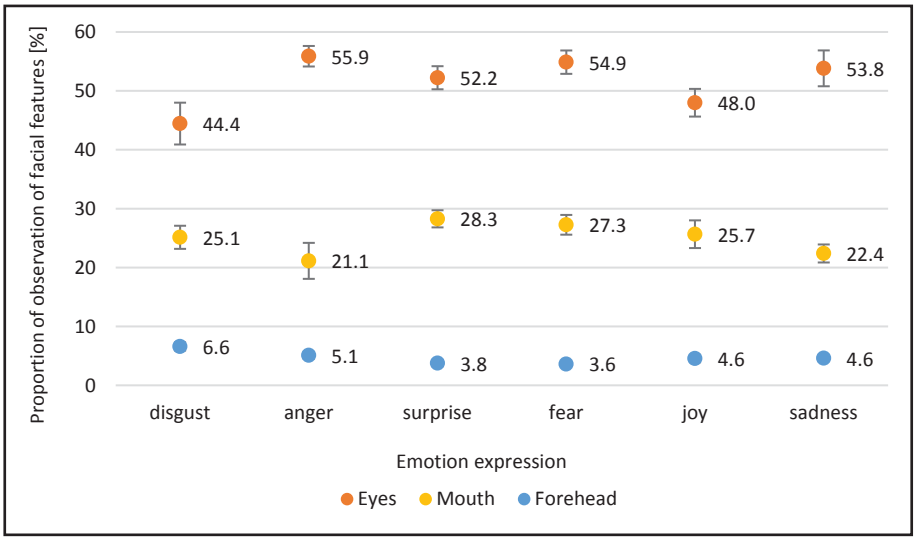


Figure 6: Proportion of observation time for eyes, mouth, and forehead for frontal facial images

The results of fixation duration of three facial feature for all six emotion expressions are shown in Figure 7. In general, the longest fixation durations are for the mouth and the shortest for the forehead.

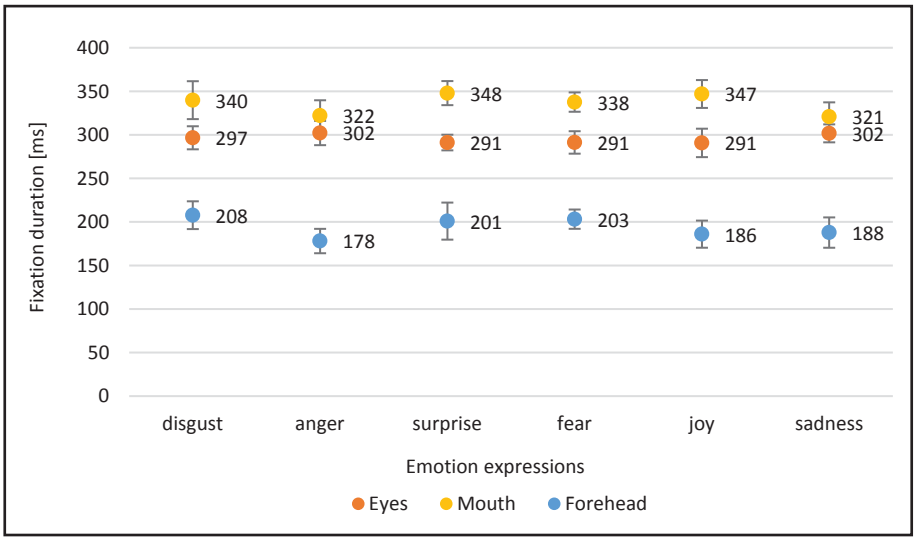


Figure 7: Fixation duration time for eyes, mouth, and forehead for frontal facial images

3.2 Profile facial images

Table 2 shows the results of emotion expression recognition in frontal facial images. All coloured fields are indicated as for frontal facial images.

Table 2: Results of recognition of emotion expression for profile facial images

		Presented emotion expression					
	Recognition [%]	disgust	anger	sadness	fear	surprise	joy
Participants' response	disgust	73,3	9,2	2,5	7,5	2,5	0,0
	anger	10,8	75,8	9,2	0,0	0,8	0,0
	sadness	1,7	5,8	71,7	0,0	0,0	0,0
	fear	11,7	6,7	8,3	59,2	16,7	0,0
	surprise	2,5	2,5	8,3	33,3	80,0	0,0
	joy	0,0	0,0	0,0	0,0	0,0	100,0

Same way as for the frontal facial images, the results of the proportion of observation of three facial features for all six emotion expressions are presented in Figure 8. Participants spent about half of the observation time observing the eyes, about a quarter of the time observing the mouth, and a small proportion of the total time observing the forehead (even less than for frontal facial images).

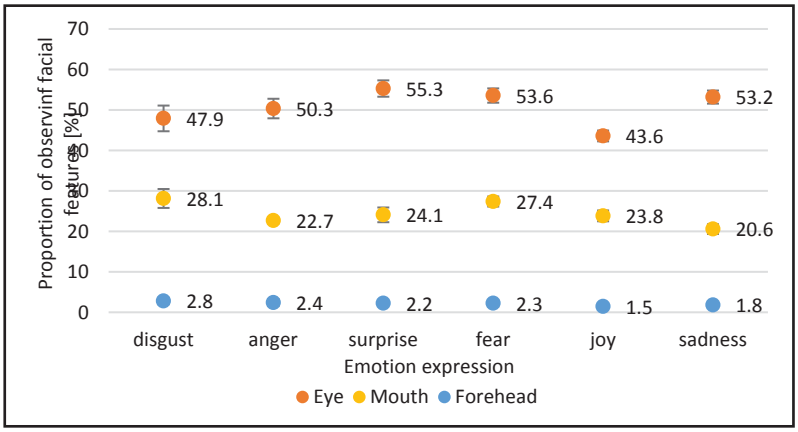


Figure 8: Proportion of observation time for eyes, mouth, and forehead for profile facial images

The results of fixation duration of three facial feature for all six emotion expressions are shown in Figure 9. In contrast to frontal facial images, fixation duration for profile face images is longest for the eyes and shortest for the forehead.

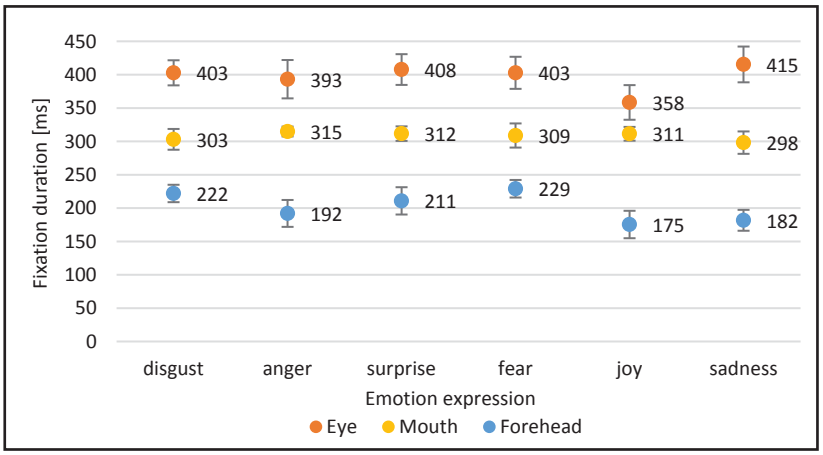


Figure 9: Fixation duration time for eyes, mouth, and forehead for profile facial images

4. DISCUSSION

The results in table 1 shows that participants made the most wrong recognitions of the facial emotion exoression of fear that it showed surprise (20.0%). The reverse case (when surprise was shown, they answered fear) was shown in a lower percentage of substitutions, although the percentage was still quite high (11.7%). When expressing fear, participants also answered that it was an emotion of disgust in a considerable percentage (10.8%). The reason for this, in our opinion, is the similar mouth expressions for these two emotions. There was also a relatively large number (15%) of wrong recognition between the representation of sadness and the participants' responses that fear was represented. We believe that the reason for this is that fear was not clearly expressed in some of the facial images in the selected face database. For example, the facial images of the emotion fear had some similarity with the facial images of the emotion sadness (drooping lips, eyebrows at the edges also downward). In terms of correct recognition, the emotion Fear had the lowest recognition rate (63.3%), followed by anger (75.0%) and sadness (77.5%). Well recognized were the emotions disgust (84.2%) and surprise (85%), and completely successful (100%) was the recognition of joy. Significant level of wrong recognition was for the combination of disgust/fear (7.5%), anger/disgust (6.7%), anger/fear (7.5%), and anger/surprise (8.3%). These results confirm some of the earlier research (Guo & Shaw, 2005; Green & Guo, 2018).
Our main question was whether these results could also be confirmed by the percentages of observation of facial parts shown in Figure 8. There we see that for the emotions fear and surprise there is a high percentage of observations of the mouth (fear 27.3%, surprise 28.3%). The reason for this is that in these two emotions, the mouth changes a lot compared to the neutral facial expression, thus attracting attention. Since their shape is also similar, these two emotions are often wrong recognized. These two emotions also have a high proportion of eye observation (fear 54.9%, surprise 52.2%), which means that they also attract participants' attention, and since the eye expression is similar (the eyes are wide open), they are also more often misrecognized. The emotion disgust also has a relatively large proportion of the observation of the mouth (25.1%). Again, it can be concluded that the similar shape and large proportion of observation of the mouth is the reason for the frequent confusion between the emotions fear and disgust. Wrong recognition between the emotions anger and disgust can be confirmed by the results of the observation of the forehead, as we can see that these two emotions attract the attention of the test participants much more than the other four emotions (disgust 6.6%, anger 5.1%). Basically, both emotion expressions have a similar shape for the area between the eyes that contracts and frowns.
In terms of fixation duration, the results are most likely to be interpreted as indicating that participants' gaze stayed longer on facial features that attract attention, and thus fixation duration is longer. This is even most evident in the area of the mouth, which changed significantly for the emotions fear, disgust, surprise and joy, and thus fixation duration was longer (from 338 ms to 348 ms). For the emotions anger and sadness, the mouth changes only slightly, i.e., it attracts little attention (sadness 22.4%, anger 21.1%), and accordingly the duration of fixations is shorter (sadness 321 ms, anger 322 ms). All six emotion expressions, where you can see similarities in the facial features are shown in Figure 10.

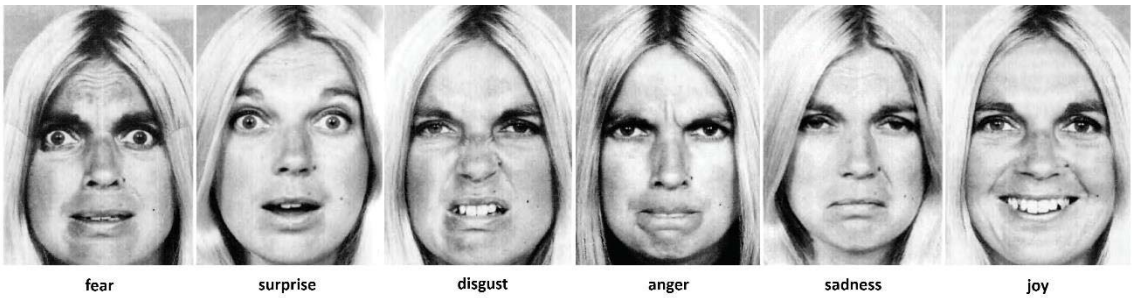


Figure 10: All six emotion expressions (Ekman & Friesen, 2003)

Similar findings can be made for profile facial images, as observation of facial features can be used to confirm incorrect recognition of certain emotion expressions. The most incorrect recognitions were between the emotions of fear and surprise (33.3% and 16.7%). These two emotions have the highest percentage of observations (fear 53.6%, surprise 55.3%), which means that they attract a lot of attention and are similar to each other (eyes wide open). A large percentage of wrong recognition is also between fear and disgust (11.7% and 7.5%). In Figure 8 we see that these two emotions stand out in terms of percentage of mouth observations (fear 27.4%, disgust 28.1%) and are also similar (open lips and

clenched teeth). In the case of wrong recognitions of anger and sadness (9.2% and 5.8%), we see a low proportion of mouth observations (anger 22.7%, sadness 20.6%), where we can also note the similarities in mouth shape (pursed lips). The main difference between these two emotions is the eyes, but since we see only one eye from the side in profile images, wrong recognition occurred much more frequent than in frontal facial images (3.3% and 2.5%), where we see both eyes, which are quite different for the emotion expression of sadness and anger. A large percentage of wrong recognitions between the emotions of anger and disgust (10.8% and 9.2%) can be partially explained by the highest values when observing the forehead (anger 2.4% and disgust 2.8%), which look similar (furrowed brow) but their values differ only slightly from those of the other emotions. As with the frontal facial images, the emotion of joy is perfectly correctly recognized (100%), as it is otherwise very different from the other five. On the other hand, it is difficult to explain wrong recognition of certain emotion expressions in terms of fixation duration results, because the results do not differ sufficiently to draw the same relevant conclusions.
In general, it can be said that the recognition of emotions is significantly better in frontal facial images than in profile facial images, mainly because the depicted faces contain more information in the frontal view than in the side view.

5. CONCLUSIONS

In our research, we focused on retrieving the expressions of six basic emotions for two types of facial images: frontal and profile. In the first part, we obtained the correctness of emotion recognition and, as a result, incorrect recognition or emotion interchanges, the results of which were presented in the confusion matrix. As expected, the emotion recognition results are better for frontal facial images, since only these, contain more information about the face itself compared to profile images. We aimed to confirm the results of incorrect recognition of emotions by analyzing the proportion of observation of facial features and by analyzing the fixation durations. The first proved to be very effective, as we were able to detect some of the most common misidentifications (e.g., fear/surprise, anger/disgust, disgust/fear, sadness/anger) by observing the same proportions of three facial features (either eyes, mouth, or forehead).The analysis of fixation durations was somewhat less effective, as here the results of fixation durations on specific facial features were very similar for all emotions, and only in the case of the misidentifications of anger and sadness was a correlation found between their misidentifications and fixation durations on the mouth.
However, a test of the heatmap-based surface method is currently underway, and we are trying to confirm the results incorrect recognition of emotions.

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