COGNITIVE PSYCHOLOGY

Research Article
UDC 159.9
https://doi.org/10.21702/rpj.2023.2.7

The Process of Comparing Images of Emotional Expressions

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Abstract

Introduction. We conducted an experiment in the paradigm of direct comparison of images of strong and weakly expressed emotional expressions with a detailed justification of the assessment made and registration of eye movements. **Methods**. Photo images from the VEPEL database (video images of natural transient facial expressions: joy, sadness, fear, surprise, anger, disgust, calm face) were used as stimulus material. The subjects were students of Moscow universities (72 people, of which 10 men, 62 women; age from 18 to 39 years, average age = 22.0, standard deviation = 4.0. Exposure time is unlimited, until the justification is completed. Research objective: image comparison (rank scale of similarity between images from 1 to 9) with registration of eye movements. **Results**. Based on individual assessments of similarity between images of emotional expressions, the reconstruction of the two-dimensional space was performed using the multidimensional scaling method. The reconstruction is described by Core Affect model by J. Russell. The presence of individual variability of similarity scores (the tendency to select a certain range of scores) is shown. The following individual indicators were singled out for further search of possible predictors: the average similarity score between images, the standard deviation of the similarity score between images, and the average individual duration of fixations. The presence of variability of estimates for different pairs of compared images is shown. The minimum variability of similarity estimates is achieved for the next pairs: fear–fear weak, joy – joy weak; anger – anger weak; disgust weak – anger; neutral – sadness weak. The maximum variability of similarity estimates is achieved for pairs of joy weak – fear weak; joy – fear weak; sadness – joy weak; joy weak – anger weak; neutral – joy weak. The analysis of the duration of visual fixations during the similarity assessment was carried out. It is shown that different similarity scores correspond to different distribution patterns of fixation durations in the evaluation process. **Discussion**. Based on our results, we can conclude that there are several convergent evaluation justification processes based on an initial similarity score between images.

Keywords

emotional expressions, emotions, comparison, Core Affect, valency, scoring process, eye movements, fixation, decision time, multivariate scaling

Funding

The work was supported by the Russian Science Foundation grant 20-68-47048 "Psychological and biological mechanisms and determinants of the perception of emotionally colored scenes and emotional facial expressions".

For citation

Zhegallo, A. V., Basyul, I. A. (2023). The process of comparing images of emotional expressions. Russian psychological journal, 20(2), 106–121. https://doi.org/10.21702/rpj.2023.2.7

Introduction

For decades, research on emotions and their perception has been actively carried out within the framework of the neurocultural theory of P. Ekman (Ekman, 1971; Ekman 1999; Ekman & Corado, 2011; Ekman, 2017). The attractiveness of neurocultural theory is due to the fact that the idea of emotional expressions as universal communication signals facing outward, carrying information about the internal state of a person, opens up wide opportunities for practical application. For a detailed background and criticism of the theory, see (Crivelli & Fridlund, 2019).

The popular experimental paradigm, based on neurocultural theory, involves the performance of two tasks: the task of identification and the task of discrimination (Etcoff & Magee, 1992) on the material of transition series between images of “basic” emotional expressions according to P. Ekman. When performing a discriminatory task, the subject is sequentially presented with two similar but different images A and B, which are successive phases of the transition from one emotional expression to another, and then the target image X. It is required to indicate which of the images A or B matches X. Accordingly, this variant is called **ABX discrimination task**. In the task **of identification**, it is required to indicate what kind of emotional expression is present in the image, which is a transitional form between the "basic" emotional expressions.

This experimental paradigm assumes that the distinction between transitional forms between "basic" emotional expressions is carried out solely due to their different identification as corresponding to different "basic" emotional expressions. Thus, the result of solving the identification problem will be an S-shaped curve with a well-defined boundary between the categories, and in the discrimination task there will be a maximum accuracy of the solution corresponding to the boundary between the categories.

The theoretical model and experimental procedure were developed in analogy with previous studies of categorical perception in acoustic modality (Liberman, Harris, Hoffman & Griffith, 1957). By the end of the 1980s, the concept of categorical perception as the basis for distinguishing acoustic stimuli became widespread (Harnad, 1987).

Numerous studies in this paradigm - for a review, see (Barabanschikov, Zhegallo, Korolkova, 2016) have shown that the experimental results obtained are not consistent with Ekman's neurocultural theory of emotions. Individual results can vary greatly, and the distinction between images is not always associated with their different categorical assignment.

The newly developed experimental paradigm is based on the component theory of emotions by K. Scherer (Scherer, 2001; Scherer, 2019). Considering the generation and perception of emotions as a process divided into separate components, we come to the need to choose an experimental paradigm that contains a single monolithic task that allows obtaining the maximum amount of various kinds of information, which facilitates further interpretation of the results. At the same time, the component theory, in principle, allows for a certain "flexibility" of individual components associated with the individual characteristics of the observer.

In our study, we propose to use the task of **comparing images of emotional expressions**. The subject needs to indicate the value of the similarity between the images on the Likert scale and justify his assessment in free form. Thus, the researcher simultaneously receives information both about the similarity between images and about the reasons for such similarity. It should be noted that, according to the predictions of P. Ekman's theory of "basic" emotions, there should be significant differences between images of strongly expressed "basic" emotions and slight differences between images of strongly and weakly expressed "basic" emotions of the same modality. Thus, the result of multidimensional scaling would be a space of dimensions equal to the number of "basic" emotions. At the same time, explanations of similarities and differences will be given in terms of expressed emotions. On the other hand, according to the predictions of "multidimensional" theories of emotions (Russell, Barrett, 1999; Russell, 2017), the reconstructed space should have a low dimension, and similarity scores should be explained in terms of "dimensions".

The proposed experimental paradigm is based on the tradition of comparison studies in the structure of cognitive processes (Samoilenko, 2010; Nosulenko, Samoilenko, 2019). According to the available data (Basyul, Samoilenko, 2019), the comparison results depend on the "comparison context", that is, the entire set of objects compared with each other, and the context is set explicitly through the presentation of strongly pronounced "basic" emotional expressions on the periphery of the image frame.

It should be noted similar studies with a relatively shorter exposure time without substantiating the similarity score with the further use of the multidimensional scaling method to reconstruct the similarity space between images. These studies included the study of perceived differences between schematic representations of a human face (Izmailov, Korshunova, Shekhter, Potapova, 2009); study of perceived differences between composite images of emotional expressions (Bondarenko, Menshikova, 2020).

The ongoing work is a continuation of the study (Zhegallo, 2021) and is aimed at studying the individual characteristics of similarity scores and eye movements when performing a comparison task.

Methods

Photographic images of “basic” emotional expressions (joy, sadness, fear, surprise, anger, disgust, calm face) from the VEPEL database were used as stimulus material in the study (Kurakova, 2012). We used images with a maximum (100%) degree of expression and with a 40% degree of expression of emotions, selected from the corresponding transition series (Kurakova, 2012; Barabanshchikov, Zhegallo, Korolkova, 2016). Image sizes - 227 x 315 pixels.

To present the stimulus material, an ACER KG251Q monitor with a resolution of 1280x1024 was used (the working area occupied the central part of the screen). A pair of images was located vertically in the center of the screen, and the distance between image centers was 240 points horizontally. On the periphery of the screen were six images of strongly pronounced "basic" emotional expressions that set a constant context for comparison. The images were displayed on a neutral gray background: RGB (102, 102, 102). The angular dimensions of the compared images at a distance of 60 cm from the screen were 9.1° x 6.6°.

The experiment was carried out individually. Presentation of stimulus material, fixation of ratings, and audio recording of the responses of the subjects regarding the justification of their ratings were performed using a modified version of the PxLab software (Zhegallo, 2016). The volume of the experiment when comparing 13 emotional expressions with each other, with the exception of comparison with oneself and without taking into account the location, is (13 * 12) / 2 = 78 experimental situations (ES) per subject.

The study involved students of Moscow universities in the framework of training courses in specialized disciplines, 72 people (10 men, 62 women). Age – 18 to 39 years old, mean age = 22.0, standard deviation = 4.0. Images of emotional expressions remained on the screen all the time while the subjects assessed the degree of similarity of the images. The exposure time of the images and, accordingly, the duration of the description offered by the subjects were not limited, the subjects could provide as complete a justification for the differences between the images as they considered necessary. The median duration of description of one image was 1 2.9 seconds, IQR (interquartile range) = 7.7–22.4 seconds.

The maximum time for describing one image was about 4 minutes. The total time for completing the task by the subjects ranged from 7 to 65 minutes, median – 21 minutes, IQR – 14–27 minutes.

During the experiment, two experimental setups were involved. One with eye tracker Eyegaze Analyzing System (sampling rate 120 Hz), another with an eye tracker GazePoint (sampling rate 150 Hz). The eyetrackers were paired with the PxLab software using author's proxy programs that received UDP control packets from PxLab (the beginning and end of the experiment, marks on the progress of the experiment) and transferred control to standard control programs in the required format. Thus, the uniformity of the experimental procedure was achieved on different types of eye trackers.

Further processing of the eye-tracking data was performed using the ETRAN package in the statistical processing environment R (R Core Team, 2020). Fixation detection was performed using the I – DT algorithm (Dispersion Threshold Identification), threshold dispersion – 60 pixels, minimum duration of fixations – 12 samples for the eye tracker EyeGaze, 15 eyetracker samples Gaze Point, which in both cases gives a minimum commit duration of 100 milliseconds. In view of the high noise level of the initial data on the eye tracker GazePoint before detection, additional kernel smoothing was performed (ksmooth function, KernSmooth library, bandwidth = 120).

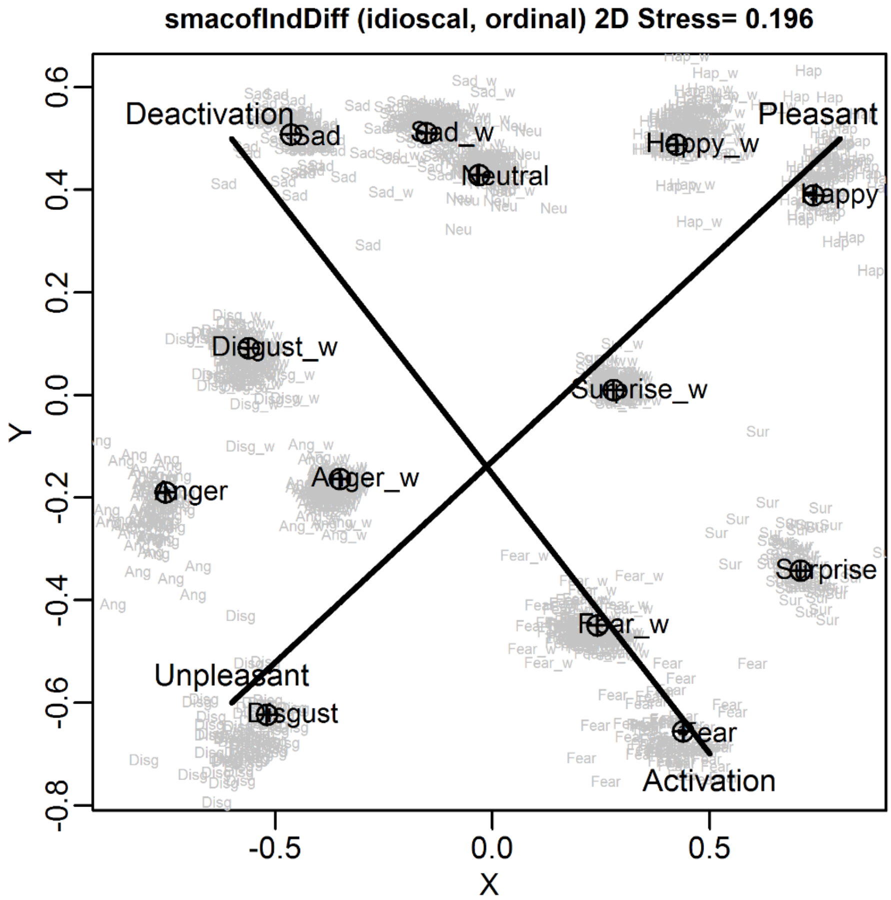
Results

Space reconstruction

The reconstruction of the semantic space according to individual data of comparison of emotional expressions was carried out in the R statistical processing environment, the smacof library (De Leeuw & Mair, 2009), smacofIndDiff function, IDIOSCAL model (Individual Differences in Orientation SCALing). The model assumes that the weight of judgments may differ for different observers, and individual variations in the orientation of the similarity matrices are also possible. The additional argument type = ordinal indicates that the comparison data is presented in an order scale.

The quality of the reconstruction is assessed using the stress -1 value. For dimensions from 1 to 6, the stress -1 value takes on the values 0.321; 0.196; 0.14; 0.108; 0.086; 0.068 respectively. For the reconstruction of dimension 2, the "pleasant-unpleasant" and "activation-deactivation" axes described by the J. Russell's Core Affect model can be distinguished (Russell & Barrett, 1999). It should be noted that in our earlier study, with the qualitatively same image similarity structure, the value of stress -1 was 0.116. The deterioration in the quality of the new reconstruction may be due to increased individual variability in participant scores in the new study. The results are shown in Figure 1.

Figure 1
Reconstruction of space, based on individual results of pairwise comparison of images of emotional expressions.



***Note**. Black color shows the position of the compared images in the reconstructed space for the sample as a whole. Individual results of individual participants are plotted in gray, which allows you to visually assess the individual variability of estimates. The interpretation of the selected axes "fear" - "sadness" (activation-deactivation) and "joy" - "disgust" (pleasant-unpleasant) is given in accordance with the Core Affect model by J. Russell.*

Variation in Similarity Scores Between Pairs of Images

To assess the degree of variability of similarity scores between different pairs of images, their standard deviations were calculated. The median standard deviation is 2.09; IQR = 1.93–2.55. The maximum standard deviation is 2.53, the minimum is 1.30.

Ten pairs of images with **the minimum** variability of assessments (ordered in ascending order sd): fear - fear weak (hereinafter, "fear" means an image of emotional expression with maximum severity; "fear weak" means an image of a weakly expressed emotional expression - 40% severity); joy - joy weak; anger - anger weak; Disgust weak - anger; neutral - sadness weak; surprise weak - disgust; disgust weak – anger weak; joy - anger; joy weak - anger; joy - disgust

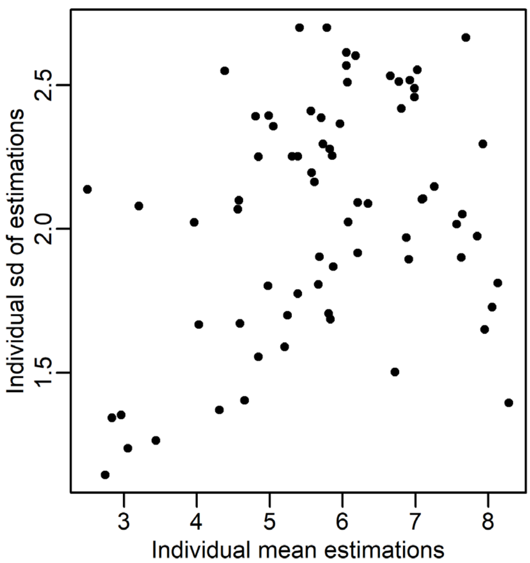
Ten pairs of images with **the maximum** variability of ratings (sorted in ascending order sd): sadness – anger weak; anger weak – fear weak; sadness weak – joy weak; joy – fear; joy weak – fear weak; joy – fear weak; sadness – joy weak; joy weak – anger weak; neutral – joy weak.

The analysis of sources of high variability of similarity estimates requires the use of verbal characteristics of compared images and will be performed in the course of further data processing.

Variation in Individual Similarity Scores

The individual features of the assessment are characterized by the average value of the similarity score and the standard deviation. The average similarity score for individual study participants ranges from 2.5 to 8.28. Me = 5.81; IQR = (4.94, 6.88). The standard deviations of the similarity score range from 1.14 to 2.70. Me = 2.09; IQR = (1.76, 2.39). The magnitude of the similarity score positively correlates with the standard deviation: r = 0.33, p = 0.005. At the same time, visualization shows the presence of a U -shaped trend (Figure 2), low values of the standard deviation correspond to high or low average individual similarity scores. The maximum variability of similarity scores is achieved with average values of scores from 5 to 7.

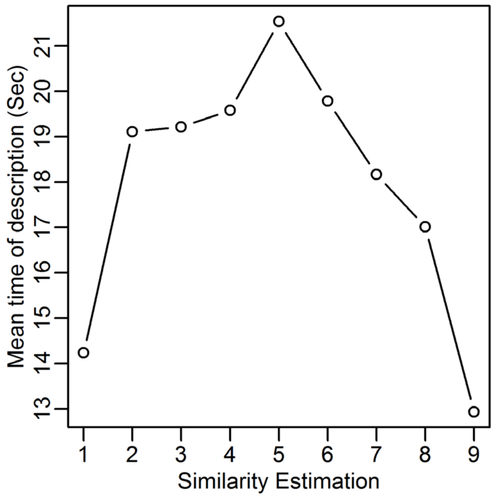
Figure 2
Ratio of means and standard deviations of individual similarity scores



Dependence of the problem solving time on the estimation option

The duration of the task solution depends statistically significantly on the assessment option given by the participant; Kruskal -Wallace criteria $\chi^2 = 296.7$ (8), $p < 10^{-6.}$ The maximum description time is reached for a score of "5", which may be due to the fact that in order to justify it, it is necessary to equally provide evidence of both similarities and differences between images (Figure 3).

Figure 3
The ratio of the similarity scores given by the participants and the average length of the description



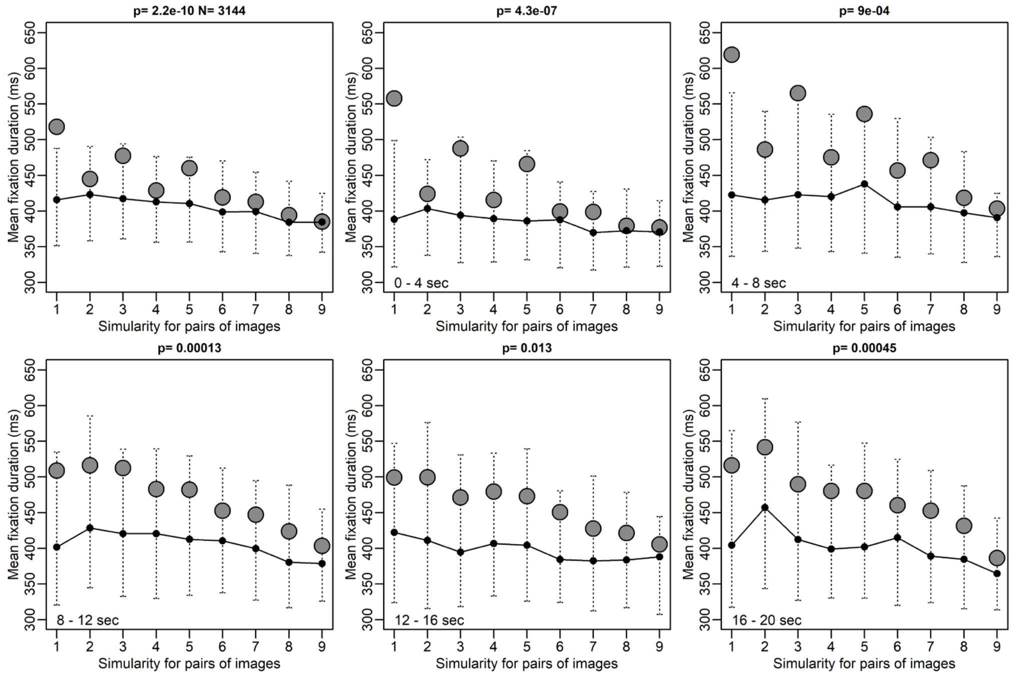
Eye Movement Parameters When Performing Similarity Assessments

For each experimental situation (ES), the recording quality (Prop) was estimated as the ratio of the total duration of the detected fixations to the total duration of the ES. For eye tracker EyeGaze Me(Prop) = 0.85, IQR = (0.78, 0.88). For eyetracker Gaze Point Me(Prop) = 0.61, IQR = (0.45, 0.73). For the sample as a whole, Me (Prop) = 0.74, IQR = (0.56, 0.83). Further analysis was carried out for ES with a recording quality above 0.7. For each ES, as a characteristic of the ES, the average duration of fixations along its entire length was calculated. Also, the average duration of fixations was calculated over consecutive intervals of 4 seconds (fixations that began in a given interval were taken into account). Next, the average duration of fixations for the ES as a whole and consecutive 4-second intervals was compared with the similarity score given to the subjects in this situation.

The Kruskal-Wallace test shows that significant differences in the duration of fixations for different assessment options are observed for the average duration of fixations for ES as a whole, as well as for the average duration of fixations during the first five 4-second time intervals. The results obtained are shown in Figure 4.

Figure 4

Dependence of the duration of fixations on the similarity score given by the research participant



***Note**. Data on ES as a whole and 5 consecutive time intervals lasting 4 seconds. The solid line is the median values, the whiskers are the interquartile range, the gray circles are the average values.*

Differences in the duration of fixations for different variants of the similarity assessment are fixed throughout the entire time interval, not exceeding 75% quantile of the duration of the assessment. The obtained results can be interpreted as an indication that different similarity scores can be considered as processes requiring different levels of cognitive load. The most "simple" in cognitive terms are the "most similar" estimates; as the degree of difference increases, the rationale for the estimate becomes more "cognitively complex". Additional analysis of the duration of fixations for time intervals of 1 second shows that the initial assessment interval is characterized by a significantly shorter duration of fixations than subsequent intervals ($p < 10^{-6}$), the average duration of fixations at subsequent time intervals does not differ significantly.

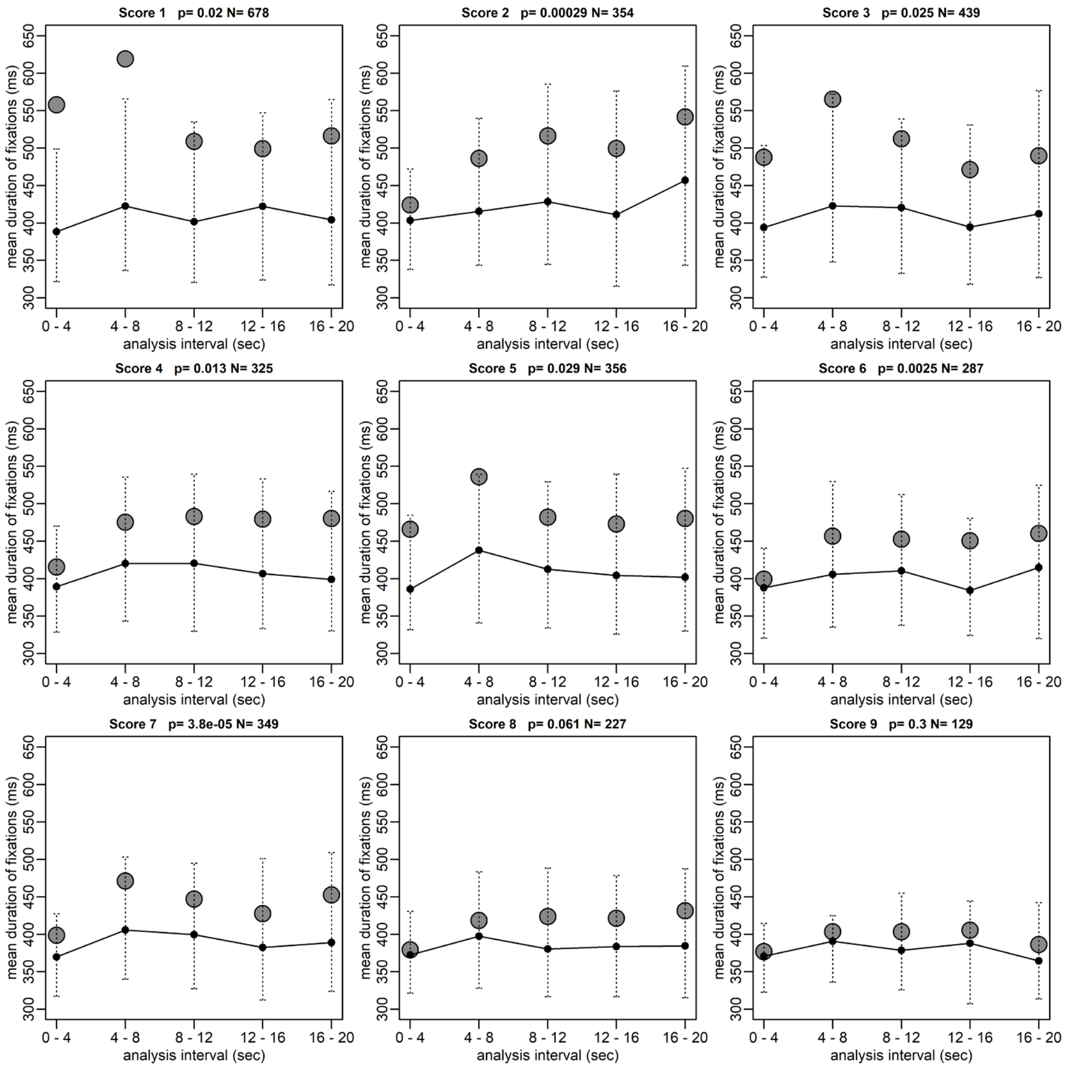
Comparison of the average individual duration of fixations with the preferred options for assessing similarity gives a correlation at the level of trends.

When calculating the individual average duration of fixations based on ES with a quality of record greater than 0.8, 45 participants are left for analysis. Pearson's correlation coefficient between the individual average duration of fixations and the experiment average similarity score $r = 0.32$ at $p = 0.03$.

Comparison of the average duration of fixations at the level of ES by 4–second time intervals gives the following results: score "1" – p = 0.02 (the number of ES n = 678); score "2" – p = 3 * 10 $^{-4}$ (n = 354); score "3" – p = 0.025 (n = 438); score "4" – p = 0.013 (n = 325); score "5" – p = 0.03 (n = 356); score "6" – p = 0.025 (n = 287); score "7" – 4 * 10 $^{-5}$ (n = 349); score "8" – p = 0.06 (n = 227); score "9" – p = 0.3 (n = 129). Thus, different estimates correspond to unique patterns of fixation duration distribution (Figure 5).

Figure 5

Duration of fixations at 5 consecutive analysis intervals for different similarity scores



***Note**. Solid line – median values, "whiskers" – interquartile range, gray circles – average values.*

Discussion

The analysis performed shows the presence of differences at the level of individual subjects using one or another preferred range of estimates. Also, a comparison of the characteristic durations of fixations indicates that the process of comparing images, including the substantive justification of a particular assessment, should be considered differentially depending on the similarity assessment given by the observer.

Scherer's component theory of emotions, relevance, importance, coping potential, and normative significance stand out as the basis for evaluation (Scherer, 2019). Each of the grounds can then be expanded into several sub-tests. At the same time, the observer himself with his life experience, motives and needs is the central element of the evaluation process. The solution of the comparison problem indirectly also relies on the previous experience of the observer. However, in this case, the grounds for evaluation are not directly expressed in the verbalizations of the subjects.

It can be assumed that there are several convergent mechanisms for evaluating facial expressions, which are updated depending on the task assigned to the observer. Under normal conditions, the operation of different evaluation mechanisms gives an equivalent result. Here we can draw an analogy with the level system of construction of movements by N. Bernshtein (1990). In this system, the same motor task can be implemented at different levels of movement construction. Valence and activity are measured by direct evaluation of memories of past events (Yik, Russell & Steiger, 2011), and by direct evaluation of video recordings of emotional expressions (Mehu & Scherer, 2015). In our study, the substantiation of differences is given at the level of discrete emotional states and their partial mimic signs, but at the same time, the required dimensions are implicitly found in the structure of differences. Thus, the dichotomy between "discrete" and "continuous" approaches to describing emotions is removed (Zachar & Ellis, 2012). The work of various components (levels) of the assessment system is generally mutually consistent, but in conflict situations, it is possible to simultaneously generate several inconsistent assessments (Russell, 2017). Outlining the paths to interpreting the next dimensions of the space we are reconstructing, we can start from the results of a semantic analysis of the characteristics of emotional states (Beermann et al, 2021); the highlighted measurements are interpreted as valency, power, arousal and novelty.

We consider the assessment of similarity between images as a process that is repeated many times by observers throughout the description interval. At the same time, stable differences in the duration of fixations for different assessments indicate that different variants of similarity assessment are performed by processes with different levels of cognitive load.

When performing a similarity assessment, two stages can be distinguished. During

the preliminary stage, characterized by shorter visual fixations, an initial assessment of the degree of similarity is performed, which, as a rule, remains unchanged in the process of further description. At the second, **main** stage, multiple re-evaluation is performed and specific arguments are given that testify in its favor. Multiple reassessment of similarity may be due to the need to achieve a high level of confidence in judgments (Shendiapin, Skotnikova, 2015). The authors of the component model of emotions indirectly imply its possible cyclic nature (Sander, Grandjean & Scherer, 2018).

The use of eye movement registration in this study proved to be effective. At the same time, the chosen design turned out to be too complicated for a detailed analysis of fixation localization. Almost the entire volume of visual fixations is concentrated in the central part of the screen; qualitative analysis shows that context-setting images are considered by individual participants only during the first few ESs. Most of the participants in the study ignore contextual images. In the future, one could limit oneself to a single setting of the context at the beginning of the experiment by demonstrating the entire set of images used in the experiment. In this case, it would be possible to increase the size of the compared images. Unfortunately, the images in the VEPEL database are small, which is due to the technical capabilities of the equipment used for shooting.

The study shows that the registration of eye movements, in principle, makes it possible to single out individual steps within the similarity assessment process, which could then be compared with the elements of the component model (Scherer, 2001, 2019). However, to solve this problem, equipment is needed that is more resistant to small changes in the position of the subjects and, possibly, with better temporal resolution. Using the available equipment, we cannot unambiguously judge whether the differences in the form of distribution for successive time intervals reflect certain features of the process of evaluating the similarity of images.

The originally set task of identifying individual features that characterize the features of image comparison can be considered solved. As such features, we can further consider: the average score of similarity between images; standard deviation of the similarity score between images; average duration of fixations when performing similarity assessment.

Conclusions

Comparison of images of emotional expressions, performed with an additional justification of the assessment, with an unlimited exposure time, is a reciprocal-cyclic process, at the initial stage of which an initial similarity assessment is performed, and then multiple repeated confirmations of this assessment are performed. The comparison process may use several convergent mechanisms, depending on the originally generated similarity score.

Estimates of the similarity of images of emotional expressions are individually variable, the search for determinants of similarity estimates is the task of further research. As characteristic indicators of an individual similarity assessment, one can consider: the average individual assessment of similarity between images; standard deviation of the similarity score between images; the average individual duration of fixations when performing a similarity assessment.

Thus, the following main provisions of the article can be distinguished:

- Multidimensional scaling of the results of pairwise comparison of images of emotional facial expressions gives a two-dimensional space described by the Core Affect model by J. Russell ;
- Different similarity scores correspond to specialized evaluation processes characterized by specialized cognitive strategies that correspond to unique patterns of distribution of fixation durations;
- The range of similarity scores given by the observer is individually variable. The duration of fixations during the comparison task is individually variable.

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Received: 28.11.2022

Revision received: 24.03.2023

Accepted: 06.04.2023

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Conflict of Interest Information

The authors have no conflicts of interest to declare.