Research Article
UDC 159.9.072
https://doi.org/10.21702/rpj.2023.4.5

Oculomotor Activity During the Perception of Faces of People, Animals and Objects: the Role of the Emotional Coloring of Stimuli

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Abstract

Introduction. Faces are an important aspect of social interaction, containing a wealth of information that facilitates communication. Eye movement studies are relevant for uncovering cognitive mechanisms in various mental disorders. Purpose of the study – analysis of the parameters of oculomotor activity when perceiving social stimuli containing images of people's faces, and comparing them with the parameters of oculomotor activity when perceiving stimuli containing images of animals or inanimate objects. **Methods.** The study was carried out using the eye tracking method using the Neurobureau software and hardware complex. Total number of respondents – 60 people (age – 15–45 years). **Results.** Social scenes containing images of people's faces require more cognitive resources to perceive than images of animals or inanimate objects. This is typical for neutral and positive stimuli, as well as threatening stimuli. However, dysphoric stimuli containing human faces are more often avoided by subjects in a choice situation than dysphoric images of animals or objects. Attention in social scenes is distributed unevenly and focuses on faces. **Discussion.** Respondents in the 18–30 age group tend to have more experience in analyzing emotions, which may explain more fixations on social stimuli. Avoidance of dysphoric stimuli may be associated with protective mechanisms of the psyche. The results can be interpreted in two ways: 1) social stimuli are evolutionarily more significant for people, so they are analyzed more carefully and for a long time, and 2) the emotional coloring of social situations is not so clear and requires analysis of the characters' facial expressions.

Keywords

eye tracking, eye movements, fixations, saccades, visual perception, social scenes, dysphoric stimuli, threatening stimuli, positive stimuli

Funding

The work was carried out with the support of State Program 47 of the State Enterprise "Scientific and Technological Development of the Russian Federation" (2019–2030), topic 63.3. 0134-2019-0006.

For citation

Skuratova, K. A., Naumova, D. A. (2023). Oculomotor Activity During the Perception of Faces of People, Animals and Objects: the Role of the Emotional Coloring of Stimuli. *Russian Psychological Journal, 20*(4), 84–100. https://doi.org/10.21702/rpj.2023.4.5

Introduction

Scanning the visual environment that surrounds us every day, we are faced with an excessive array of its constituent elements. But a detailed analysis of each component element is impossible, since the capabilities of the human visual system are limited. To cope with limitations, the human brain is forced to evaluate the priority of incoming visual signals and allocate the greatest amount of cognitive resources to processing significant elements and events. But which elements and events are considered significant?

It is assumed that the main way of prioritization is by assessing the emotional significance of a stimulus or event (Compton, 2003). Stimuli that are assessed as emotionally significant are subject to enhanced processing. Although the emotional significance of stimuli may vary from person to person, there are some stimuli that are emotionally meaningful to most of us – human faces, for example. The significance stems from the fact that humans are an inherently social species whose brains have specialized areas that are sensitive to a variety of visual social cues, particularly faces (Landsiedel, Daughters, Downing, & Koldewyn, 2022).

The orbitofrontal cortex and ventral striatum respond to socially reinforcing stimuli such as beautiful or smiling faces, while lesions of the orbitofrontal cortex impair interpersonal behavior in neuroimaging studies (Hornak et al., 2003). Research also shows that both the ventral and dorsal striatum respond to more complex social information, such as cooperation or the opportunity to punish a traitor (Sanfey, 2007). In addition, the amygdala plays an important role in calculating and updating the value of social information. It has also been shown that perceiving faces expressing emotions causes increased activity in the amygdala because emotions are biologically significant

stimuli that enable us to anticipate critical events in our environment (Davis, Johnstone, Mazzulla, Oler, & Whalen, 2010). Thus, the study of the distribution of visual attention depending on emotional and social significance contributes to the understanding of the mechanisms by which the psyche analyzes objects in the environment and prioritizes stimuli.

Neuroimaging has found that images of faces preferentially activate visual cortical areas corresponding to the central visual field, whereas other images, such as buildings, produce stronger activation in areas responsible for peripheral vision (Wang et al., 2013). It is important to note that face recognition and discrimination are impaired when peripheral vision is used (Mäkelä, Nasanen, Rovamo, & Melmoth, 2001). This is because face perception is a challenging cognitive task because its constituent structures are small in size as well as have a low signal-to-noise ratio (Behrmann & Avidan, 2022).

Faces are very effective at attracting attention if they express a particular emotion. For example, researchers have found that fearful and angry expressions are recognized faster than neutral and happy expressions (Lanfranco, Rabagliati, & Carmel, 2023). In the emotional Stroop test, speed of naming facial color is slower when the facial expression is angry rather than neutral, suggesting that processing angry faces requires more cognitive resources (van Honk, Tuiten, De Haan, van den Hout, & Stam, 2001).

Features of facial perception change in some mental and neurological disorders. For example, people with depressive disorder pay more attention to sad faces (Holas, Krejtz, Wisiecka, Rusanowska, & Nezlek, 2020; Holas, Krejtz, Rusanowska, Rohnka, & Nezlek, 2019; Ding et al., 2019). Anxiety increases attention to fearful and angry faces (Weeks, Howell, Srivastav, & Goldin, 2019; Wermes, Lincoln, & Helbig-Lang, 2018) and decreases attention to happy faces (Kraines, White, Grant, & Wells, 2019). Autism spectrum disorders in general affect visual processing of faces, causing avoidance of eye contact (Billeci et al., 2019; Wan et al., 2019). Studying the perception of people's faces, including those expressing a particular emotion, can shed light on the cognitive mechanisms of perception of social information in various psychopathological conditions (Lanfranco et al., 2023).

Social interaction plays a central role in human life. People observe and participate in numerous social scenes every day. Visual processing of human faces underlies the detection, recognition and identification of conspecifics, and is also an important aspect of social interaction. Faces contain a wealth of information (e.g., emotional and physical states, intentions) that facilitate communication. The ability to process such information represents a highly developed skill in visual perception (Haxby, Hoffman, & Gobbini, 2000; Geringswald, Afyouni, Noblet, & Grosbras, 2020).

The purpose of this study is to compare the parameters of oculomotor activity during the perception of social stimuli containing human faces and stimuli containing images of animals or inanimate objects in a choice situation.

Further research in this area can be scaled up with larger samples of participants in different age groups and a variety of stimuli. This approach may lead to more reliable results.

Careful study of different groups of people will provide a better understanding of how age, experience, and personality influence oculomotor activity during the perception of social scenes. In addition, research may shed light on the relationship between oculomotor activity in social scenes and various mental disorders such as autism, anxiety disorders or schizophrenia spectrum disorders. This approach could contribute to the development of new methods for diagnosing these disorders, which will help improve the quality of life of patients, as well as tailor therapeutic approaches to their individual characteristics.

In practical terms, the results of the study have significance in the fields of psychology, psychiatry and social work. They can help us better understand which aspects of social stimuli attract our attention and how they relate to emotional responses and cognitive processes. This knowledge can be valuable for developing training programs and techniques, training social skills and providing support to people suffering from mental disorders.

Methods

The study was carried out using an eye tracking method using ***Neurobureau hardware and software complex*** (Skuratova, Shelepin, Shelepin, 2022).

Stimulus material consisted of 25 stimuli, of which 20 were experimental and 5 control. The experimental stimuli contained 4 images of different emotional colors (positive, dysphoric, threatening, neutral), and the control stimuli contained 4 neutral images. One part of the stimuli contained social scenes with images of people's faces, the other part contained scenes with animals or inanimate objects. All images used were CC0 licensed, and their selection and emotional categorization was carried out using expert assessment.

Between stimuli, a fixation cross was presented for 3000 ms to fix the gaze position at the center of the screen. Stimuli were presented in random order.

The subjects' task I had to carefully look through the images and choose the most attractive ones. The time for stimulus presentation was not limited.

Participated in the study ***60 people*** from 15 to 45 years. The subjects were divided into three age groups: 15–17, 18–30 and 30–45 years. The sample was normed by gender. All subjects had normal and corrected-to-normal vision, and were free of mental and neurological diseases.

For statistical processing of quantitative data, Student's t-test for dependent samples was used.

There were also two stages of interpretation of the results. At the first stage, the influence of the social content of the stimulus on the choice of the subjects was analyzed. At the second stage, a preliminary assessment of age-related characteristics in preference for stimuli was carried out.

Results

Analysis of the influence of the social content of a stimulus on human oculomotor behavior depending on the emotional coloring of the stimulus

The subjects paid attention faster to neutral images if they contained human faces than to images of animals or objects, looked at them longer, making more fixations and saccades, and also returned to them more often. Saccades of shorter amplitude are typical for the perception of images of people's faces, since their content requires more detailed analysis. Also, shorter amplitude saccades may be associated with difficulties in the holistic perception of social scenes, since the peripheral processing of faces is more complex than the peripheral processing of other images (Table 1).

Table 1
Parameters of oculomotor activity when viewing neutral images

Parameter of oculomotor activity	Average value		t test	p
	images of people's faces	images of animals or objects		
Number of fixations before first fixation	4,046	4,968	3,17	0,002
Time to first fixation (seconds)	1,278	1,594	3,35	0,001
Total viewing time (seconds)	1,798	1,362	-3,30	0,001
Total number of returns	1,695	1,371	-3,00	0,003
Average duration of fixations (seconds)	0,317	0,305	-1,10	0,272
Total number of fixations	6,150	5,100	-2,77	0,006

Parameter of oculomotor activity	Average value		t test	p
	images of people's faces	images of animals or objects		
Average amplitude of saccades (angular degrees)	2,945	3,445	4,34	0,000
Total number of saccades	3,572	2,922	-2,13	0,034
Total scan path length (angular degrees)	10,441	9,707	-0,80	0,426

Positively colored images of animals or objects attract attention faster than positive images of people. At the same time, positive social situations are analyzed over a longer period of time and in more detail (Table 2).

Table 2
Parameters of oculomotor activity when viewing positive images

Parameter of oculomotor activity	Average value		t test	p
	images of people's faces	images of animals or objects		
Number of fixations before first fixation	4,496	3,535	-3,91	0,000
Time to first fixation (seconds)	1,420	1,061	-4,70	0,000
Total viewing time (seconds)	1,692	1,428	-2,21	0,027
Total number of returns	1,696	1,743	0,37	0,709

Parameter of oculomotor activity	Average value		t test	p
	images of people's faces	images of animals or objects		
Average duration of fixations (seconds)	0,317	0,331	1,19	0,235
Total number of fixations	5,861	4,883	-2,75	0,006
Average amplitude of saccades (angular degrees)	2,839	2,989	1,36	0,173
Total number of saccades	3,301	2,294	-3,82	0,000
Total scan path length (angular degrees)	9,111	6,210	-4,01	0,000

Dysphoric social scenes, on the contrary, are more often avoided by subjects than dysphoric images of animals or objects (Table 3).

Table 3
Parameters of oculomotor activity when viewing dysphoric images

Parameter of oculomotor activity	Average value		t test	p
	images of people's faces	images of animals or objects		
Number of fixations before first fixation	4,809	4,651	-0,54	0,588
Time to first fixation (seconds)	1,504	1,396	-1,18	0,239
Total viewing time (seconds)	1,179	1,403	2,04	0,042

Parameter of oculomotor activity	Average value		t test	p
	images of people's faces	images of animals or objects		
Total number of returns	1,073	1,197	1,23	0,221
Average duration of fixations (seconds)	0,325	0,332	0,69	0,491
Total number of fixations	4,084	4,833	2,08	0,038
Average amplitude of saccades (angular degrees)	2,896	2,586	-2,43	0,015
Total number of saccades	2,177	2,791	2,11	0,035
Total scan path length (angular degrees)	6,168	7,265	1,32	0,187

When viewing threatening images containing human faces, subjects made longer fixations than when viewing images containing objects or animals (Table 4). We can hypothesize that analyzing a threatening social situation containing an image of a person is more complex and requires more cognitive resources.

An attentional bias toward threatening faces may evolutionarily provide a critical survival advantage (Öhman, 2002).

Table 4

Parameters of oculomotor activity when viewing threatening images

Parameter of oculomotor activity	Average value		t test	p
	images of people's faces	images of animals or objects		
Number of fixations before first fixation	4,101	3,735	1,38	0,167
Time to first fixation (seconds)	1,276	1,210	0,72	0,471
Total viewing time (seconds)	1,293	1,269	0,21	0,837
Total number of returns	1,099	1,102	-0,03	0,980
Average duration of fixations (seconds)	0,322	0,292	2,56	0,011
Total number of fixations	4,601	4,773	-0,46	0,645
Average amplitude of saccades (angular degrees)	2,869	2,926	-0,52	0,605
Total number of saccades	2,644	2,815	-0,58	0,563
Total scan path length (angular degrees)	7,313	8,321	-1,22	0,224

Preliminary analysis of age-related characteristics of perception of stimuli depending on their social content and emotional coloring

On stimuli containing social scenes, adolescents aged 15–17 years are quickest to notice threatening images, and on stimuli containing only objects or animals - positive images. Neutral images are the last thing to attract teenagers' attention.

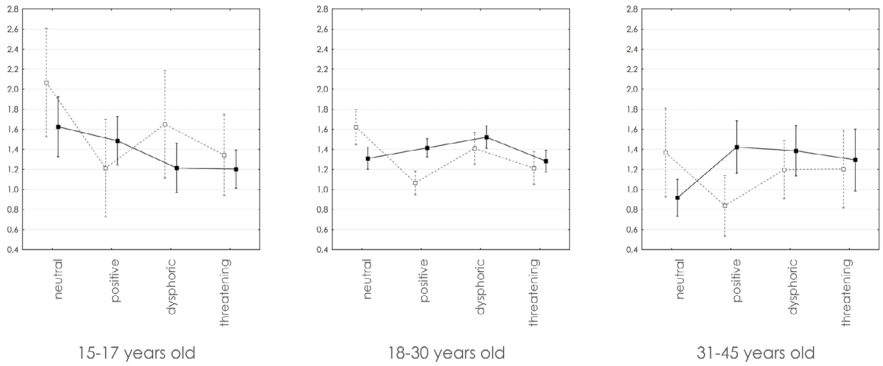
Subjects aged 18 to 30 are quickest to pay attention to positive images of objects or animals.

Subjects over 30 are quickest to notice neutral social scenes and positive images of animals and objects.

The results are presented in more detail in the graphs in Figure 1.

Figure 1

The time until the first fixation on a stimulus depending on its social content and emotional coloring by subjects of different age groups.



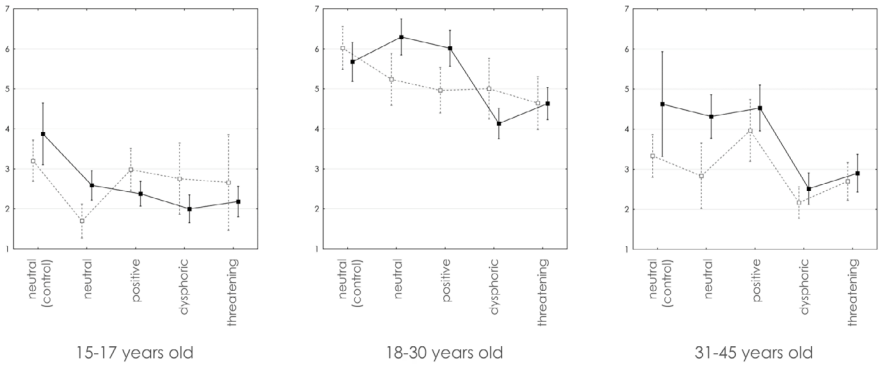
Note. The gray color on the graph indicates stimuli containing objects or animals, the black color indicates social scenes.

Among all age groups, teenagers 15–17 years old make the fewest fixations, which makes their choice more impulsive. At the same time, they make the most fixations on control stimuli, since the same neutral emotional coloring makes it difficult to choose the image they like. Among emotionally charged images, more fixations are made on images with animals and objects than on social scenes.

People from 18 to 30 years old require the most fixations to select the image they like, which may be due to the higher level of anxiety in this age group, identified on the basis of clinical scales (Spielberger-Hanin Anxiety Scale). The graph shows that respondents try to avoid dysphoric and threatening social scenes, giving greater visual preference to neutral and positive images of people. It can be assumed that protective mechanisms of the psyche, in particular avoidance, play a role here. The results are presented in more detail in the graphs in Figure 2.

Figure 2

The number of fixations on a stimulus depending on its social content and emotional coloring by subjects of different age groups.

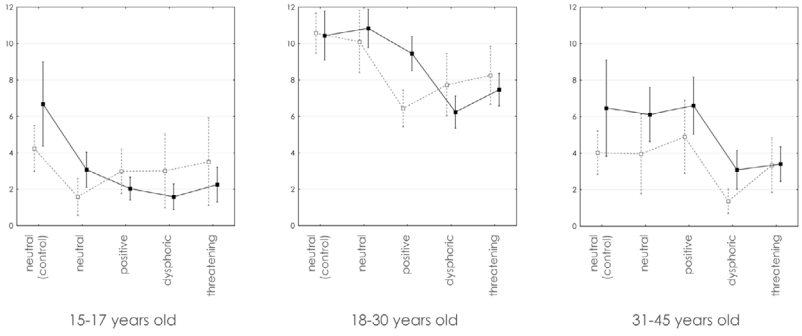


The longest scanning path length is typical for subjects aged 18 to 30 years. This suggests that they analyze the proposed images in the most holistic way.

Despite the fact that the sample of subjects from 18 to 30 years old is the largest, the data turned out to be more consistent with the smallest variations. Perhaps further analysis of the psycho-emotional state of the subjects in this group will help to understand why their perception patterns are so similar. Additionally, study participants completed the following clinical questionnaires: Spielberger-Hanin Anxiety Scale; Beck Depression Inventory; Beck Hopelessness Scale. A preliminary analysis of the results of clinical scales showed that subjects in this group had high rates of anxiety, hopelessness, and more pronounced depressive symptoms. Among subjects over 30 years of age, there are more people with indicators within the normal range. The results for the scanning path length are presented in more detail in the graphs in Figure 3.

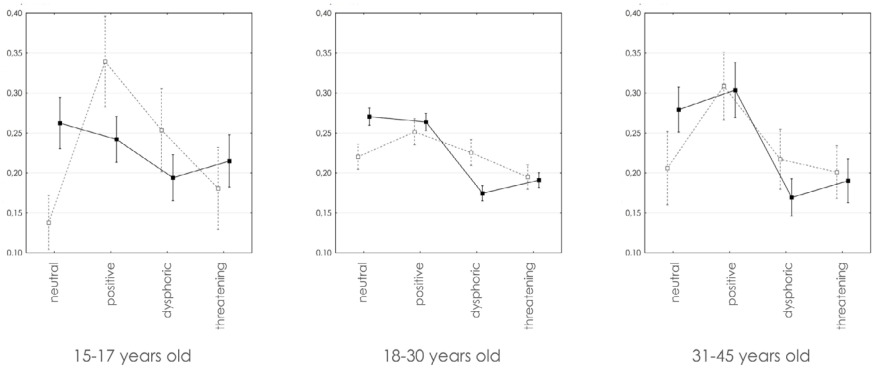
Figure 3

The length of the scanning path on a stimulus depending on its social content and emotional coloring by subjects of different age groups.



Attention index is calculated as the ratio of the time spent viewing an emotionally charged image to the total time spent viewing the stimulus. The results of calculating the attention index are presented in the graphs in Figure 4.

Figure 4
Index of attention to a stimulus depending on its social content and emotional coloring by subjects of different age groups.



Among social scenes, adolescents aged 15–17 years prefer neutral images and avoid dysphoric ones. Among images of animals and objects, positive ones are preferred and neutral ones are avoided.

Among social scenes, people from 18 to 30 years old prefer neutral and positive images, and avoid dysphoric and threatening ones. Among images of animals and objects, positive ones are preferred, and threatening ones are avoided.

Among social scenes, people over 30 prefer positive images and avoid dysphoric and threatening ones. Among images of animals and objects, they prefer positive ones, and pay much less attention to all others.

Discussion

As expected, social scenes containing images of human faces require more cognitive resources during perception than images of animals or inanimate objects. But this is typical only for neutral and positively colored, and also, partially, for threatening stimuli. Dysphoric stimuli containing human faces, on the contrary, are more often avoided by subjects in a choice situation than dysphoric images of animals or objects.

Qualitative analysis of heat maps confirmed our hypothesis that attention in social scenes is unevenly distributed and focused on faces.

The results obtained can be interpreted in two ways.

First, social stimuli are evolutionarily more significant for people, so they are analyzed more carefully and for a long time. This raises the question of why social dysphoric

situations, on the contrary, are more often avoided.

Secondly, the emotional coloring of social situations (except for dysphoric ones) is not so unambiguous and requires analysis, including the facial expressions of the characters, so they have to be considered longer and returned to more often.

Teenagers (15–17 years old) make the fewest fixations when analyzing emotionally charged images, while young people aged 18 to 30 make the most fixations. Adolescents are also less likely to return to re-analysis of images and make more fixations on images with animals and objects. People over 30 make more fixations on social stimuli. This may be due to differences in cognitive processes, empathy development, and different experiences among different age groups. The active formation of one's personality in adolescents can affect the ability to analyze emotionally charged images (Feldstein, 2008). Adolescents may also have difficulty recognizing and understanding complex emotions (Dubrovina, 1999; Lyusin, 2006), which may make it difficult to analyze such images. Adults in the 18 to 30 age group typically have more experience analyzing both their own emotions and the emotions of those around them, which may explain more fixations on social stimuli. Fixation on images of animals and objects may indicate lower levels of empathy in adolescents compared to adults, who may be more successful in identifying and recognizing emotions in people (Savazzi et al., 2022; Luna, Velanova, & Geier, 2008).

The most holistic analysis of the proposed images is typical for people from 18 to 30 years old. They avoid dysphoric and threatening social scenes and tend to return to positive images. It is assumed that this may be associated with protective mechanisms of the psyche, in particular, avoidance - refusal of activity that causes discomfort (Kirshbaum, Eremeeva, 2000; Romanova, Grebennikov, 1996).

Conclusion

This study breaks new ground in understanding how different objects in emotionally charged scenes affect people's oculomotor activity and reactions. The significance of this work is evident in its ability to expand our knowledge of the mechanisms of perception and processing of emotional stimuli. The results of the study have important implications for psychological research and can make significant contributions to the development of theories that explain emotional processes in people.

The stimulus material developed in this study is planned to be used to analyze oculomotor patterns during the perception of emotionally charged scenes by people with various mental disorders (for example, depressive disorder, anxiety disorder). This will not only allow us to examine in more detail the cognitive mechanisms characteristic of various mental disorders, but also to develop objective methods for their diagnosis.

At the moment, we have already discovered a relationship between hopelessness and oculomotor patterns when perceiving emotionally charged social scenes (Skuratova, Naumova, 2022).

Limitations of the Study

However, some limitations of this work must be taken into account. First, the sample size is limited to only 60 participants. Larger and more diverse samples would help obtain more valid results regarding differences in oculomotor activity between groups. Second, the stimuli used may not fully reflect real-life scenarios, which may limit the generalizability of the results to real-life situations. In addition, the limited variability of emotions presented in scenes may affect the completeness of perceptual representation and oculomotor activity.

Despite these limitations, this work has immediate implications for the field of psychology. It could serve as a starting point for further research that will deepen our knowledge of emotion perception and the connection to eye movements.

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Received: May 05, 2023
Revision received: July 07, 2023
Accepted: October 13, 2023

Authors' contribution

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Conflict of Interest Information

The authors have no conflicts of interest to declare.