




Solving the Issue of Finding Differences in an Illusory Context

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Abstract

Introduction. There are two opposite theoretical descriptions of visual perception: constructivist and ecological. To solve the issue of whether the perception of visual illusions is the result of a decision or whether such perception is natural and can be described using an ecological approach, an experiment was conducted to find differences in an illusory and nonillusory context, which reflects the novelty of this study. **Methods.** The subjects were offered a series of paired images in which it was necessary to find the difference as quickly as possible. The images could be the same: One picture could be 10 % larger than another, or, due to the illusory context, one picture could seem larger than another, and the image size was subjectively distorted due to the illusion of Ponzo and Delboeuf. According to the instructions, the size difference (real or apparent) should be ignored, and it was necessary to look for other differences. The time and precision of the response were measured for each option. **Results and Discussion.** Significant differences in visual field search time were found for images with an illusory difference, a real difference in size, and identical ones. For the first time, it was found that the problem is solved more efficiently (faster and more accurately) in the presence of two exact images, and the lowest efficiency is observed when solving a problem with an illusory difference in the size of images. It is concluded that the illusory context has an additional inhibitory effect on the process of solving the problem of finding differences. The advantage of describing the perception of visual illusions using a constructivist approach is experimentally shown.

Keywords

perceptual illusions, differences tracing, constructivism, Ponzo illusion, Muller-Laiyer illusion, Delboeuf illusion, ecological approach, visual perception, post-conflict slowdown, cognitive errors

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Introduction

Illusions are usually defined as errors in which subjective perception does not correspond to the actual parameters of the object. Errors can be associated with various reasons: optical phenomena (for example, the effects of light refraction), the device of the senses (blind spot phenomenon), insincere limitations of information (size illusions that occur when observed through a hole with one eye in the Ames room), incorrect judgments about size, shape, colour (geometric illusions, some colour, and contrast illusions). For this study, it is the last significant set of illusions, namely geometric illusions. They are the subject of active theoretical discussions in the field of visual perception.

There have been two opposite descriptions of visual perception in the scientific literature for more than a century (Glottzbach & Heft, 1982) – constructivist and ecological. Both approaches have deep philosophical roots. The founder of the **constructivist** approach in the study of visual perception is G. Helmholtz (1821-1894), and the **ecological** one is J. Gibson (1904-1979) (Gibson, 1950, 1979). These approaches are also commonly referred to as «indirect» and «direct», respectively. The indirect approach assumes the need for the existence of «unconscious conclusions» based on past experience, knowledge, attitudes. The process of perception is accompanied by transformations and calculations in the visual system, thanks to which the subjective image corresponds to reality. For representatives of the **constructivist approach**, the illusions of perception are convincing proof that our perception is not direct but depends on assumptions, hypotheses, and processes of a «higher level» instead (Men'shikova, 2007). Richard Gregory, a prominent representative of constructivism, described illusions as deviations from reality, situations when what we perceive does not correspond to any physical characteristic of a particular scene (Gregory, 1997). For example, two equal segments seem to be different in length (Muller-Lyer illusion or Ponzo illusion), two same circles seem to be different in size (Delboeuf and Ebbinghaus illusions) (Stuart, Day & Dickinson, 1984; Bertamini, 2018; Evans, 1995). You can check and verify your own mistake by using a ruler, but even knowing that objects are equal does not free a person from illusory perception.

COGNITIVE PSYCHOLOGY

From the point of view of the **ecological («direct») approach** representatives, illusions are not at all a valid justification for the correctness of constructivists (de Wit, van der Kamp, & Withagen, 2015). J. Gibson emphasises that the process of obtaining information is «direct», that is, there is no need for intermediaries in the form of «installations», «thinking», or experience. Perception is presented as a direct «scooping» of information from structured optical stimulation. Stimulation contains all the information about the outside world, so there is no need to use any mental constructs for subjective perception to correspond to reality since it already corresponds to reality. The correspondence of reality is provided by the optical system, which is constantly changing under the influence of the movements of the observer and the surrounding space and is specific to different situations.

Thus, an **illusion** from the point of view of an ecological approach is a certain situation in which perception corresponds to what is commonly called an illusion. Brian Rogers writes that the best definition of illusion is the discrepancy between the available information and what we perceive. With this interpretation, the available «information» becomes an «objective or physical reality». That is, there are no illusions in the sense that this phenomenon is not a mistake at all, but the inevitability of processing «available» information (Rogers, 2017). The author compares the illusion with thresholds: If dim light is not visible or a quiet tone is not heard, we assume that this is how our **perception systems work**. That is, all sensory systems have thresholds, but we do not believe that these are visual or auditory illusions. Naturally, under certain conditions, we may not hear a sound or see light if these are subthreshold stimuli. We do not consider our inability to see the smallest details of objects far away from us as an illusion, it is just a consequence of our limited visual acuity. It follows from this fact that perception effects such as illusions, by analogy with the phenomenon of thresholds, demonstrate the work of perception systems. As soon as we understand how and why a specific effect is created, for example, colour metameres (or thresholds), we no longer consider it as an illusion but a specific aspect of the perception system. If this is the case, then it suggests that the only remaining «illusions» are those aspects of perception that we do not yet understand! (Rogers, 2022) It seems that the statement that illusions are perceptual phenomena that we do not yet understand is very convincing. If only there were aspects that we would understand well. It is known that sensory systems have thresholds, but the very nature of the threshold remains a mystery (Allakhverdov, Karpinskaya, 2021), however, as well as the phenomenon of metamerism, which still has no unambiguous explanation (Hurlbert, 2019). Thus, such a view does not reveal the nature of illusions of perception, but only states the fact of their existence.

It is impossible to determine with the help of perceptual illusions which of the approaches – constructivist or ecological – is preferable. However, the issue of whether the illusion is a mistake, the result of a decision and an unconscious conclusion, or a natural phenomenon caused by the work of the senses under certain conditions is of interest in itself.

Decision-making occurs when it is necessary to choose two or more alternatives. The effect of the so-called «post-conflict slowdown» is known when solving problems where incongruent stimuli are introduced that must be ignored. (Rey-Mermet & Meier, 2017). Post-settlement deceleration is investigated in the task-switching paradigm, the prospective memory paradigm, as well as in Stroop, Simon and flanker tasks (Stroop, 1935; Simon & Rudell, 1967; Eriksen & Eriksen, 1974). All these tasks are united by the need to ignore stimuli that conflict with the correct answer, since one or more properties of these irrelevant stimuli correspond or corresponded to the correct solution in the previous series of tasks, which led to the learning to answer according to the (already) irrelevant characteristic. Since the slowdown is present in all tasks where there is a conflict of several stimuli or properties, you can use this indicator as an indicator of conflict. That is, a decrease in the reaction rate in a task where it is necessary to ignore any characteristic implies the presence of a conflict. The mechanism of such a slowdown is described in various works on the study of cognitive control. It is believed that when a person is faced with a conflict, cognitive control allows them to choose properties relevant to the goal and block irrelevant properties. Thus, the presence of a conflict and the reaction to it affect the effectiveness of solving the problem (for example, Moroshkina & Gershkovich, 2008; Allahverdov, 2014; Botvinick, Braver, Barch, Carter, & Cohen, 2001).

If we imagine a task in which the subjects need to find differences in two pictures that differ in two parameters (one explicit and one parameter that requires additional effort in the search), then due to the conflict of obvious and hidden differences, we should expect a decrease in the efficiency of searching for the second difference compared to two images with only one implicit difference. For example, if the subject needs to find differences in two identical images and two images that are different only in size (while the size is declared insignificant, an irrelevant parameter that should be ignored), then it is likely that the time to search for differences in two images that are different in size will be longer than in two identical images. A similar deceleration effect can be assumed for two pictures that differ in size only due to an illusion. Even if the difference in size is illusory, the stimuli are still recognised and perceived as different, which means that this fact must be ignored, so cognitive control mechanisms associated with slowing will be involved.

Let us imagine that the hypothesis that the search for differences will be less effective if it is necessary to ignore differences in the size of images (it does not matter if the differences are actual and illusory) has been confirmed. This would only indicate that illusory perception does not differ from the perception of actual differences; similar patterns can be observed when solving the problem of finding differences in illusory and nonillusory stimuli. But this does not allow us to answer the question whether the illusion is the result of an unconscious conclusion and a kind of «erroneous» decision or is it a natural result under given conditions and not at all a manifestation of a cognitive error.

The study of errors has a long history. The effect of slowing down after an erroneous decision «post-error slowing» is widely known. Rabbit (1966) wrote about the slowdown that occurs after an error, but in their experiments, it was mainly about conscious mistakes

COGNITIVE PSYCHOLOGY

that the subjects could correct. Presumably, the delayed response to the stimulus that followed after the erroneous response is associated with the need (to correct the error, be more careful in the future, and not make a new mistake), as well as with the fact that the error knocks out of the «rhythm» when solving a series of problems (Rabbit, 1966). Currently, it is believed that the primary purpose of slowing down and correcting after making a mistake is to optimise the behaviour and avoid its recurrence. There are a large number of studies revealing the effect of slowing down after an error (Jentsch & Dudschig, 2009; Hoonakker, Doignon-Camus & Bonnefond, 2016; Purcell & Kiani, 2016; Wang, Pan, Tan, Liu & Chen, 2016). The response time increases even after an unconscious error. For example, in Cohen's electroencephalographic studies (2009), neurophysiological effects associated with errors (post-error adaptation) were recorded regardless of whether the error was realised or not. In addition, the «go/no-go» paradigm revealed that the slowing effect occurring after an error is also characteristic of unconscious errors. In particular, the subjects performed «go» trials after unconscious errors more slowly compared to correct answers. In the case of conscious errors, more time is required for a subsequent response than in the case of unconscious ones (Cohen, 2009). Presumably, greater involvement of cognitive control resources is required to confirm unconscious errors, which leads to a lack of these resources in the subsequent processing of new stimuli (Shalgi, O'connell, Deouel & Robertson, 2007). If we consider an illusion as some kind of judgement error, then the error presence should affect the speed of solving the problem (slowdown) associated with this error, regardless of whether the error can be corrected or not.

In our studies, we offered the subjects a series of paired pictures in which it was necessary to find the difference as quickly as possible. There were three options for pairs: in the first option, the images in the pair were exactly the same; in the second option, the images of the pairs differed in size by 10 percent (one image in which it was necessary to look for a difference was larger than the other); in the third option, the size of the images was subjectively distorted due to the illusion of Ponzo and Delboeuf, so that one image only illusory seemed larger than the other. The subjects had to decide whether there were differences or not, ignoring the difference in size (subjective or objective).

Purpose of the study: Revealing the differences in the efficiency of solving the problem of finding differences in identical images, in images differ in one parameter (size), and in images having illusory differences in one parameter (size).

Hypotheses:

- In a difference search task, the response time will be longer for images that already have an obvious difference in size (illusory or real) compared to images without size differences. This is due to the need to ignore information that corresponds to the parameters of the problem solution, but, according to the instructions, appears irrelevant.
- Finding differences in images that only illusory differ in size will take longer

compared to images that actually differ in size. The increase in reaction time is the result of the unconscious fixation of the error (illusion) and the subsequent slowing effect after the error.

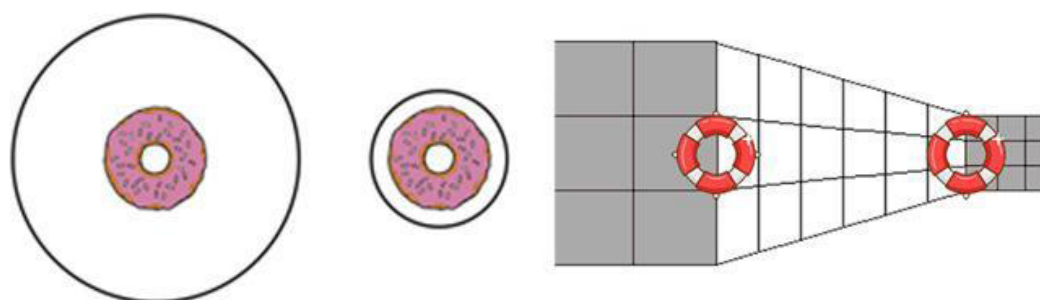
Methods

The experiments involve 49 people (42 women and 7 men aged 18 to 35 years), who participated voluntarily. Subjects had normal or corrected to normal visual acuity.

Pairs of images were used as stimuli. An example of stimuli is shown in Figure 1.

Figure 1

Example of stimuli with the Ebbinghaus and Ponzo illusion



All stimuli were presented on a 19-inch computer screen. PsychoPy software was used to present stimuli and record responses.

Participants were asked to answer whether the two images differ in **details**, such as extra strokes or lack of some details. The differences in size or context surrounding the image had to be **ignored**. The stimulus images were divided into two equal parts: one had differences, and the other did not.

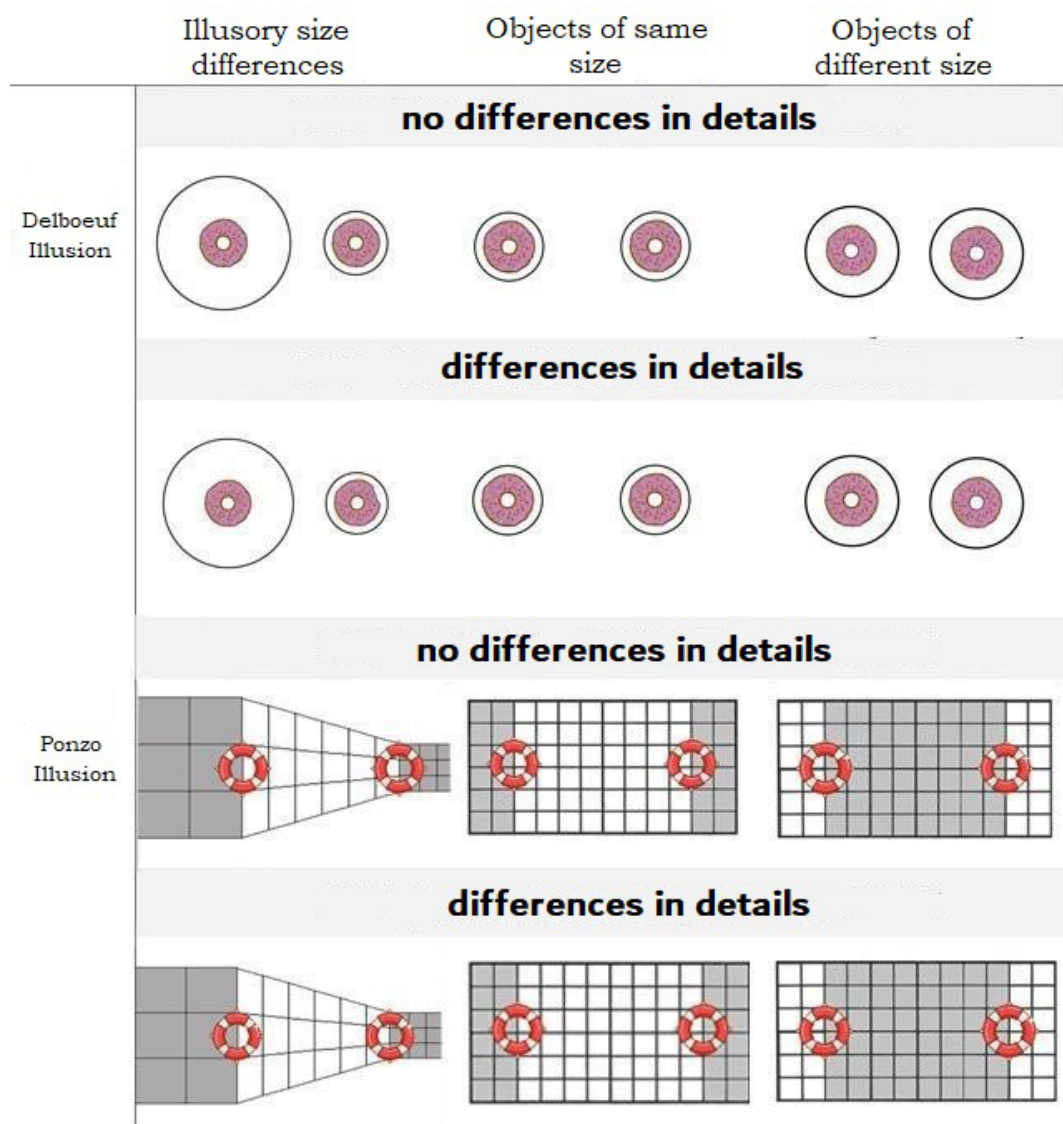
In total, the subject was shown 72 pairs of objects in random order: 24 pairs of objects of the same size, 24 pairs with a 10% difference in size, and 24 pairs with an illusory size difference. Of every 24 pairs, 12 had differences and 12 did not. A pair of images were shown on the screen simultaneously for 5 seconds, then the participants had 2 additional seconds to respond by pressing the keys on the keyboard (there is a difference, there is no difference).

For the illusory difference in size, we used 12 pairs of Ponzo illusions (+12 pairs without illusions and 12 pairs with a 10% difference in size), as well as 12 pairs of Delboeuf illusions (+12 pairs without illusions and 12 pairs with a 10% difference) (Fig. 2). As a result, each

COGNITIVE PSYCHOLOGY

subject received 12 pairs with illusions and the same number of control stimuli (without the illusion of equals and different in size).

Figure 2
Examples of stimuli with and without differences



Note: Extra attention should be paid to the sides of the donut, and the details on the lifebuoy edges in the examples «with differences in details». These are the relevant differences in the pair that the subject must find.

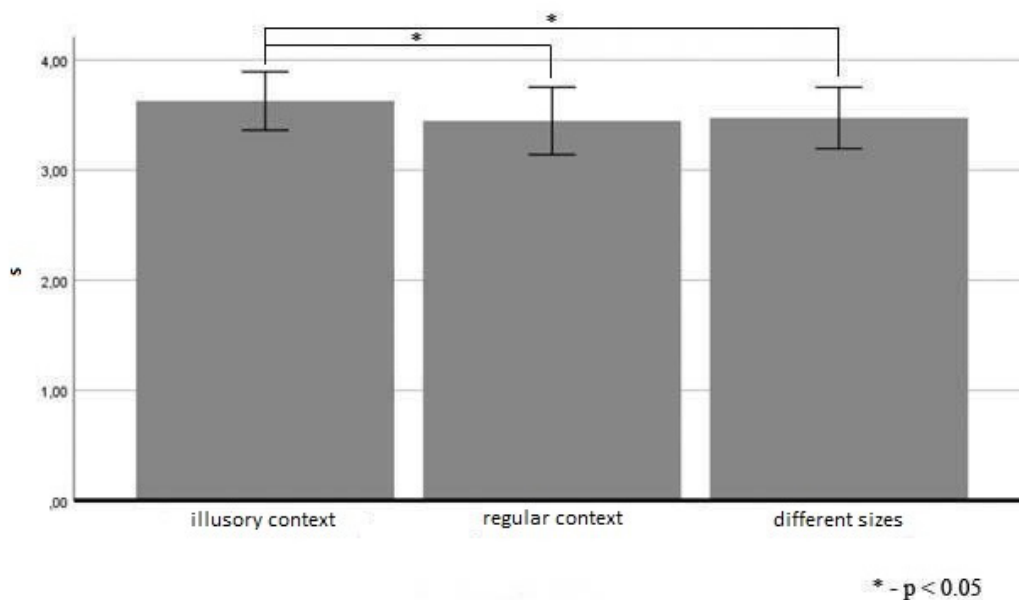
Results

Experiments were conducted, and the response time was recorded in a situation where a decision was made about the presence/absence of differences in pairs of images, where there were no differences and where differences were actually present (in addition to the stated real or illusory size differences). Everywhere in the results we are talking about differences that have nothing to do with size (real or illusory) or context. The differences are the details of the drawing, as indicated above in the example in Fig. 2.

We found that when there was an illusion of a difference in size, participants took longer to respond compared to situations where there was no illusion ($F(2,48) = 3,32$; $p < 0,05$) (Fig. 3, Fig. 4).

Figure 3

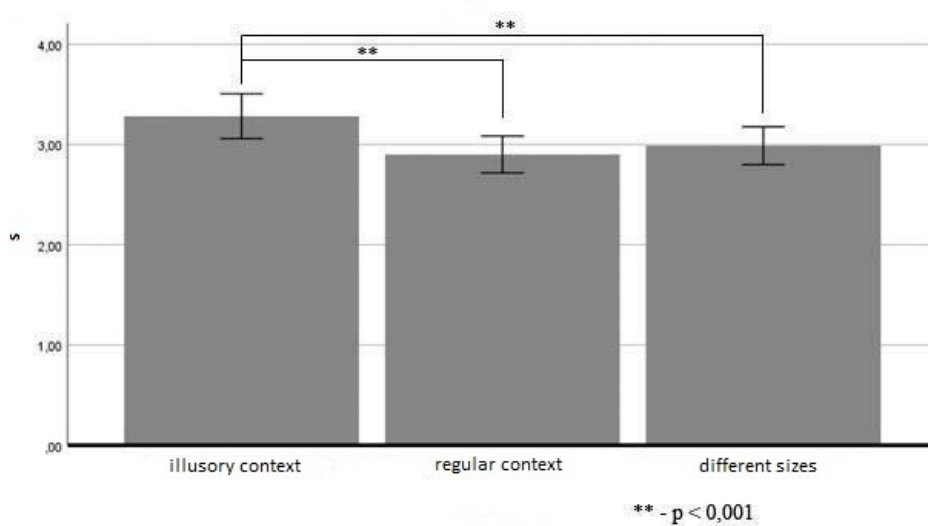
Response time when searching for differences in pairs of objects without differences



COGNITIVE PSYCHOLOGY

Figure 4

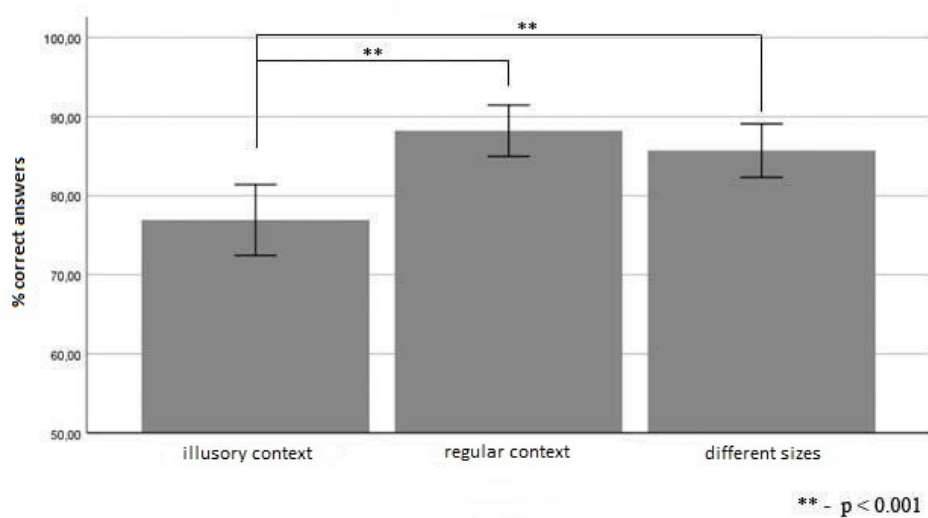
Response time when searching for differences in pairs of objects with differences



In addition, in the illusory context, participants made more mistakes and reacted more slowly than in other contexts (Fig. 5, Fig. 6). This is true both for pairs of the same size and for pairs with a 10% size difference. In the absence of differences between the objects, the subjects made more false alarm errors than in the illusory context ($F(2,48) = 13,7$; $p < 0,001$).

Figure 5

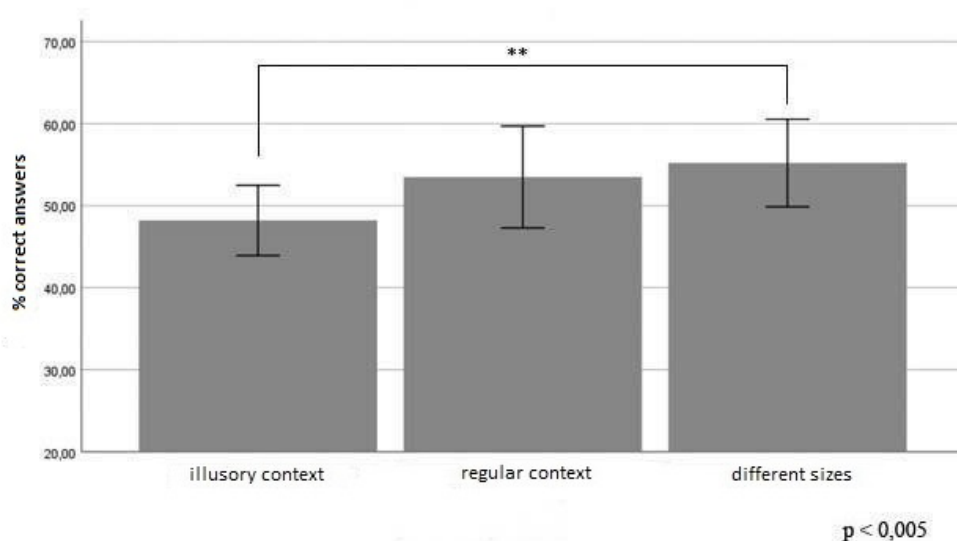
Response accuracy when searching for differences in pairs of objects without differences



In cases where there were differences between objects, the subjects made more omission errors in the illusory context ($F(2,48) = 3,68$; $p < 0,05$). The difference was significant between pairs with illusion and pairs with an illusory context.

Figure 6

Response accuracy when searching for differences in pairs of objects with differences



As a result, we found that illusory conditions lead to a decrease in the efficiency of finding differences between two objects (in cases with and without differences). This affected both accuracy (the number of errors) and reaction time.

Discussion

The results of the experiment showed that the efficiency of finding differences in an illusory context differs significantly from that in conditions without illusion. This is expressed in an increase in reaction time when deciding on the presence/absence of differences in the pictures, as well as in an increase in the number of errors (both false alarms and omission errors). There is no unequivocal opinion in the literature on what aftereffect an erroneous decision has on the parameter of subsequent errors. There are experiments that demonstrate both a decrease and an increase in the number of errors after a wrong answer. The mechanism associated with increasing the accuracy of responses after an error is most often cited as cognitive control, due to which subjects become more careful with subsequent responses (Williams, Heathcote, Nesbitt & Eidels, 2016). The articles most often report a follow-up increase in the accuracy of answers,

COGNITIVE PSYCHOLOGY

which is considered a consequence of increased cognitive control. However, there are other studies that show that the relationship between error and subsequent increase in accuracy is not so conclusive (Buzzell, Beatty, Paquette, Roberts & McDonald, 2017). It is known that with a short interval between the stimulus and the response, there is not an increase, but a decrease in the accuracy of the response (thus, the subjects make more errors of missing or false alarms). The authors state that the very process of error detection leads to a limitation of attention due to the fact that resources are directed to determine whether an error has been made. In turn, this can actively inhibit task-related sensory processing. The results show that errors do not lead to increased control and suggest that there are competing processes of distraction and control that follow errors (Dutilh et al., 2012).

In our study, the hypothesis that the task with illusion will be solved least efficiently compared to other conditions was confirmed. As it turned out, the effect of illusory size differences leads to a more significant increase in response time compared to the effect of real differences in size. The data show that for the observer, the situation of illusory size differences is not identical to the situation of equal objects' sizes, nor the situation of real size differences. The illusion complicates the task, which expresses itself in an increase in the solution time and the number of errors.

As we mentioned above, there are two opposing views on the nature of illusions: the ecological approach considers illusions as a natural consequence of perception in the environment, where the observer is not able to perceive illusory different objects as equal; and constructivism that considers the perceptual illusion as an error of interpretation (in the case of our study, this error concerns precisely the size of objects).

When looking for differences, a person needs to identify two objects and then choose the parameter by which these objects differ. If there are no obvious differences (colour, size, shape, and others) between the two stimuli, the search process begins as soon as the task is given. If there are any differences, for example, different sizes of stimuli, then these differences will interfere with the search for other differences for some time. It will be until the observer is distracted from this parameter and stops considering it in their task, thus identifying two stimuli. Only after that one can move on to the next difference. This effect, which manifests itself as an increase in response time, is observed in the task with actually different stimuli compared to the task with identical images.

However, what if the difference between the stimuli is an illusion? When comparing the task with the illusion and the task with real differences, we found a decrease in performance in the task involved with the illusion. We believe that the nature of this slowdown in our experiments is similar to what happens in experiments with an unconscious error: the observer fixes the illusory difference as an error, which has an additional inhibitory effect on the search for a relevant difference (not related to size). Thus, the solution time increases not only in comparison with the situation of identical stimuli, but also in the situation of indeed different stimuli.

The results of our experiment testify in favour of the constructionist idea on illusion as an erroneous perception.

Conclusion

- Perceptual illusion is a unique phenomenon, concerning which discussions are developing within the framework of two opposite approaches to visual perception: constructionist and ecological. According to the constructionist, illusory perception is the result of a decision; and, according to ecological, illusory perception is natural under certain conditions, since this is how our senses operate.
- The lowest efficiency of problem solving was revealed when using illusory differences compared to the presence of differences and their absence.
- It is concluded that the illusory context has an inhibitory effect on the problem of finding the differences. This is consistent with the constructionist approach to visual illusions.

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Valeriia Yulevna Karpinskaia designed the experiment, moderated article content.

Natalia Vladimirovna Andriyanova designed the experiment, processed data.

Margarita Georgievna Filippova collected data, organized the experiment.

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Conflict of interest information

The authors have no conflicts of interest to declare.