DIRECT IMAGE COMPARISON: THE BOUNDARIES OF APPLICABILITY OF THE "DISCRETE" AND "MULTIDIMENSIONAL" MODELS OF PERCEPTION OF EMOTIONAL EXPRESSIONS

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Studying perception of emotional expressions suggest, supposed to analyze effectiveness of discrimination between images or the severity of specific emotional experiences. Neither paradigm allows us to fully explicate the observer's subjective ideas about the relationships between different facial expressions, and to reconstruct the whole subjective space of perceived emotional expressions. In the experiment, a direct assessment was made of the similarity of images of strongly and weakly expressed "basic" emotional expressions. In addition to actually evaluating the similarities, the study participants in free form gave the rationale for their decision. It was found that when performing direct comparison of images of emotional expressions presented for an unlimited time, observers mainly focus on assessing the emotional state in terms of "basic" emotions or equivalent to them. As a rule, strongly expressed emotional expressions are evaluated as "completely dissimilar" to each other. However, in the case of similar semantics of the expressed emotions, the expressions are evaluated as more similar, despite the fact that the observer distinguishes them well enough. Reconstruction of multidimensional space according to pairwise comparison indicates that the "basic" emotional expressions are not independent from each other constructs. The relationships between them correspond to the semantic space described by the Core Affect model. Thus, explicitly the participants in the experiment in explaining the degree of similarity describe the compared images in terms of "discrete" emotions; at the same time, the implicit structure of similarity corresponds to a two-dimensional semantic space with dimensions "pleasant — unpleasant" and "activation — deactivation".

Keywords: comparison, emotional expressions, face perception, basic emotions, Core Affect.

ПРЯМОЕ СРАВНЕНИЕ ИЗОБРАЖЕНИЙ: ГРАНИЦЫ ПРИМЕНИМОСТИ «ДИСКРЕТНОЙ» И «МНОГОМЕРНОЙ» МОДЕЛЕЙ ВОСПРИЯТИЯ ЭМОЦИОНАЛЬНЫХ ЭКСПРЕССИЙ

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Исследования восприятия эмоциональных экспрессий предполагают, как правило, изучение эффективности различения похожих изображений либо выраженности конкретных эмоциональных переживаний. Ни та ни другая парадигмы не позволяют в полной мере эксплицировать субъективные представления наблюдателя о соотношениях между различными выражениями лица, реконструировать целостное субъективное пространство воспринимаемых эмоциональных экспрессий. В проведенном эксперименте выполнена прямая оценка сходства изображений сильно- и слабо выраженных «базовых» эмоциональных экспрессий. Помимо собственно оценки сходства участники исследования в свободной форме представляли обоснование своего решения. Обнаружено, что при выполнении прямого сравнения изображений эмоциональных экспрессий, предъявляемых на неограниченное время, наблюдатели в основном ориентируются на оценку эмоционального состояния в терминах «базовых» эмоций, либо эквивалентных им. Как правило, сильно выраженные эмоциональные экспрессии оцениваются как «совсем непохожие» друг на друга. Однако в случае сходной семантики выражаемых эмоций экспрессии оцениваются как более похожие, несмотря на то, что наблюдатель достаточно хорошо различает их между собой. Реконструкция многомерного пространства по данным попарного сравнения указывает, что с точки зрения семантических характеристик «базовые» эмоциональные экспрессии не являются независимыми друг от друга конструктами. Взаимоотношения между ними соответствуют семантическому пространству, описываемому моделью Core Affect. Таким образом, эксплицитно участники эксперимента при объяснении степени сходства описывают сравниваемые изображения в терминах «дискретных» эмоций; в то же время имплицитная структура сходства соответствует двухмерному семантическому пространству с измерениями «приятный—неприятный» и «активация—деактивация».

Ключевые слова: сравнение, эмоциональные экспрессии, восприятие лица, базовые эмоции, Core Affect.

Introduction

In studies of the perception of emotional facial expressions, two main theoretical concepts can be distinguished. The first is P. Ekman's neurocultural theory of emotions, historically based

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on the research of Charles Darwin. P. Ekman points out that one of the key characteristics of "ba-sic" emotions is the presence of a specific universal signal directed outward. For the survival of an individual, it seems evolutionarily useful both to have unambiguous information about the state of other individuals of the same species at the present time, and to accumulate a certain experi-ence, taking into account the nearest past and the possibility of transferring it to the near future. As an example, it is indicated that the expression of disgust is a response to something unpleasant to taste or smell (in a direct or metaphorical sense) and that the person is likely to turn away from the source of stimulation [8].

The practical conclusion from this theory is the unambiguous "discrete" perception of emo-tional expressions, independent of gender, socio-cultural and other differences. An unambiguous relation between of emotional facial expressions and specific emotional states makes it possible to conduct training programs aimed at teaching the "correct" perception of facial expressions [9] and the creation of technical tools for facial expressions analyzing.

The second concept — the "multidimensional" model goes back to the views of W. Wundt, according to which emotions and, accordingly, their external manifestations are the dynamics of elementary feelings. In the original version, three dimensions were distinguished: pleasure — displeasure, excitement — inhibition (tranquillization), tension – relaxation. In the modern ver-sion — J. Russell's Core Affect model, two dimensions are used: pleasant-unpleasant and activa-tion-deactivation. In the multidimensional model, the "basic" emotions, according to Ekman, will correspond to areas of multidimensional space. The multidimensional model predicts that the "dimensions" of the multidimensional space should be perceived directly. This model is attractive for its versatility — a wide class of states can be characterized in terms of elementary feelings. For a practical assessment of the emotional state of a person, it is inconvenient.

The experimental paradigm aimed at confirming the "discrete" theory involves compar-ing the results of solving the discrimination ABX task and the identification task on the basis of transition series between stimuli corresponding to opposite categories. The ABX discrimi-nation task in studies of this type involves the simultaneous or sequential presentation of two similar stimuli A and B, after which stimulus X is presented, which exactly corresponds to one of them. The subject is required to answer which of the stimuli is equal to X: A or B? This technique was originally used in experiments related to the study of the specificity of phoneme perception [12]. It is postulated that the categories associated with the fulfillment of the iden-tification task are objective (determined by a set of attributes); independent of the observer; all members of the category are equal among themselves. Discrimination of objects is based only on their different categorical affiliation. Intra-categorical differences cannot be the basis for stimuli distinguishing. Later, this model became widespread in studies of the categorical perception in the acoustic modality [11].

The objective nature of the categories allows for the artificial construction of stimuli, the degree of difference of which is determined by objective indicators controlled by the experiment-er. It also becomes theoretically justified to combine the results obtained on a small (about 20 participants) sample and to solve the identification problem in the paradigm of forced choice. If the initial assumptions are confirmed, the result of solving the identification problem will have the form of an S-shaped curve; at opposite ends of the row, images will be recognized as unam-biguously matching the opposing categories. A well-expressed maximum of the accuracy of solv-ing a discriminatory task will correspond to the category boundary determined by the results of the identification task.

With the development of image manipulation technologies, this research technique was adapted for the case of perception of emotional expressions [10]. In the next 20 years, it became widespread. An overview of the studies and our results are described in [2]. The main patterns of perception of emotional expressions of a person, obtained as a result of research in this paradigm, can be formulated as follows.

• Images of "basic" emotional expressions when identified by the forced choice method (both alternative and multiple) are recognized almost unambiguously.

• Images of transient emotional expressions are recognized as a combination of "basic" emotional expressions, but the distribution of the results does not necessarily have the form of a "step", as predicted by the original hypothesis

• The expressed maximum of the accuracy, corresponding to the category boundary when solving the identification problem is only a special case. At the same time, the distribution of the accuracy in most cases differs from the uniform one.

• In experiments aimed at comparing the results of solving the discrimination task in individual and paired experiments, the distribution of the accuracy qualitatively had the same form, and in the paired case the solution to the problem was basically really based on the indication of the categorical belonging of the images to be distinguished. In addition, an individual variability of the characteristics of images identified during recognition was found, associated with the description of transient emotional expressions.

• The effectiveness of distinguishing emotional expressions is explained by their different categorical affiliation only partially (up to 40% of the explained variance). Thus, the initial provisions of the hypothesis — the objective nature of the categories and the distinction of images based on their categorical affiliation — do not find complete confirmation within the framework of the experimental methodology used. We are faced with the task of finding alternative variants of the experimental procedure.

An alternative theoretical approach involves the reconstruction of the perceptual space of emotional expressions of the face and the interpretation of its dimensions [14]. Experiments aimed at testing this hypothesis, as a rule, consist in a direct assessment of the assessed image, event, and emotional state according to scales corresponding to the "dimensions" of the hypothetical space [15]. The analysis of the results comes down to confirming or refuting the a priori hypothesis, but fundamentally does not allow to fully establishing the actual structure of the relationships between the evaluated stimuli (in our case, between various emotional expressions).

The proposed solution to the question of the actual relationship between different emotional expressions is to perform a direct comparison between images of different emotional expressions. The advantage of this approach is that a direct assessment of the degree of similarity can be used on a wider range of stimuli than the discriminatory ABX task. When solving the problem of direct comparison, we will obtain a complete similarity matrix that allows us to reconstruct the actual relationships between various emotional expressions, not tied to our a priori ideas about the "categorical" or "multidimensional" nature of their perception. Within the framework of the proposed technique, it is possible to establish which features the observers are actually guided by, assessing the similarity / difference of images. The fundamental limitation of the direct comparison problem is the relatively high labor intensity for the study participants, which increases in proportion to the square of the number of compared stimuli.

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Experimental Procedure

As a stimulus material in the study, we used photographic images of "basic" emotional expressions (happy, sadness, fear, surprise, anger, disgust, neutral face) from the VEPEL database; used images with the maximum (100%) degree of severity and 40% severity, selected from the corresponding transition series [5; 2] (Fig. 1). The size of the images is 227x315 pixels. Images were exposed on a Viewsonic VG903 LCD screen, screen size — 1280x1024, resolution — 33 pixels / sm. A pair of images was positioned in the center of the screen vertically, horizontally, the distance from the images to the edge of the screen was 206 pixels, and the distance between images was 413 pixels. On the periphery of the screen, there were seven reduced (136x189 pixels) images of strongly pronounced emotional expressions that set a constant context for comparison (Fig. 2). Images were displayed against 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 °.

Fig. 1. Stimulus material. First line: fear (strongly and weakly expressed), anger (strongly and weakly expressed). Second line: disgust (strongly and weakly expressed), neutral face, happy (strongly and weakly expressed). Third line: sadness (strong and weak), surprise (strong and weak)

The instruction to the participants was formulated as follows: "You will be shown two faces of the same person, expressing different emotions. Rate the image similarity on a 5-point scale. Explain in detail why you gave this or that rating. The scale included the following answer options: 1 — "completely dissimilar", 2 — "slightly similar", 3 — "moderately similar", 4 — "strongly similar", 5 — "maximally similar". In this case, the result of the comparison had to be explained in an arbitrary form. There was no explicit indication from the experimenter of the method of comparison (characteristic of the emotional state; manifestation of facial features; certain measurements).

The experiment was carried out individually. Presentation of stimulus material, recording of marks, and audio recording of responses were performed using the PxLab software. Images containing a pair of compared emotional expressions and a comparison context were previously prepared using ImageMagic software. The size of the experiment when comparing 13 emotional expressions with each other with the exclusion of comparison with oneself and without taking into account the location is (13 * 12) / 2 = 78 experimental situations (ES) per subject. For technical problems, the experiment did not include comparisons for pairs "weak fear — strong surprise" and "weak fear — neutral face". Thus, the actual volume of the experiment was 76 ES per subject.
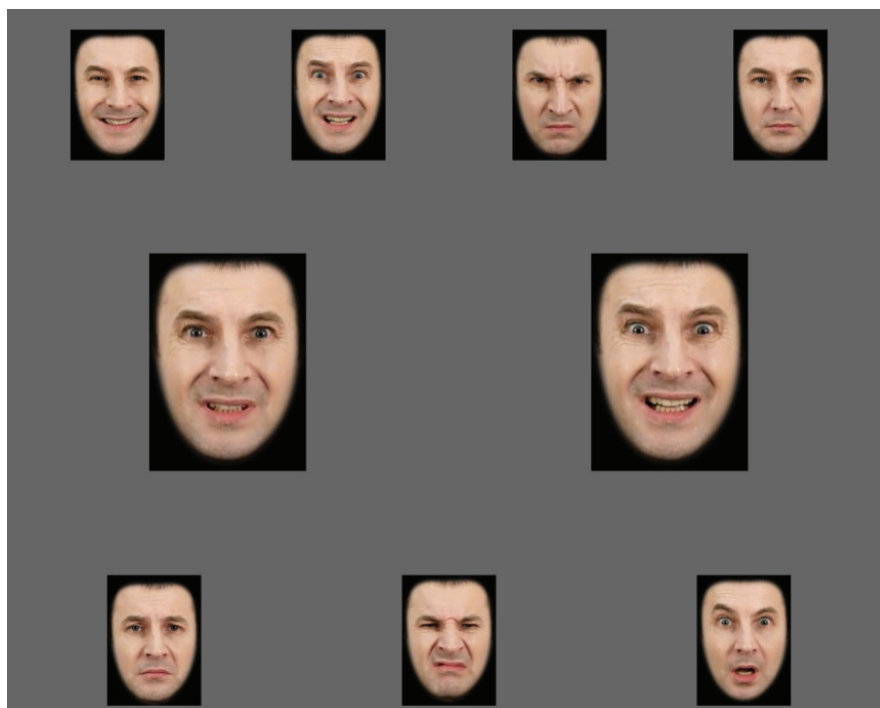

Fig. 2. Example of exposure of a pair of compared images

The study involved students of the Moscow Institute of Psychoanalysis (first higher education), 30 people (11 men, 19 women). Age — from 17 to 34 years old, m = 20.4, sd = 4.4. Images of emotional expressions remained on the screen all the time while the subjects evaluated 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 saw fit. The median duration of the description of one image was 15 seconds, IQR = 11-17 seconds. The maximum time for describing one image was 12 minutes. 35 sec. Long (more than 50 seconds) descriptions were associated with a detailed description of hypothetical situations associated with the manifestation of the corresponding emotional expressions or personal experience of the subjects and accounted for 4% of all experimental situations. The total time for completing the task by the subjects was from 16 minutes. up to 125 min., median — 24 min., IQR — from 20 min. up to 30 min. For comparison,

the time it took to complete the task by the author of the work with a minimum meaningful description of the differences between the compared images was 12 minutes.

The hypothesis about the categorical nature of the perception of emotional expressions [10] predicts that various "basic" emotional expressions should be assessed as maximally dissimilar to each other, that is, for all pairs of strongly pronounced emotional expressions, observers should have rated "maximally dissimilar". Weakly expressed emotional expressions should be assessed as similar to the corresponding strongly expressed and dissimilar to each other. Russell's Core Affect hypothesis predicts that based on the results of mutual comparison of images of emotional expressions with each other, it is possible to reconstruct a two-dimensional perceptual space, the axes of which correspond to the dimensions Pleasure — Displeasure and Activation — Deactivation. In the case of categorical perception of emotional expressions, the dimension of the reconstructed space of similarity would have to be 6 (the number of independent categories), and a decrease in dimension without a significant deterioration in the explanatory power of the model would be impossible.

Results: Comparison Strategies

The most frequently used comparison strategy was a reference to the experienced emotional state of the sitter, and the description had a compact form, for example: "here the score is 1; the left is afraid, the right is contemptuous". This strategy was used by 25 participants. Detailed or generalized descriptions of emotional states were used by 6 participants. There was no systematic explicit reference to "dimensions" as a basis for comparison, even among the participants using generic descriptions. Positive and negative modalities of emotions were used as a generalization in the case when the subjects had difficulty in recognizing a particular emotion. The reference to partial facial features was used by 6 participants. Example: "score 4", the lower part of the face is similar, the lips are closed, and the eyes are different". Some subjects used different comparison strategies at the same time. Example: "score 3, left angry right surprised, similar eyebrows, nasolabial folds, lips seem to be curved, but not too much".

High complexity and difficulty of solving the problem was noted by 3 participants. The monotony and tediousness of the proposed task were noted by 4 participants. In general, the proposed experimental paradigm can be considered an acceptable compromise between the required experimental size and fatigue of the participants. At the same time, further increase in the volume of work with a separate participant is not advisable.

The indirect pressure on the subjects, leading to the choice of a certain comparison strategy, can be considered minimal. When planning further research in this paradigm, it would be advisable to try altogether to exclude the use of the word "emotions", but in this case the question arises of how to characterize the demonstrated stimulus material in general terms.

Results: Comparison of Emotional Expressions

An analysis of the results of comparing strong emotional expressions makes it possible to distinguish three types of pairs of images on the basis of ordering by the number of «1» scores.

1. Perceived as completely different. The number of «1» scores (completely different) is 25—29. The average score is in the 1.03 to 1.23 range. Pairs: "fear-neutral face", "anger-happy", "disgust-happy", "disgust-surprise", "disgust-neutral face", "happy-sadness", "surprise-neutral face".

2. Perceived as slightly similar. The number of «1» scores is 18—24. The average score is in the range from 1.30 to 1.60. Pairs: "fear-anger", "fear-disgust", "fear-happy", "fear-sadness",

"anger-sadness", "anger-surprise", "anger-neutral face", "disgust-sadness", "happy — surprise", "happy — neutral face", "sadness — surprise".

3. Perceived as moderately similar. The number of «1» scores is 4—6. The average score is in the range from 2.87 to 2.97. Pairs: "fear — surprise", "anger — disgust", "sadness — neutral face."

A qualitative analysis of the structure of the descriptions indicates a tendency towards partial transfer of the characteristics of one of the compared images to another. A detailed analysis of this effect would require a significant expansion of the sample size.

Comparison of the corresponding strong and weak emotional expressions shows that the corresponding facial expressions are mostly perceived as "strongly similar" (4) or "very similar" (5).

For fear expressions, the response rates are [0, 2, 6, 15, 7], m = 3.90. Images are generally described as fear or fright of varying degrees of severity. A score of 2 ("slightly similar") matches the descriptions of both facial expressions as surprise. "Both pictures show surprise, but on the left he is unpleasantly a little surprised, a little less than on the right," that is, a high degree of difference is associated with the perception of an additional modality.

For expressions of anger, the response rates are [0, 2, 9, 10, 9], m = 3.87. The images are mainly described as anger, spite, resentment, irritation of varying degrees of severity. A score of 2 in one case is associated with the perception of different modalities of emotions (mild anger is perceived as contempt), in the other case — with the description of differences at the level of partial signs.

For expressions of disgust, the response rates are [1, 7, 8, 9, 5], m = 3.33. The images are mostly described as disgust, contempt, squeamishness, anger, dislike. Scores 1 and partially 2 are associated with the perception of mild disgust as other modalities (negative superiority, sadness, indifference).

For expressions of happy, the response frequencies are [0, 4, 7, 13, 6], m = 3.70. Images are mainly described as smile, happy, laugh, pleasure, happiness. Weak happy can be described as an arrogant smile, contempt, grins, gloating.

For expressions of sadness, the response rates are [2, 2, 9, 10, 7], m = 3.60. Images are mostly described as sadness, sorrow. Weak sadness can be described as a calm face, lack of emotion.

For expressions of surprise, the response rates are [5, 7, 5, 10, 3], m = 2.97. The images are mostly described as surprise, perhaps with a touch of additional emotion (horror, disgust). The scores of 1 are partially related to the description of weak surprise as calmness. At the same time, strong surprise is described as fear, fright. Scores 2 are mainly associated with the description of images as surprise of varying degrees of severity. The lesser degree of similarity compared to other pairs is associated with significant perceptual differences between the images (closed mouth in case of weak surprise).

A comparative analysis of the results obtained allows us to assert that when comparing strongly and weakly expressed emotional expressions of the same modality, a fairly accurate recognition of these emotions occurs as expressing the same state of varying severity, and the quantitative assessment of the degree of similarity in this case partially depends on individual characteristics of subjects. As noted above, if the hypothesis of the categorical nature of perception is correct, weakly expressed emotional expressions should differ from each other to the same extent as the corresponding strong emotional expressions. To test this statement, we compared the estimates of the degree of similarity between pairs of im-

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ages of strongly and weakly expressed emotional expressions. For each pair, the average similarity index was calculated, the presence of differences between the similarity scores was checked using the Wilcoxon test, and the Hodges-Lehmann inter-sample shift was additionally calculated (in the table — the EST column). Comparisons for pairs of images "weak fear – neutral face" and "weak surprise — neutral face" were not carried out. The bold box in the table shows pairs of strong emotional expressions for which the degree of similarity exceeds 2.

Table

Comparison of similarity scores for pairs of strongly and weakly expressed emotional expressions

Expression 1	Expression 2	Mean Score (strong)	Mean Score (weak)	p-level	EST
Fear	Anger	1,60	2,03	0,02	1
Fear	Disgust	1,60	1,60	insignificant	0
Fear	Happy	1,53	1,50	insignificant	0
Fear	Sad	1,37	1,53	insignificant	0,5
Fear	Surprise	2,93	2,23	< 0,01	-1
Fear	Neutral	1,07			
Anger	Disgust	2,97	3,23	insignificant	0,5
Anger	Happy	1,03	1,43	< 0,01	1
Anger	Sad	1,60	1,93	0,07	1
Anger	Surprise	1,40	1,73	0,02	1
Anger	Neutral	1,40	1,73	0,03	1
Disgust	Happy	1,17	1,60	< 0,01	1
Disgust	Sad	1,60	2,13	< 0,01	1
Disgust	Surprise	1,20	1,73	0,01	1
Disgust	Neutral	1,17	2,07	< 0,01	1,5
Happy	Sad	1,17	2,03	< 0,01	1,5
Happy	Surprise	1,30	1,73	0,04	1,5
Happy	Neutral	1,53	2,33	< 0,01	1,5
Sad	Surprise	1,43	2,30	< 0,01	1
Sad	Neutral	2,87	4,57	< 0,01	2
Surprise	Neutral	1,23			

A comparative analysis of the results shows that out of 19 pairs of emotional expressions in 13 cases, weak expressions are assessed as more similar than strong ones. In 5 cases (pairs "fear – disgust", "fear – joy", "fear – sadness", "anger – disgust", "anger – sadness"), the indicators for assessing the degree of similarity did not reveal significant differences. In one case ("fear — surprise" pair), weak expressions are assessed as less similar than strongly pronounced ones. The latter result may be related to the specificity of the image of a weak expression of surprise.

Based on the totality of the results obtained, it can be argued that the assessment of similarity, in addition to the perceived modality of emotions, is determined by the severity of facial features.

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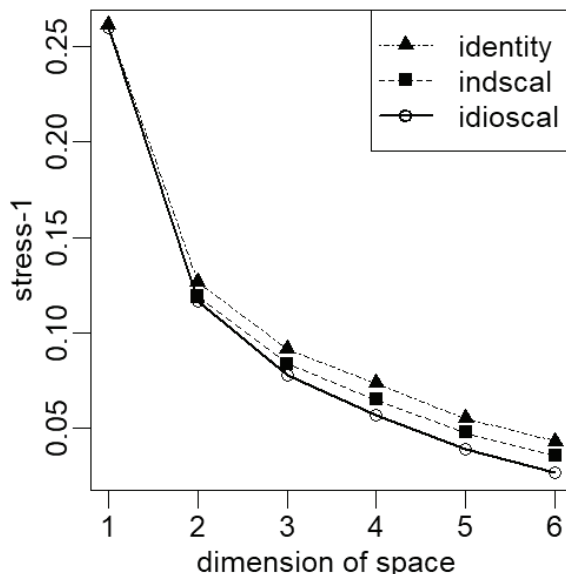## Results: reconstruction of the perceptual space

Fig. 3. Quality of reconstruction by the method of multidimensional scaling for different
dimensions of space

Reconstruction of the semantic space according to individual data of comparison of emotional expressions was carried out in the R statistical environment, the smacof library [7], the smacofIndDiff function. The type = ordinal argument indicates that the comparison data is in a scale of order. To estimate the dimension of space, multidimensional scaling was performed for spaces with dimensions from 1 to 6. In Fig. 3 shows a Scree Plot for stress-1, which is an indicator of the quality of the reconstruction. The stress-1 indicator was calculated for dimensions from 1 to 6, restrictions on the model: IDENTITY, INDSCAL (INdividual Differences Scaling), IDIOSCAL (Individual DIfferences in Orientation SCALing). The IDENTITY model assumes that different observers correspond to a single system of judgments about the similarity of objects; INDSCAL additionally admits that the weight of judgments may vary from observer to observer; IDIOSCAL additionally allows for individual variations in the orientation of the similarity matrices. Thus, for the same space dimension, the IDIOSCAL model allows obtaining the best reconstruction quality.

The analysis of the results shows that using the IDIOSCAL model the value of the stress-1 indicator for the dimension of space from 1 to 6 takes the following values: 0.260; 0.116; 0.077; 0.057; 0.039; 0.026. Thus, for further analysis it is advisable to consider a space of dimension 2. The results of multidimensional scaling (dimension 2, IDIOSCAL model) are shown in Fig. 4. As can be seen from the comparison with the Core Affect model [13] (Fig. 5), the reconstruction obtained by us, accurate to the orientation of the axes, qualitatively corresponds to this model.

Discussion of the results

If the "discrete" theory of emotions was fully confirmed, the space reconstructed based on the results of direct comparison would have six independent dimensions, each of which would
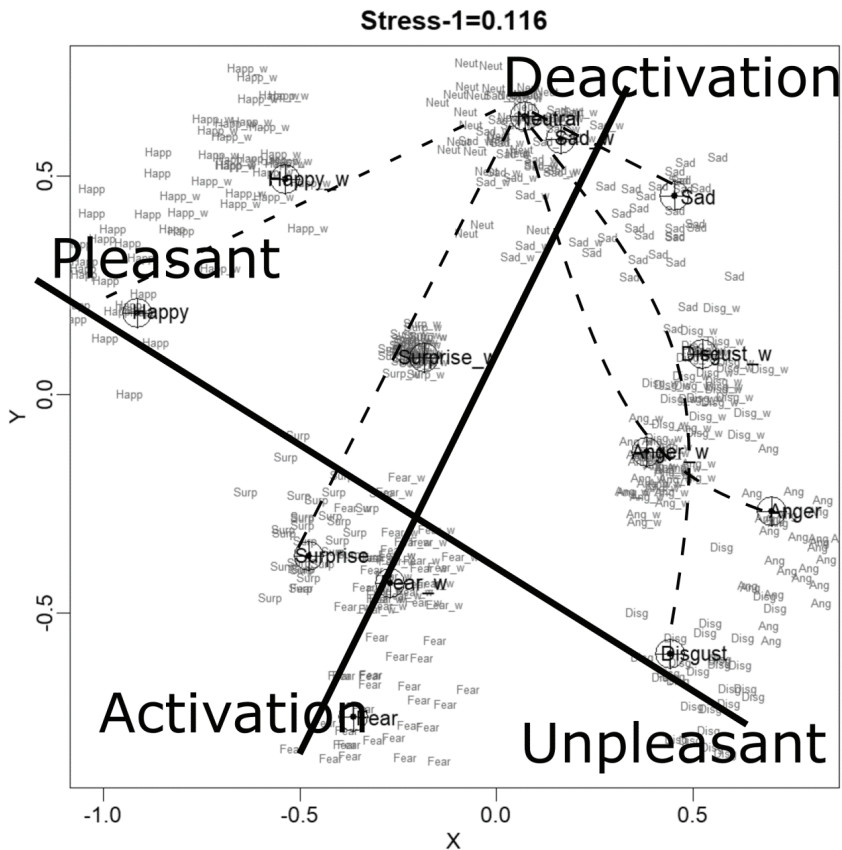
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Fig. 4. Reconstruction of space according to individual results of pairwise comparison of images
of emotional expressions. Individual results of individual participants are marked in dark gray. The axes
"fear-neutral expression" (activation-deactivation) and "joy-disgust" (pleasant-unpleasant) are plotted in
accordance with the Core Affect model. The dotted line shows the supposed paths of the transitional series
from strongly expressed emotional expressions to a neutral face

correspond to one of the "basic" emotions. In this case, all pairs of strong emotional expressions
should be judged as "completely different". Corresponding strongly and weakly expressed expres-
sions (different degrees of severity of the same emotion) should be assessed as "maximally similar"
or "strongly similar". The degree of difference between weakly expressed facial expressions should
be the same or slightly less than for pairs of strong expressions.

The obtained results confirm the hypothesis of a set of independent "discrete" emotions
only partially. When performing a direct comparison of images of emotional expressions, observ-
ers are really mainly guided by the assessment of the emotional state in terms of "basic" emotions
or equivalent to them.

The assessment of the similarity of images of emotional expressions of a face is carried out
by observers, as a rule, based on the modality of the perceived emotional state of the sitter, and as
a result, compared images of strongly expressed emotional expressions are generally assessed as
"completely different". At the same time, among the set of emotions, couples (surprise and fear;
anger and disgust; neutral and sadness) can be distinguished, which are rated as "moderately
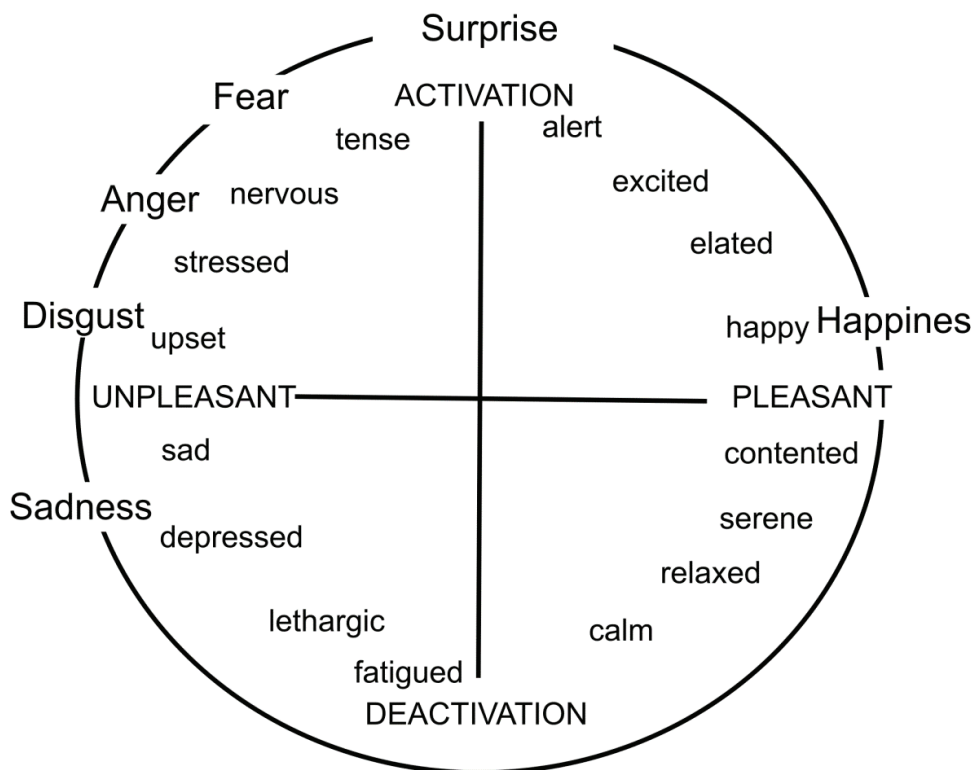
Fig. 5. Structure of the Core Affect [cited in: 13]

similar" to each other. Emotions, the semantics of which are similar for observers, are assessed as more similar, despite the fact that the observer distinguishes them well enough from each other. Also, observers can gradually assess the degree of expression of emotions; indicate that two compared facial expressions can represent successive slices of the dynamics of an emotional state.

Thus, from the point of view of the participants in the experiment, "basic" emotions are not constructs independent of each other. The relationships between them correspond to the semantic space described by the Core Affect model. Explicitly, when explaining the degree of similarity, the participants in the experiment describe the compared images in terms of discrete emotions; at the same time, the implicit structure of similarity corresponds to a two-dimensional space with the dimensions "pleasant-unpleasant" and "activation-deactivation". On the obtained reconstruction (Fig. 4), the relations for four groups of emotions turn out to be linear: "neutral — weak joy — strong joy"; "Neutral — weak sadness — strong sadness"; "Neutral — weak surprise — strong surprise"; "Neutral — weak fear — strong fear". For these emotions, the change in intensity is fully described by a linear combination of space coordinates. For the groups of emotions "neutral — weak anger — strong anger" and "neutral — weak disgust — strong disgust," the relationship is not linear, their explanation requires further analysis.

This results refer only to ecologically valid images, corresponding to the expression of "basic" emotions of varying degrees of intensity. Further research is needed to understand the place of transitional emotional expressions in the structure of this space. The size of the experiment is limited, since further increase in the number of comparisons will lead to increased fatigue of

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study participants and incorrect results. At the same time, instead of images of weakly expressed emotional expressions, it is fundamentally possible to use images of transitional emotional expressions as a stimulus material. A hypothetical complete experiment would include 15 transitions between 6 "base" expressions. If we take the discreteness of the rows in the amount of 20%, then for each row there are 2 reference and 4 transition images; a total of 60 transition images. If the available volume of the experimental series is preserved, up to 10 experimental series will be required to fully study the structure of perceived similarity, which seems to be a technically possible task. The high labor intensity of this technique is mainly associated with the need to collect and then analyze verbal descriptions. A possible abbreviated version of the experimental procedure consists in performing only similarity estimates without explaining the criteria used. With information about the similarity scores for the full procedure, we may be able to validate a simplified version of the methodology.

The most significant technical problem is that, in addition to the VEPEL database (which includes images of transient expressions of a single model), there are no other natural images of transient expressions, and the photographic images obtained using the morphing procedure contain artifacts, which in themselves can serve as grounds for distinguishing images. Our colleagues' attempts to obtain images of natural transient expressions have shown that solving this problem requires models to have extremely high control over their emotional state.

It can be expected that further experiments, in which the stimulus material will be expanded by adding images of transient expressions, will make it possible to understand the reasons for the observed differences in the accuracy of solving the discriminatory problem in previous studies.

A quantitative comparison of the structure of descriptions of emotional expressions remained outside the scope of the analysis. In particular, it is of interest to clarify the question of the change in the contribution of different options for describing a particular emotion by its image, depending on which of the opposite in valence emotions is compared with. The available material is, in principle, sufficient to compile a complete dictionary of used descriptions by analogy with [3]. However, the comparison of the frequencies of occurrence of rare descriptions requires an increase in the sample size.

The limitation of the proposed research paradigm is that it allows one to study only subjective ideas about the similarities and differences between the emotional expressions of a person and the corresponding emotions. The study of the objective mechanisms of perception of facial expressions remains outside the scope of the study. In our opinion, the only practically feasible way to study such mechanisms is to compare the results of field experiments and mathematical models. The end result of experimental research in the direct comparison paradigm is a pairwise similarity matrix for all stimuli used. After that, a criterion appears for testing possible mathematical models describing the differences between stimuli. In our research, when creating such models, we rely on a vector model for distinguishing stimuli [6]. In this case, the model is adjusted by choosing a specific set of initial signals that describe the distinguishable images of facial expressions at different levels of detail [4; 1].

An analysis of the descriptions presented by the participants in the experiment showed that an explicit explanation of the differences between the images in terms of configuration features in the received verbal descriptions is rather weak. Based on our earlier studies [2], it can be assumed that the use of partial facial features instead of a holistic representation of facial expression is associated with difficulties in recognizing and distinguishing emotional

facial expressions in conditions of incomplete information (noisy images, limited exposure time, etc.). In this case, the structure of the reconstructed space should depend on the conditions of the exposition. Also, as exposure conditions deteriorate, there should be an increase in the number of explanations associated with reliance on partial facial features. On the contrary, with the facilitation of the conditions of perception, the structure of space will approach the "ideal" ideas about the semantic relationship of emotionally colored categories, expressed by the structure of Core Affect.

Considering further areas of research to clarify the patterns of distinguishing emotional expressions of a face, the following key tasks can be identified:

— the accumulation of empirical results about the perceived similarity of facial expressions;

— analysis of scientific data on the physiology of visual perception, which makes it possible to offer additional justification for the selected version of the discrimination model;

— further refinement of the model by comparing empirical and theoretically calculated data on the magnitude of similarity between images.

Conclusions

In the absence of difficulty in perceiving emotional expressions, the similarities between their images are described by observers in terms of discrete "basic" emotions. The implicit structure of the reconstructed space corresponds to a two-dimensional space with the dimensions "pleasant-unpleasant" and "activation-deactivation", which corresponds to the Core Affect model of J. Russell with an accuracy of the orientation of the axes.

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