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UDK 159.937
Original scientific paper

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INATTENTIONAL BLINDNESS AND PERCEPTION OF ILLUSORY CONTOURS[2]

Abstract

This paper seeks to address questions and variations regarding the importance of attention in the perception of illusory contours within the paradigm of *inattentional blindness*. Previous research has predominantly focused on the perception of illusory contours within the framework of Treisman's Feature integration theory, which can conditionally be regarded as a different approach to the theory of inattentional blindness. Inattentional blindness is a phenomenon in which stimuli that are presented to us are not perceived when we are engaged in a task that requires attention. This concept provides a direct insight into the necessity of attention in the perception of illusory contours, in a way that higher *inattentional blindness* requires a greater degree of attentional engagement. The first part of this study describes two experiments that examined the perception of one type of illusory contour - the illusory triangle. The experiments also sought to determine if there were specified differences in perception of these configurations, considering a position of presentation. In the first experiment the illusory triangle was displayed in the center, and in the second experiment on the periphery, in order to evaluate the potential for differential perception. The second part of this study discusses two additional experiments examined the perception of contoured forms as a variation to the controls detailed in part one of the study. The purpose of these additional experiments was to compare two groups that worked in inattentional conditions in order to examine differences in the processing and perception of illusory and non-illusory contours (contoured form). The findings that the phenomenon of *inattentional blindness* is evident in the perception of both contour variations, implies the need for engagement of attention in order to form a holistic perception. The findings also demonstrate that the position of these stimuli has a tangible effect on inattention perception.

Keywords: visual attention, inattention blindness, illusory contours, contoured forms

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[2] Presented research was partially financially supported by Ministry of Education, Science and Technological Development of the Republic of Serbia under contract # ON179033.

Introduction

Illusory contours are specific configurations of stimuli evaluated by theorists interested in the problem of binding of object properties. The specificity of our visual system is reflected in the ability to complete internal perception, that is, creating coherent perceptual units on the basis of incomplete or insufficiently specific stimulation. Illusory contours are product of this process, and can be defined as amodal completion – or articulation of perceptive units that does not exist on the stimulation or sensory level. Kanizsa (1955, as cited in Gvozdenović, 2011) was the first theorist who presented illusory contours in this context, using the Gestalt Principles to explain the perception of this phenomenon. Kanizsa emphasized the importance of perceptual economy and the concept of closure, according to which our perceptual system tends to, with the least possible effort, articulate a meaningful, coherent, and well-organized level of perception. Obviously, this idea fits well as a possible explanation of illusory contours perception.

However, in this paper we will try to address a different question concerning illusory contours perception. So far, it is not sufficiently clear as to whether the perception of this particular phenomenon depends on attention and causing excitation of higher-level cognitive mechanisms, or is done automatically in the early stages of seeing (in the absence of attention). Some neuropsychological studies support the processing of lower level. Studies on monkeys have shown that certain neurons in the visual cortex (area V1 and V2) respond to illusory contours (von der Heydt & Peterhans, 1989). Studies in humans have shown that illusory contours, of Kanizsa's type, evoke responses of neurons in V2 area, but not in V1 area (Vuilleumier & Landis, 1998). Classical behavioral studies, visual search for example, mainly examined the process of perception of illusory contours within the conception of Treisman's Feature Integration Theory (Treisman & Gelade, 1980). The most important postulate of the Treisman's approach is the existence of two phases of perception – preattentive and attentive vision. Preattentive vision occurs without the involvement of cognitive processes and includes rapid detection and assimilation of elemental characteristics of stimuli according to the laws of perceptual organization. Focused vision refers to the integration of detected elemental characteristics from a holistic perception of an object through visual attention. Although identical in their initial theoretical assumptions, the different studies of illusory contours have demonstrated different and often contradictory results. The research carried out by Grabowecky and Treisman (1989) contests the hypothesis of early vision with regard to illusory contours, while the findings of other authors (Davis & Driver, 1998) are consistent with the thesis of early vision. Their results indicate parallel coding for multiple Kanizsa subjective figures. They found parallel emergence of occluding subjective surfaces even though participants had no intention of searching for subjective surfaces.

Within the Treisman's theory it is not clear whether the perception of illusory contours requires attention or is carried out automatically, during the early stages of vision. However, there are a number of relatively new theoretical considerations that cast a fresh light on the process of this form of perception. This alternative theoretical approach is based on the Gestalt Principles, also contesting the methodology that researchers have utilized in the previous studies. Specifically, attention has not been eliminated in these previous studies, despite the response of subject being predicated on its inclusion. In all the methodologies of the visual search task, where participants had to observe the computer screen and try to detect a target, which may (or may not) be present, attention remained a constant. A task like this implies an intent leading to an engagement of attention, highlighting the key weakness of the research undertaken to date based on the visual search paradigm. A relatively new methodological paradigm has now been created based on this pervasive flaw. This paradigm, known as *inattentional blindness* (Mack & Rock, 1998, 2000) ensures the absence of expectations and directed attention on the stimulus that is the subject of the research. It should be noted that the relative importance of attention was studied in the framework of two varying approaches – Feature Integration Theory by Treisman and Inattentional Blindness.

Most and colleagues (Most, Scholl, Clifford, & Simons, 2005) point out that inattentional blindness is a phenomenon in which people do not perceive the stimuli that appear in front of their eyes, when they are engaged in an attentional demanding task. The same authors emphasize that there is a surprisingly large percentage of stimuli that people cannot perceive. On the other side, if people detect a new stimulus when their attention is focused on other content, it means that the perception of that stimulus is possible without mediation of visual attention.

Research within the field of the inattentional blindness paradigm is questioned if the elementary characteristics of stimulation are detected during the early stages of vision. Treisman and Gelade (Treisman & Gelade, 1980) revealed that the shape, color, orientation, length, and density are observed without the attention mediation. Other studies have demonstrated that the width, number of elements, and textural segregation are also detected in the early phase of seeing (Bergen & Jules, 1983). However, experiments based on this new methodological framework show that these basic characteristics of the stimuli cannot be perceived under conditions of inattention (Mack & Rock, 2000).

Illusory contours represent the specific set of stimuli which show that these perceptual structures cannot be equated with physically presented contours. The question to which there is still no clear answer is the level of their processing. Whether illusory contours are perceived automatically, in the early stages of seeing or the perception of these forms is guided by complex visual attention mechanisms?

This study attempts to examine the importance of attention in the perception of illusory contours within the theoretical framework of inattentional blindness, since this methodological approach, based on the distraction of attention, provides direct insight into the presence of attention in perception. Borojević and Gvozdenović (2013) found that illusory square is more likely to be detected in inattention condition than some simple geometric shapes suggesting that in certain cases with certain types of stimuli attention is not necessary for perception. It is possible that illusory contours represent these specific types of stimuli that differ from the completed forms. So, this study attempts to further examine the perception of illusory contours through the experimental procedure of inattentional blindness. The simplest type of illusory contour is selected for this research - the illusory triangle.

The research also attempts to determine whether the site of the illusory contour's exposure, influences the perception under the conditions of attentional distraction, considering that numerous studies have shown that manipulation of the focus of attention (presented with circular area whose diameter depends on the length of the crossline) can increase the amount of inattentional blindness. This study examines whether such effect exists in these visually specific forms.

Experiment 1

The aim of this experiment was to determine the effectiveness in detecting a small illusory triangle, shown on the periphery (outside the focus of attention, which is determined by a circular area around the lines of cross). This effectiveness was tested under conditions of full attention, divided attention, and inattention. If the percentage of subjects who perceive and accurately identify this stimulus under inattention conditions was higher than chance (so that there is no significant difference referring to the full attention condition) it would mean that the perception of this configuration is possible also without the active involvement of attention. Conversely, if a large number of participants failed to notice the illusory triangle in inattention condition, this would mean that perception of these visual forms involves the attention system.

Method

Sample

Sixty students (85% females) participated in the experiment. Participants were students at two departments (Psychology and Pedagogy) at the Faculty of Philosophy, the University of Banja Luka. Their mean age is 20.4 years. All participants had normal or corrected to normal vision. They were tested individually, randomly divided into three groups, which corresponded to the three different experimental conditions (inattention, full attention, and divided attention).

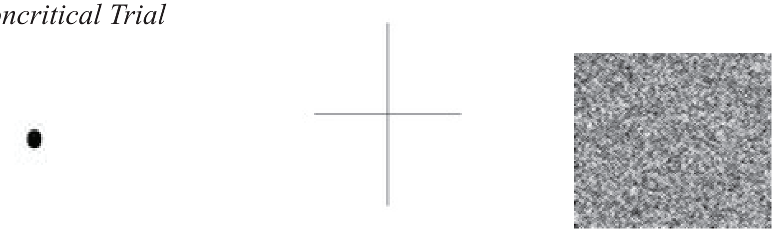
Stimuli

The same stimuli were used for all three subject groups – a cross, displayed in the center of the computer screen and an illusory triangle on periphery as critical stimulus. Structural parts of this illusory contour are the so-called "packmen". Spatially separate black packmens (sectored circles with 1.5° in diameter) give the impression of a white triangle. The illusory triangle was displayed on the periphery of the visual field and subtended approximately 3.5° of visual angle. In each trial, the cross dimensions varied, with the length of lines ranging from 2.6° to 4.5°. The cross appeared in every trial, while the critical stimulus appeared in only one trial (third critical trial) during the experiment.

Procedure

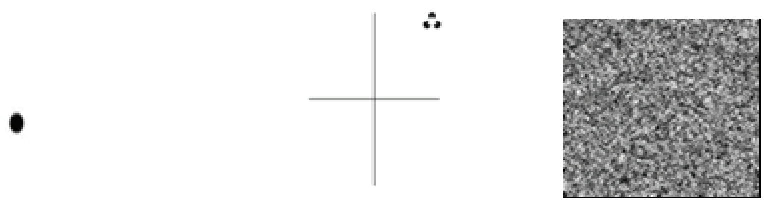
The stimuli were presented on a laptop screen, at a distance of 50 centimeters from the subjects. Subjects' answers were recorded in a specially prepared paper form, designed for this research. In the first two trials, the procedure was the same in all three groups of subjects (Figure 1). Before each trial, a fixation mark was presented in the center of the screen. The subjects were given the instruction to focus on the mark. Subsequently, a cross was presented in the center of the screen and the subject's task was to assess which two lines of the cross were longer (horizontal or vertical). The cross was displayed for 200 ms, which is less time than it generally takes to move the eyes from one location in space to another (Mack & Rock, 1998). The crosses' dimensions changed from trial to trial. After each presentation of the cross a pattern mask (that covered the entire area of the visible screen) appeared for 1500 ms. In the third trial, simultaneously with the cross, the critical stimulus (the illusory triangle) was presented. The subjects then answered the question if they saw something else on the screen, beside the cross? If they answered "yes", they were given a recognition test in which they should recognize the critical stimulus in a series of multiple choice forms (*supplementary material*). Correct identification was considered only in selecting the exact shape, whilst the incorrect response was considered a misidentification or inability to select any of the forms in the recognition test.

a) Noncritical Trial



Fixation 1500 ms | Stimulus 200 ms | Mask 500 ms

b) *Critical Trial*



Fixation 1500 ms | Critical stimulus 200 ms | Mask 500 ms

Figure 1. Graphical representation of experimental procedure for noncritical trial (a) and critical trial (b).

The difference between the three groups of subjects was the instruction they received. The first group received no additional instruction (inattention), the second group was instructed to observe the entire screen area (divided attention), while the third group was instructed to ignore the cross but to observe the appropriate quadrant of the cross (full attention). Giving the instruction to keep the eyes fixated in position cannot guarantee that the subjects will follow that instruction. But some researches who research the relationship of the inattention blindness and eye movements show that visual attention and fixation position can be dissociated. Even when subjects can move their eyes freely and direct them to the critical stimulus, amount of inattention blindness is high and new stimulus remains unnoticed (Koivisto, Hyönä, & Revonsuo, 2004).

Results and discussion

The distribution of the results in Figure 2 indicate that more subjects reported their perception of the critical stimulus relative to the number of subjects who correctly identified it. The least successful groups in the accuracy of identification were groups that worked in inattention and divided attention conditions. The differences were statistically significant, χ^2 (2, N = 60) = 23.03, $p < .001$ for seeing a critical stimulus; χ^2 (2, N = 60) = 20.23, $p < .001$ for accuracy of identification.

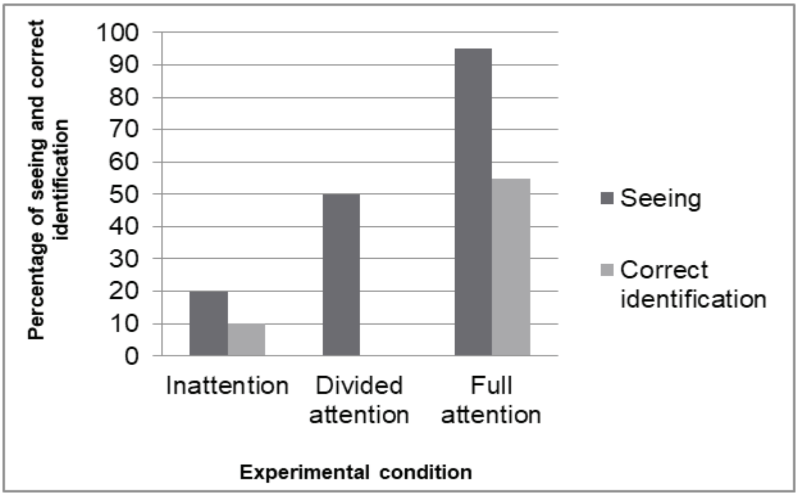


Figure 2. Illusory contours perception accuracy plotted separately in three conditions in Experiment 1.

But, separate comparisons between the groups confirmed significant differences between the groups that worked in inattention and full attention conditions (*Fisher's exact test*: p = .000 for seeing; *Fisher's exact test*: p = .006 for accuracy of identification) as well as between groups that worked in divided attention and full attention condition (*Fisher's exact test*: p = .003 for seeing; *Fisher's exact test*: p = .000 for accuracy). Considering that for this study the most important difference is between the first and the third group, the results indicate that in a group of subjects working under inattention conditions, there are only two (10%) correct identifications of the critical stimulus, whilst in the third group there are eleven (55%) correct identifications. It can therefore be asserted that there are no adequate perceptions of the illusory triangle without focused attention.

Although the main goal of this experiment was to examine the possibility of the perception of illusory triangle in inattention conditions, these results do not provide a clear answer. A small number of subjects who saw, and correctly identified the critical stimulus, thus demonstrate the existence of "inattentional blindness". However, nine subjects failed to correctly identify the illusory triangle when their attention was actively focused on it. These results, although not expected, are not entirely inexplicable. In cases where we need to discern details, we must focus on the image so that it falls on the fovea. Only foveal vision provides good visual acuity and the ability to distinguish details effectively (Goldstein, 2007). Considering that the critical stimulus was displayed on the periphery, with time limited exposure, visual acuity was reduced, so that a large number of subjects saw the critical stimulus, but only a small number correctly identified it. These results may also indicate the phenomenon of "illusory conjunctions". It is termed as incorrectly binding of stimuli characteristics, resulting in restrictive perceptual conditions, due to short-term stimulus exposure (Treisman & Schmidt, 1982).

Experiment 2

The aim and expected outcomes of this experiment mirrored the methodology and outcomes of the first. Sixty new subjects (divided into three groups) participated in this experiment. The only difference was with regard to the characteristics of critical stimulus – specifically its position (place of presentation of illusory triangle). The critical stimulus was presented in the center. Central position referred to the presentation within the "zone of attention" that was determined by a circular area around the lines of the cross.

Results and discussion

The results in the Figure 3 demonstrate that 11 (55%) subjects in the first group saw "something new" on the screen, but only one of them was able to correctly identify it. In the second group, which worked in condition of divided attention, the number of correct identifications was slightly higher, whilst the third group had the highest number of correct identifications. Based on the chi-square test, χ^2 (2, N = 60) = 9.13, p < .05 for seeing a critical stimulus; χ^2 (2, N = 60) = 15.92, p < .001 for accuracy of identification, it is concluded that the difference between all groups is statistically significant. The same results are obtained when only the first and third group are compared (*Fisher's exact test*: p = .008 for seeing; *Fisher's exact* *test*: p = .000 for correct identification), and second and third just for accuracy of identification (*Fisher's exact test*: p = .022).

These results suggest that adequate perception of the illusory triangle required the active engagement of visual attention. In support of this statement we can refer to the results of the second group.

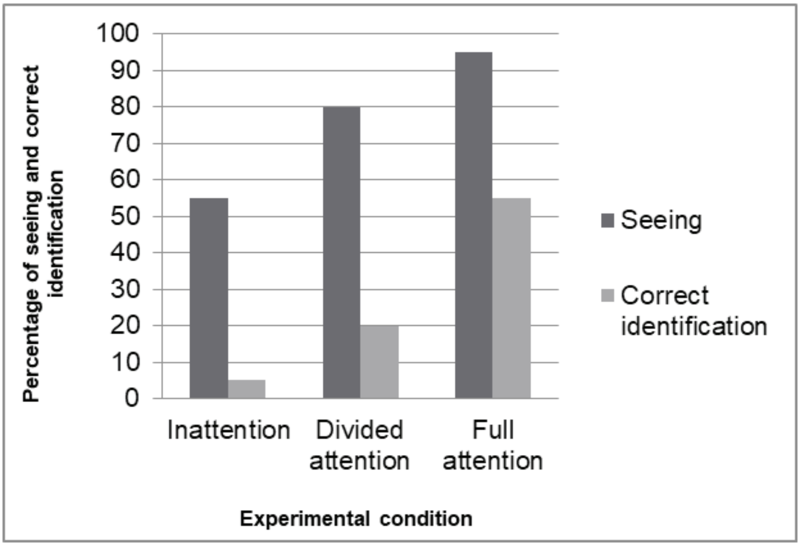


Figure 3. Illusory contours perception accuracy plotted separately in three conditions in Experiment 2.

Even though sixteen of sixty subjects report of seeing critical stimulus, only four subjects correctly identified it, meaning that even a divided attention is not sufficient for proper perception of this type of illusory contours. But, as in the previous experiment, there are several subjects who incorrectly identified the illusory triangle even though they focused attention to it. These results may be explained with a phenomenon of "illusory conjunctions".

Some earlier study (Grabowecky & Treisman, 1989) has shown that visual search of illusory contours cannot be equated with the search of completed figures. There are also a numerous studies that have examined completed and uncompleted figures in parallel identifying their similarities and differences (Gegenfurtner, Brown, & Rieger, 1997; Imber, Shapley, & Rubin, 2005; Larsson et al., 1999). In order to examine if there are fundamental differences in perception of illusory and completed contours when this relationship is viewed within the framework of the inattentional blindness paradigm, two new experiments were performed.

Experiment 3

The aim of this experiment was the same as in the Experiment 1. Sixty new subjects participated in this experiment, randomly divided into three groups. The only difference was, again, in the type of critical stimulus. In this experiment the contoured form of the triangle was shown instead of an illusory contour.

Results and discussion

When the triangle was displayed outside the zone of attention four out of 20 subjects reported seeing it in an inattention trial, but none of them were able to correctly identify the stimulus. In contrast, eighteen of 20 subjects noticed the critical stimulus in the full attention trial and sixteen of them correctly identified it. These differences are significant, Yates χ^2 (2, $N = 40$) = 17.07, $p < .001$ for seeing a critical stimulus; Yates χ^2 (2, $N = 40$) = 23.44, $p < .001$ for accuracy of identification, and indicate that perception of simple geometric form requires active engagement of attention.

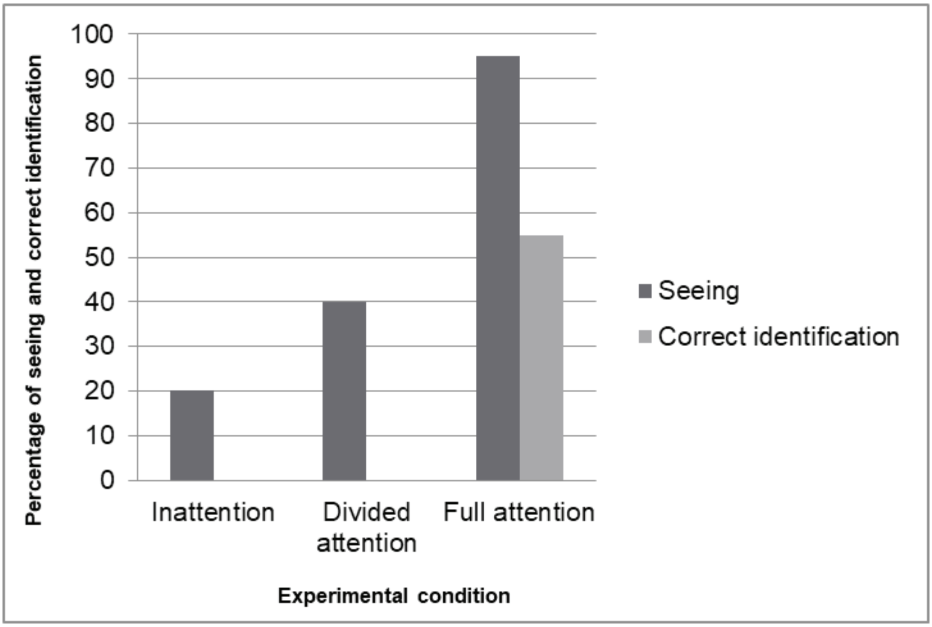


Figure 4. Distribution of results with triangle displayed on the periphery as a critical stimulus.

Unexpectedly, eight out of 20 subjects reported seeing a critical stimulus in the divided attention condition, but none of them had correctly identified it. These results support the limited capacities theory of attention. Presumably, the assessment of crosses' lines exhausts the attention resources, so the critical stimulus remains undetected.

EXPERIMENT 4

The goal of this experiment was the same as in the Experiment 2. Sixty new subjects participated in this experiment, randomly divided into three groups, exposed to different experimental conditions. In this experiment a contoured form of the triangle was shown instead of an illusory contour.

Results and discussion

Results presented in Figure 5 show that six out of 20 subjects reported seeing something else besides the cross in the inattention trial. In the full attention trial all 20 subjects (100%) noticed the triangle.

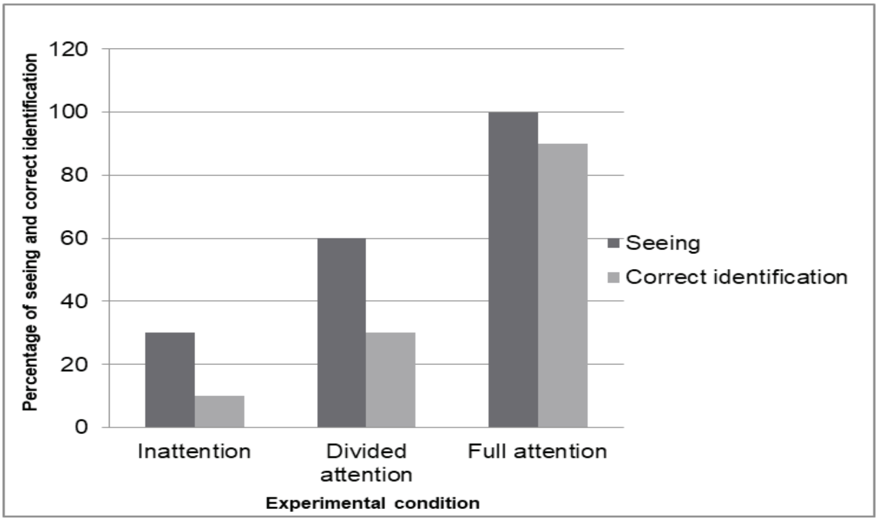


Figure 5. Distribution of results with triangle displayed in the center as a critical stimulus.

This difference is significant, χ^2 (2, N = 40) = 18.57, $p < .001$ for seeing. Two subjects correctly identified the triangle under the inattention condition and eighteen subjects under the full attention condition. This is also statistically significant, χ^2 (2, N = 40) = 22.5, $p < .001$. So, we concluded that geometric shape of triangle could not be perceived without attention.

EXPERIMENT 1-4: Effect of position and type of stimulus on *inattention blindness*

Although the primary aim of this study was to determine the possibility of perceiving illusory contours in the absence of attention, comparison with real, completed figures should supplement the knowledge of the specificity of the amodal figures. It should also provide a better understanding of the perception process. The data obtained in all four experiments were analyzed in order to test whether our visual system is able to form the outline of objects from an incomplete information, automatically at an early level of processing, without activating attention mechanisms.

Since the position of a critical stimulus is a factor that has an effect on inattentional blindness, it is included in the analysis to determine its contribution to the perception of these specific visual structures in an inattention condition.

Using the analysis of variance (Table 1), a significant effect of stimulus position on seeing a critical stimulus was found ($p < 0.05$). Although the percentage of the explained variance is very small, this result is consistent with the findings of Mack and Rock (1998) in that spatial factors may influence the likelihood of critical stimulus detection.

Table 1

Analysis of variance for seeing a critical stimulus as dependent variable

Source	*df*	*F*	Ŋ	*p*
Type of figure	1	1.53	.020	.220
Position	1	4.95	.061	.029
Type of figure*Position	1	1.53	.020	.220
Error	76			

$R^2 = .09$ ($\Delta R^2 = .06$)

Type of figure was not a significant source of variation for seeing a critical stimulus without attention engagement. This result indicates a strong expression of inattentional blindness, which suggests that, the perception of both the real and the illusory contours requires focused attention.

Table 2

Analysis of variance for identification a critical stimulus as dependent variable

Source	*df*	*F*	Ŋ	*p*
Type of figure	1	0.21	.003	.649
Position	1	0.21	.003	.649
Type of figure*Position	1	1.88	.024	.174
Error	76			

$R^2 = .03$ ($\Delta R^2 = .01$)

When the analysis of variance was applied on the identification as a dependent variable (Table 2), the obtained results showed that there is no significant effect of the stimulus position or the type of figure on the recognition in the absence of attention.

General discussion

This research examined the role and importance of the visual attention in the perception of one type of illusory contour within the theoretical and methodological approach of inattention blindness. The results showed that the amount of inattention blindness is very high when an illusory triangle is a critical stimulus. This means that an adequate vision of this type of stimulus occurs only with the active participation of attention. This confirms the results of research conducted within the opposed approach based on the Feature Integration Theory (Grabowecky & Treisman, 1989). Most authors consider that the visual system encodes inductors (packmen), including their organization and orientation, then integrates them all into a holistic perception of an illusory triangle using visual attention. It appears that the visual system does not encode even the slightest fragments of the illusory triangle without the active participation of attention, demonstrated by the fact that none of the subjects chose a shape even similar to the illusory contour in the recognition test. It also negates the thesis of the existence of subliminal perception discussed by Bressan and Pizzighello (2008). A number of subjects in the study selected the correct form in the recognition test, although they had previously stated that they had not noticed anything other than the cross. The results in this study show the opposite, with more subjects indicating the presence of something else on the screen, although unable to identify the exact figure in the series of proposed forms. It must also be emphasized that only one type of illusory contour was used in this study and that was the illusory triangle. Conci, Müller, and Elliott (2009) showed that illusory triangle was harder to detect than other illusory contours, because of its complexity. Namely, the number of possible rotations and reflections of stimulus configurations is higher for triangles than for squares (e.g.) causing different processes of completing.

It can be concluded that this study confirmed the results of the earlier research projects, although the approach based on Feature Integration Theory and approach based on Inattentional Blindness paradigm are, conditionally speaking, opposite, with both referring to the same conclusion – that there is no adequate perception of illusory triangles without the active engagement of attention.

A significant part of this paper was the comparison between the illusory contour perception and non-illusory contour (contoured form) perception. The most general results show that there is no difference in perception without the engagement of attention between these types of stimuli. This means that our visual system cannot form complete perceptive units at the earliest level of processing, without the engagement attention. The amount of inattention blindness is very high in all experiments. Although different in its configuration, illusory and non-illusory contours seem to be perceived in the same way. These results are consistent with earlier studies (Larsson et al., 1999) which confirm that the cortical areas responsible for processing illusory contours are overlapping with areas responsible for processing contoured forms. In contrast, there is evidence of faster processing of real contours compared to illusory versions (Imber et al., 2005). Some authors also showed that triangles defined by packmen

(Kanizsa triangles) are processed more slowly than triangles defined by line segments. We have not confirmed it since exposure time was the same for both contours, but our results demonstrate that illusory triangles are more noticeable under inattention condition, although this difference is not large enough to reach statistical significance in data analysis. One possible explanation of such results is that all inducing elements in both types of contours are processed separately, independently, and automatically. After that, the process of contour continuation is initiated for all segments and it takes some time until connections between inducers make a unique shape. This is called “interpolation” (Gegenfurtner, Brown, & Rieger, 1997). So, it can be concluded that interpolation of real and illusory contours requires attention engagement, although interpolation speed can be dissimilar. It is possible that the color of packmen makes the illusory contour more visible, considering that some authors (Mack & Rock, 1998; Ro, Singhol, Breitmeyer, & Garcia, 2009) categorize color as one of the fundamental properties of a given stimulus that could be processed without awareness at early level of visual processing, without the engagement of attention.

One interesting aspect of our results is that we found significant difference in noticing illusory and real triangle considering the position of presentation, but not for correct identification. This is consistent with earlier finding that spatial factors may influence the likelihood of detection and support a location-based model of attention (Most, Simons, Scholl, & Chabris, 2000).

Although earlier research has shown that it is possible to perceive the illusory square in a lack of attention (Borojević & Gvozdenović, 2013), there is a strong expression of inattentional blindness in this research when the illusory triangle is used. It is possible that the speed of contour interpolation from a certain number of inducers varies in different forms. It could be that a larger number of inductors facilitates and accelerates the formation of illusory contours, thus some other forms of illusory contour should be used in the next research, different in complexity (number of inductors that define them).

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„SLJEPILO USLJED NEPAŽNJE" I OPAŽANJE ILUZORNIH KONTURA

Apstrakt

Ova studija proučava značaj i ulogu vizuelne pažnje u percepciji iluzornih kontura kroz paradigmu „sljepila usljed nepažnje". Prethodna istraživanja su ovaj problem uglavnom ispitivala u okviru Trizmanove teorije integracije karakteristika, koja se, uslovno rečeno, može smatrati opozitnom pristupu zasnovanom na „sljepilu usljed nepažnje". To je fenomen neregistrovanja prezentovanih stimulusa kada je pažnja fokusirana na određeni zadatak. Ovaj pristup omogućava direktan uvid u prisustvo pažnje u percepciji, na način da veća količina „sljepila usljed nepažnje" ukazuje na neophodnost većeg angažovanja pažnje. Prvi dio studije se odnosi na dva eksperimenta u kojima se ispituje percpecija jednog tipa iluzornih kontura-iluzornog trougla. Cilj tih eksperimenata je bio ispitivanje postojanja određenih razlika u opažanju oblih figura u zavisnosti od pozicije izlaganja. U prvom eksperimentu je iluzorni trougao prikazan u centru, a u drugom na periferiji. Drugi dio studije se odnosi na ispitivanje percepcije realne figure, odnosno geometrijskog oblika trougla. Cilj dodatnih eksperimenata je bio ispitivanje razlika u obradi i opažanju iluzornih i kompletiranih formi. Rezultati istraživanja pokazuju da je fenomen „sljepila usljed nepažnje" veoma izražen u percepciji oba tipa figura, što ukazuje na potrebu aktiviranja pažnje u stvaranju cjelovitog percepta. Rezultati, takođe, pokazuju da pozicija stimulusa ima određen uticaj na percepciju u uslovima nepažnje.

Ključne riječi: vizuelna pažnja, sljepilo usljed nepažnje, iluzorne konture, realne konture

Received: 30. 05. 2018.
Revision received: 25. 08. 2018.
Accepted for publication: 27. 08. 2018.

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Supplementary material

Експеримент: ______________________________

Датум: ______________________________

Испитаник: ______________________________

НКС1:	Х	В	И
НКС2:	Х	В	И
НКС3:	Х	В	И
КС:	Х	В	И

КС: Видео/ла Није видео/ла