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Experimental Verification of the Relationship Formation Model in the Process of Visual Perception

Sergei L. Artemenkov

Faculty of Information Technologies, Moscow State University of Psychology and Education (MSUPE), Moscow, Russia
Email: slart@inbox.ru

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Abstract

The transcendental psychology approach to the study of perception (A.I. Mirakyan) assumes that in the perception there are so-called structurally-generative processes. Their study is based on an axiomatic methodology, which includes general natural principles for the formation of relationships that provide conditions and opportunities for creating forms in visual perception. The conducted experiment was devoted to the experimental verification of a theoretical model presenting a hierarchy of center-symmetrical and temporary relationships. Experiments included perception of short-term displayed contour symmetric objects that vary in size at a fairly high speed. The method was based on the detection of the place of the Fröhlich effect (onset or offset) for stimuli increasing and decreasing in size. The studied model indicated the possibility of the appearance of subjects of the reversed Fröhlich effect (it is offset as representational momentum but reversed in time) for stimuli decreasing in size at high speeds. The experiments showed that for a speed of 15 deg/s, the percentage of such subjects was 8%, and for a speed of 30 deg/s—22%, while for a speed of 60 deg/s this percentage exceeds 65%. For the last speed, there were a significant number of tests with the reversed Fröhlich effect, which was predicted by the model. Thus, we see possibility to verify the proposed theoretical model, although the conclusions made require further theoretical and experimental verification. Transcendental psychology approach provides alternative explanations for phenomena, which are determined by the principles of Gestalt psychology.

Keywords

Visual Perception, Transcendental Psychology, Model, Center-Symmetrical Relation, Temporary Relationship, Size-Changing Stimuli, Reversed Fröhlich Effect

1. Introduction

The visual perception of the world is dynamic, as objects and/or other aspects of the scene move or change over time. Understanding how the perceptual system processes such "dynamic events" presents a major challenge to theories of perception, memory, and cognition. It is known that the mechanisms of the process of visual perception are very complex and not well studied.

The theoretical and experimental difficulties observed here contribute to the fact that research in visual psychophysics is in many ways phenomenal. At the same time, various special phenomena of perception that are constantly encountered in practice, which are often difficult to unambiguously explain, are studied in a multilateral way. An example here is spatial distortions in perception and cognition (Hubbard, 2018).

Gestalt principles of perceptual grouping have been proposed to reflect the dynamic aspects of mental representation. These aspects have been attributed to the principle of Prägnanz (a bias toward simplicity in interpretation of a stimulus). The Gestalt psychology approach worked well and continues to improve at the present time (Wagemans et al., 2012a, 2012b). It is currently shown that the principle of Prägnanz could be expanded to incorporate a bias to interpret a stimulus or scene as consistent with the subjective experience of physical dynamics attributed to that stimulus or scene. In particular, representational momentum (memory for the final location of a moving target is shifted in the direction of anticipated motion) and boundary extension (stimuli likely present just beyond the boundaries of a previously viewed scene are remembered within that viewed scene) could be considered new Gestalt principles (Hubbard, 2021). Other empirical findings relate to representational gravity, where the judgment of the location of a previously viewed moving or stationary target location often moves in the direction of gravitational attraction. It is suggested that representational gravity is an important adaptation that aids observers in interactions with physical objects in the environment (Hubbard, 2020).

In the experimental practice of this article, we rely on the effect associated with the Fröhlich effect, the difficulty in realizing the correct localization of the initial position of the moving stimulus. An illusion was reported in studies at the beginning of the last century, in which the error was that the strip of light passing through the screen was not seen first at the edge of the screen, but further into it (Fröhlich, 1923). Various other effects related to mislocalization illusions were then discovered and investigated along with the Fröhlich effect, including the flash-lag effect, representational momentum, and others (Rubin, 1930; Freyd & Finke, 1984; Nijhawan, 1994; Kerzel, 2010; Hubbard, 2014). Memory for the final location of a moving target is also displaced in the direction of target motion, and this has been referred to as representational momentum. This displacement appears to play a critical part in localizing stimuli in the environment (Hubbard, 2005; Müsseler & Kerzel, 2018).

Later studies from the present century also described an illusion, in which the error was not in the direction of motion but in the opposite direction (onset-repulsion effect (Thornton, 2002; Hubbard & Motes, 2002)). The direction of the effect depends on the broader context of perception and memory of the respondents (Hubbard & Motes, 2005).

Hubbard notes that "Momentum-like effects have been suggested to reflect dynamic processes, but such effects have not often been discussed in the broader literature on dynamic approaches to perception, cognition, and action". They "provide examples of relatively simple dynamic processes that reveal and highlight issues relevant for study of dynamic approaches in a wide range of perceptual, cognitive, and action phenomena" (Hubbard, 2019: p. 2155).

One explanation for the Fröhlich effect was based on metacontrast masking and lateral inhibition, which seemed to explain the low visibility of the initial portion of the trajectory. There is also evidence that Fröhlich effect is a predictive spatial shift produced and modulated by focal attention (Kirschfeld & Kammer, 1999; Adamian & Cavanagh, 2017).

This investigation is based on the transcendental psychology approach to perception. The approach was developed in the 1990s by prof. A.I. Mirakyan at the Psychological Institute, Moscow, Russia (Mirakyan, 1995, 1999, 2004). Transcendental psychology approach characterizes initial perception as a kind of generative process of unified creation of forms with co-represented properties. Unlike existing phenomenological approaches, it focuses on axiomatics of general natural principles. This allowed us to see the processes of perception in a new way and to work out useful theoretical and practical models supported by a number of new experimental research. It is proposed to use an axiomatic methodology based on general natural principles that provide conditions and possibilities for form creation. A number of general principles were developed, such as structure-process anisotropy, formation of symmetric relations, spatial-temporal discreteness, co-presentation, and some others. These principles are both explanatory for the generative process of perception and are the direct object of further specification and verification (Panov, 1998, 2011; Artemenkov & Harris, 2005; Nagdyan & Panov 2017; Shookova, 2013, 2020).

Thus, for the first time in psychological science, the study of perception processes is carried out without identifying the process of perception with the results of its reflection. Experiments of form-creation processes in vision and touch modalities revealed the structural and procedural specifics and other characteristics of visual perception of the shape, color, stability and movement of objects and spatial extent. Dynamic scientific viewpoint, anisotropic homogeneity of system structures, and time as factor of spatial perception are some of the concepts implied and developed by the approach. A general description of transcendental psychology in English is presented in (Artemenkov & Harris, 2005; Artemenkov, 2021a). Anisotropy of visual space that extends across and outward from the moving target is mentioned in (Hubbard & Ruppel, 2018).

It should be noted that due to the transcendental nature of the processes under consideration, experimental verification of the developed principles is initially difficult. Form generation here initially assumes that the mechanisms of the process of perception do not manifest themselves in the form of observable psychological phenomena within the functional range of perception. At the same time, the ability to identify these mechanisms can be obtained at the border of the functional range, in particular, under critical spatial-temporal conditions of perception (Artemenkov & Harris, 2005; Artemenkov, 2021a).

The Fröhlich effect is of interest for the presented experiments not because it is associated with a spatial shift or other spatial properties, the distortion of which interests the bulk of researchers. In our experimental practice, we rely on the general point related to the fact that the first position is not clearly visible and is excluded from perception. Müsseler & Kerzel (2018: p. 4) notice that "At the time of Fröhlich, it was not clear at all whether the first positions were perceptually missed or whether the first positions were simply displaced in the direction of motion. Only later studies revealed that observers have indeed no access to the first positions…Thus, a mechanism is called for that prevents the very first positions from being perceived" (Müsseler & Aschersleben, 1998; Müsseler & Tiggelbeck, 2013). Thus, we use the Fröhlich effect as evidence of the work of the proposed internal mechanism, which is under investigation.

The purpose of the study was to test the efficiency of the model of formation of symmetrical-binary anisotropic relations in space and time built on the basis of the transcendental psychology approach. Theoretical study of the model showed that at the border of the functional range of perception of rapidly transforming objects, asymmetry arises in the formation of a stream of temporal relations during the perception of expanding and contracting resizing objects. This means that stimuli decreasing in size at a high rate must show the offset Fröhlich effect, or representational momentum. This does not mean that the memory for a target is shifted in the direction of target motion, but in a certain case it can be assumed in advance that it will not be possible to see the final position of this target.

2. Model

When understanding the effectiveness of the perceiving system, A.I. Mirakyan highlights the following procedural conditions (Mirakyan, 2004: p. 354). The first is the discretization of the forms of "spatiality" and the continuity of time. The second possibility is the possibility of fixing relationships between discrete elements of a spatial form at a certain point in time. The third possibility is the possibility of forming relationships between the data of different points in time.

In a simple general model of the reflective system proposed by Mirakian, the first condition is provided by the discrete organization of the visual system. Incidentally, there is evidence that the flash-lag, Fröhlich and related motion illusions are natural consequences of discrete sampling in the visual system (Schneider, 2018). Spatial relations between primary elements are formed by secondary symmetrical-binary elements, fixing the relationship between discrete spatial elements, symmetrical about the visual center. This meets the second condition. It is known that perception of visual symmetry is fast and efficient and relies on both early low-level and late mid- and high-level neural mechanisms, and can act as a grouping cue for visual perception (Martinovic et al., 2018; Maldonado Moscoso et al., 2022). Formally, perceptual constancy and permanence of objects are invariants, also known in mathematics and physics as symmetries (Pizlo & de Barros, 2021). Relationships in time between secondary elements ensure the fulfillment of the third condition. In particular, Mirakyan proposed the idea that the spatial extent of objects can be mediated only by temporal characteristics of perceptual process and be obtained in the absence of a specialized spatial analyzer (Mirakyan, 2004; Shookova & Artemenkov, 2017).

According to these theoretical assumptions, the results of centrally-symmetric relations between the elements of the receptive field may be involved in formation of temporary relations. This refers to the phenomenon of perception of a moving object, which can be associated with the sequential formation of relations between individual discrete time instants of visual process. These relations should have certain time to establish, and that is possibly why it is hard to see the start of the process of short-term presentation of objects that move or resize at a fairly high speed. Thus, we propose a new "internal" explanation for the Fröhlich effect.

The simplified dynamic model of sequential formation of temporal relations between the results of centrally symmetrical relations of a contour size changing objects on the plane is shown in the **Figure 1** below. What is important for conducted experiments, it indicates the possibility of the appearance of the opposite reversed Fröhlich effect (occurs offset as presentational momentum but in reversed order in time) when the initial position of the decreasing stimulus is seen better than its final position since smaller object instants can be processed by the visual system earlier than larger instants of the object transformed (Artemenkov, 2005, 2007, 2009).

According to the model, the presentation of different objects to a certain perceptual system, results in forming different centrally-symmetric relations during the period of gaze fixation, leads to fixation of these relations, and then further formation of new relations between fixed results of the initial relations at different moments of time. This process is connected with a certain direction of the flow of temporary relations, shown in **Figure 1** by hollow arrows. The direction of this flow is changed in regard to the direction of the object's resizing (A—size increasing, B—size decreasing) and the speed of this resizing (C—only for the case of a high rate of size reduction).

This supposes qualitative difference in perception of the A and B objects while the speed of size changing is increasing and provides an experimental method for verification of possible formation of centrally symmetric relations using presentation of these objects within and out of the functional range of motion seeing (10 - 60 visual deg/sec). The method was based on the detection of the

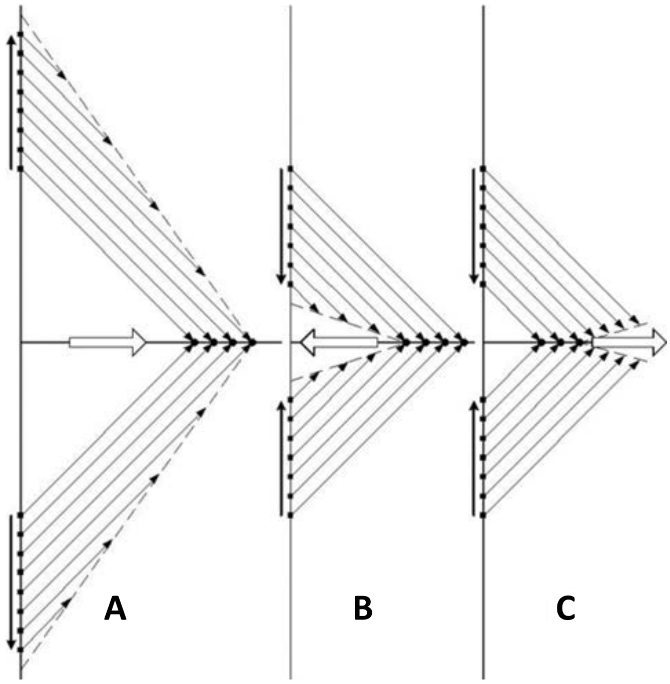

Figure 1. General model of the dynamic formation of centrally symmetric relations for display of a contour size changing objects on a conditional linear receptive field (A—increase in size; B—decrease in size at low speed; C—decrease in size at high speed; hollow arrows show the direction of the flow of the forming of secondary temporary relationship).

place of the Fröhlich effect under different speed conditions of perception of transforming contour objects.

3. Methods

Presented experiments were devoted to a systematic psychophysical study of the visual perception of symmetrical objects (in particular, contrasting images of polygons) that change their size in two directions and at different speeds, including exceeding the functional speed limits of ordinary vision. The moving visual stimuli had the shape of contour black hexagons on a gray background, ranging in size from 3.2 to 7.2 degrees of angle and with a contour line thickness of 1.2 degrees. The size of the figures was changed on the basis of frame-by-frame display of images on the monitor screen at a scanning speed of up to 300 frames per second without gaps between the contours. The rate of change in the size of the figures had three ranges: 15, 30, 60 degrees per second. For the presentation of visual stimuli, special software based on PsychoPy (Peirce et al., 2019) was used.

3.1. Participants

Thirty right-handed healthy volunteers with normal vision (Mage = 23.5 year; range = 22 - 25 years; 70% males), all monolingual Russian speakers, participated in the study. All subjects gave their written informed consent.

3.2. Procedure

The experimental procedure included short-term presentation to the subject of a random sequence of dynamic morphing visual stimuli of the same type in the center of the display screen. The stimuli were contour figures that changed in time in magnitude up or down. There were 6 options in total: figures A and B, C (in Figure 1), changing at a speed of 15, 30 and 60 degrees per second. The rate of change also randomly varied. Each of the six stimulus variants was presented 25 times.

A central dot was presented before each stimulus. Then a figure changing in size was shown, which, when it reached a larger or smaller size, disappeared. After each presentation of the figure, it was necessary to answer the question of what was seen better (more clearly) in the subject's eyes: the place of a large or small size of the figure? A small size shape corresponded to pressing the "left arrow" on the keyboard, and a large size shape corresponded to the "right arrow" on the keyboard. To start each next presentation of the stimulus, it was necessary to press the space bar. At the end of the presentation of stimuli, the inscription "End of the experiment" was displayed on the screen.

4. Results

The data received from the respondents were converted into a format that corresponded to the quality of the subjects' vision of the initial position of the presented figure, which changed in size, as a percentage in relation to the vision of the final position of the figure. The corresponding results, averaged over presentations and subjects, are shown in Figure 2.

It can be seen that at a sufficiently low rate of change of stimuli, the subjects generally see the initial position of the presented figure much worse than its final position. In principle, this corresponds to the Fröhlich effect and to the model

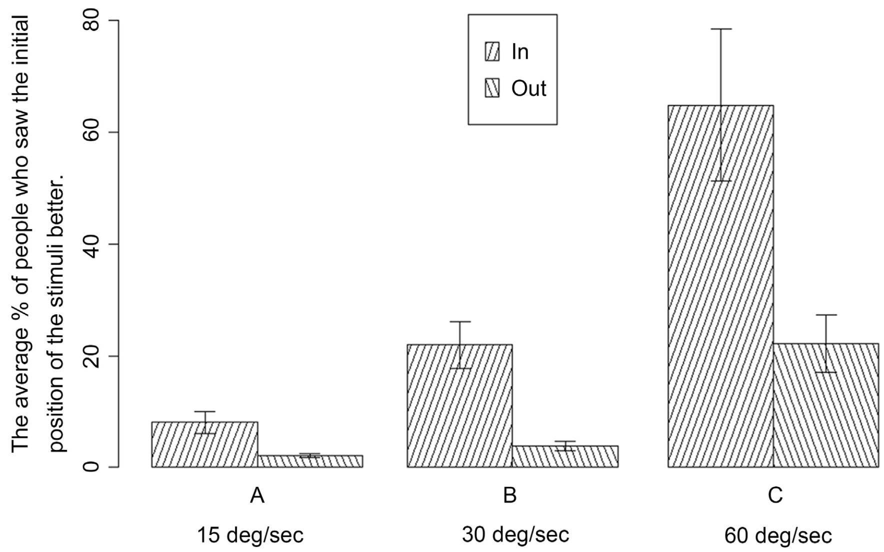

Figure 2. The average percentage of people who have better seen the initial position of the visual stimuli, decreasing (In) and increasing (Out) in size.

shown above in **Figure 1** regardless of the direction of the object shape change. Herewith, there are more cases of better vision of the initial position of decreasing objects than for increasing objects, regardless of the speed of objects' changing. At the same time, the percentage of such subjects increases significantly with an increase in the rate of change of stimuli. For a speed of 15 degrees per second, 8% of subjects saw the start position of the shrinking stimuli, while for a speed of 30 degrees per second, 22% did, and for a speed of 60 degrees per second, 65% did (Artemenkov, 2021b).

Thus, for the last high speed there were a significant number of tests with the reversed Fröhlich effect, which was predicted by the model. In this case, subjects can see the starting position of the shrinking object better than the ending one in most cases. This result allows us to verify the model of human visual perception based on the hierarchy of center-symmetrical and further temporary relationships.

5. Discussion

On the whole, the conducted experiments confirmed the preliminary experiments at lower speeds of stimulus movement (Artemenkov, 2005, 2007, 2009). The previous difficulties in reproducing fast, smooth changes in stimuli in ordinary computers explain the gap between preliminary and current experiments.

It can be argued that contour objects that change in size exhibit the Fröhlich effect. It is usually impossible for these stimuli with a speed of resizing up to 10 - 15 visual deg/s to see the start of the process, while the final position of the object can be observed better regardless of the direction of resizing.

As noted above, speaking of the Fröhlich effect, we mean not just a spatial shift in the starting position of the vision of a moving stimulus, but the fact that this start is simply absent in the representation, which follows from the proposed general model. That is why in our experimental practice, we rely on the general point related to the fact that the first position is not clearly visible as it is excluded from perception. The final position, even it can be connected with representational momentum, is regarded visible.

As it was indicated above, for the decreasing case and speed of 60 deg/s, there was a significant number of tests with the offset Fröhlich effect (representational momentum in the accepted classification), which was predicted by the model. However, we consider this phenomenon as a new inverse Fröhlich effect due to the special circumstances of its discovery.

The result obtained need further verification, since at a high rate of change in the size of objects, the subjects had real difficulty in perceiving them. It should be noted that this speed was outside the functional range of being able to track motion and see objects moving smoothly. In such conditions, attention suffers too. All this led to an increase in errors in distinguishing the clarity of vision of the beginning and end of the movement.

Some of the subjects had difficulty understanding the instructions. Others could hardly distinguish the changes taking place before their eyes. In particular, in preliminary experiments, when the thickness of the contours of the presented stimuli was reduced to such an extent that they ceased to overlap in frame-by-frame scenes, objects changing at high speed were often seen as simultaneous patterns.

Unlike studies of various phenomena of visual perception discussed in the introduction, this work is devoted to an attempt to identify a phenomenon that follows from the mechanisms of operation of a hypothetical general model of the perception process. The revealed phenomenon here is not just discovered in the experiment, but is primarily a consequence of theoretical ideas about the mechanisms of the perception process. Thus, the considered phenomenon of the reversed Fröhlich effect is new because it was predicted by the theory earlier than it was discovered (Artemenkov, 2009). As we noted earlier, the model presented in the article offers a new explanation for the Fröhlich effect, which is determined by a natural delay in establishing of relationships in time in the situation of the appearance of an object in the field of view.

From our perspective, ordinary considerations of various phenomena related to the psychophysics of perception cannot fully serve as adequate means for explaining the processes of perception. According to the theory, these processes are generative, and their mechanisms cannot be based on the properties of their products (Artemenkov & Harris, 2005).

In particular, in this case, one can doubt the correctness of using the principles of grouping of Gestalt psychology, often used to explain visual processes. These principles proceed from the phenomena of field interactions of spatial elements of images, and thus, in one way or another, they are primarily based on the phenomenology of the products of perception.

The results obtained allow us to take a fresh look at the nonretinotopic feature attributions, for example, reported in (Otto et al., 2006), which follow rules of spatial grouping. The ideas of the transcendental psychology of perception explain how these same phenomena can be understood on the basis of the formation of temporary relationships.

6. Conclusion

The Transcendental Psychology Approach to the study of perception (A.I. Mirakyan) has been developed since 1990. It assumes that in the perception there are so-called structurally-generative processes that are realized outside their mediation by conceptualization. To study these transcendental processes, it is proposed to use an axiomatic methodology based on general natural principles that provide conditions and possibilities for form creation.

Theoretical investigations (Mirakyan, 1995, 1999, 2004; Artemenkov & Harris, 2005; Artemenkov, 2021a) revealed that the process of object recognition taking place during gaze fixation may be characterized by the creation of center-symmetrical relations accompanied by the further formation of temporary relationships. The dynamic model developed on this basis showed different behavior for expanding (A) and contracting (B) symmetrical objects that change their size at different speeds (Artemenkov, 2005, 2007, 2009). With the help of Fröhlich effect an experimental method was presented in this article, which claims a qualitative difference in perception of beginning and final localization of the A & B objects while size changing speed is increasing. The Fröhlich effect is used because the first position of a moving stimulus is not seen (Müsseler & Kerzel, 2018).

The studied model indicated the possibility of the appearance for subjects of the reversed Fröhlich effect for stimuli decreasing in size at high speeds of 15 - 60 deg/s (out of the functional range of motion seeing) and this has been confirmed in experiments (Artemenkov, 2021b). The results of the experiments allow us to speak about the possibility of verifying the proposed model (showing the hierarchy of center-symmetrical and further temporary relationships), including the principles of transcendental psychology on which it is based. At the same time, the conclusions made require further theoretical and experimental verification.

Following the ideas of the transcendental psychology of perception, it is possible to take a fresh look at the explanatory principles of Gestalt psychology, which are largely based on the rules of spatial grouping and thus explain the visible and invisible elements of objects using spatial characteristics. These same phenomena can be explained by the formation of temporary relationships in the considered model.

Limitations

For greater validity of the conclusions, it is desirable to expand the sample through research within different subjects and other experimental conditions. This will allow a deeper analysis of the reversed Fröhlich effect.

Ethics Statement

Healthy senior university students participated in the study. They gave their consent.

Conflicts of Interest

The author declares no conflict of interest.

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