Vision Research 49 (2009) 1329–1335

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Perceptual objects capture attention

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ARTICLE INFO

Article history:
Received 3 October 2007
Received in revised form 25 December 2007

Keywords:
Visual attention
Attentional capture
Perceptual object
Perceptual organization
Automatic attentional deployment

ABSTRACT

A recent study has demonstrated that the mere organization of some elements in the visual field into an object attracts attention automatically [Kimchi, R., Yeshurun, Y., & Cohen-Savransky, A. (2007). Automatic, stimulus-driven attentional capture by objecthood. *Psychonomic Bulletin & Review, 14*(1), 166–172]. We tested whether similar results will emerge when the target is not a part of the object and with simplified task demands. A matrix of 16 black L elements in various orientations preceded the presentation of a Vernier target. The target was either added to the matrix (Experiment 1), or appeared after its offset (Experiment 2). On some trials four elements formed a square-like object, and on some of these trials the target appeared in the center of the object. No featural uniqueness or abrupt onset was associated with the object and it did not predict the target location or the direction of the target's horizontal offset. Performance was better when the target appeared in the center of the object than in a different location than the object, even when the target appeared after the matrix offset. These findings support the hypothesis that a perceptual object captures attention (Kimchi et al., 2007), and demonstrate that this automatic deployment of attention to the object is robust and involves a spatial component.

1. Introduction

The successful comprehension of the visual information we encounter requires both attentional processes that afford the selection of the relevant information out of the non-relevant information, and perceptual organization processes that structure the bits and pieces of visual information into larger entities that correspond to meaningful objects. In recent years, a growing body of evidence have demonstrated the close interplay between attentional and perceptual organization processes (e.g., Driver, Davis, Russell, Turatto, & Freeman, 2001; Scholl, 2001; Vecera, 2000). Several studies have demonstrated that attention can constrain perceptual organization. For instance, Freeman and colleagues provided evidence for attentional modulation of lateral interactions by showing that attention can modulate flanker-target integration (Freeman, Driver, Sagi, & Zhaoping, 2003; Freeman, Sagi, & Driver, 2001). Specifically, the detection of a central Gabor target was improved by the presence of collinear flankers when the collinear flankers were attended, but not when the collinear flankers were ignored in favor of flankers with orthogonal orientation. Kimchi and Razpurker Apfeld (2004) showed that some forms of grouping, such as grouping elements into columns/rows by color similarity (see also Russell & Driver, 2005) can take place without attention, whereas other forms of grouping, such as grouping elements into a shape by color similarity, require controlled attentional processing. Vecera and colleagues demonstrated that exogenous precue presented inside one of the regions of an ambiguous figure-ground stimulus can affect figure-ground assignment—the attended region is perceived as figure and the shared contour is assigned to the attended region (Vecera, Flevaris, & Filapek, 2004).

Other studies have demonstrated that various organizational processes constrain attentional selectivity (e.g., Davis & Driver, 1997; Driver & Baylis, 1998; Moore, Yantis, & Vaughan, 1998; Watson & Kramer, 1999). For example, responding to two features is easier when they belong to the same object than when they belong to two separate objects (e.g., Behrmann, Zemel, & Mozer, 1998; Duncan, 1984), and interference from distractor stimuli in selective attention tasks is greater when the target and distractors are strongly grouped by gestalt cues such as color similarity, good continuation, and closure (e.g., Baylis & Driver, 1992; Driver & Baylis, 1989; Kahneman & Henik, 1981; Kramer & Jacobson, 1991). Similarly, the cost associated with directing attention via spatial precues to a non-target location is smaller when the target location is on the same object as the cue location than when the target and cue appear on separate objects (e.g., Egly, Driver, & Rafal, 1994; Goldsmith & Yeari, 2003; Moore et al., 1998). Finally, neurophysiological studies have found that attended stimuli and unattended stimuli belonging to the same object elicited a very similar spatiotemporal pattern of enhanced neural activity in the visual cortex, even when the object were defined by illusory boundaries (Martínez, Ramanathan, Foxe, Javitt, & Hillyard, 2007a; Martínez, Teder-Sälejärvi, & Hillyard, 2007b; Martínez

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doi:10.1016/j.visres.2008.01.014

et al., 2006). These various findings suggest that perceptual organization and visual attention mutually constrain one another.

In a recent paper, Kimchi, Yeshurun, and Cohen-Savransky (2007) have addressed another important aspect of the interplay between perceptual organization and attention. They have demonstrated that perceptual organization can affect the automatic, stimulus-driven deployment of attention. In that study they employed a display composed of nine red and green L elements rotated at different angles and forming the vertices of four adjacent quadrants that make up a global diamond. The observers' task was to report the color of one of the elements as indicated by an asterisk presented in the center of one of the quadrants and an instruction word—'above', 'below', 'right', or 'left'—that specified the position of the target relative to the asterisk. For instance, if the word was 'left', observers had to report the color of the element left to the asterisk. Each trial began with one of the instruction words, then the display appeared and the asterisk was added in the center of one of the four quadrants. Thus, performing the task requires locating the asterisk, then locating the target relative to the asterisk based on the instruction word, and analyzing the target's color. On half the trials, the four elements of one of the quadrants were collinear and therefore formed a local diamond—an "object". There were three critical 'object' conditions: *Inside-object:* The asterisk appeared in the object quadrant (a quarter of the trials with an object—12.5% of all trials); *Outside-object*: The asterisk appeared in a non-object quadrant, but an object was presented in another quadrant (three quarters of the trials with an object—37.5% of all trials); and *No-object*: The elements did not form an object in any quadrant (50% of all trials). The diamond-like object was irrelevant to the task at hand (because the task relevant feature was the color of a single element) and did not predict the relevant quadrant or the target. Moreover, because all the elements appeared simultaneously no abrupt onset was specifically associated with the object. That is, there was no top-down incentive for the observers to deliberately attend the object, nor was there any previously known stimulus-driven cue, such as feature-singleton, abrupt onset, or any other unique transient, to automatically attract attention to the object quadrant. Nevertheless, the results showed the expected cost and benefit demonstrating capture of attention by the irrelevant object: When an object was present in the display and the asterisk appeared in the object quadrant (Inside-object condition), the observers indicated the color of the target faster than when there was no object in the display (No-object condition), and when the asterisk appeared in a non-object quadrant (Outside-object condition), the observers needed more time to indicate the target color than in the No-object condition. These findings suggest that the object captured attention in a stimulus-driven fashion.

This is an unequivocal demonstration that the mere organization of some elements in the visual field into an object, that otherwise do not have any unique property (including abrupt onset or other unique transients), suffices to attract attention automatically. Previous studies that found object-based attentional effects have always employed endogenous or exogenous information, in addition to the presence of objects, to direct attention to the relevant object. For instance, some studies employed a brief flicker presented in one end of the relevant object to exogenously summon attention (e.g., Egly et al., 1994; Goldsmith & Yeari, 2003; Marino & Scholl, 2005; Moore et al., 1998; Pratt & Sekuler, 2001), and other studies used central cues, instructions, or task-related factors to encourage observers to direct their attention to one of the objects (e.g., Behrmann et al., 1998; Duncan, 1984; Martínez et al., 2006, 2007a, 2007b; Matsukura & Vecera, 2006; Watson & Kramer, 1999). Because other factors were always present, previous studies do not show that the object *per se* was the factor that attracted attention. In Kimchi et al.'s (2007) study there was no additional factor that may have attracted attention apart from the organization of some elements into an object, and therefore a stimulus-driven attentional capture by the object is the most likely interpretation of the cost and benefit effects found there. These findings suggest that the visual system favors perceptual unit that conforms to Gestalt factors such as closure and collinearity. Granting priority to coherent units is advantageous for a system whose goal is to construct a meaningful representation of the physical world because these coherent perceptual units are likely to imply meaningful objects in the environment.

Interestingly, in the Outside-object condition, in which the asterisk appeared in a non-object quadrant, the instruction word of some of the trials referred to a target-element that actually "belonged" to the object (i.e., one of the four elements forming an object in another quadrant) whereas instruction word of the other trials referred to a target-element that did not belong to the object. A separate analysis of the cost for these two types of trials showed costs for both types of trials with somewhat higher cost for target-elements that belonged to the object. This finding suggests that some of the observed cost may be also attributed to difficulty in "extracting" an element that was already grouped into an object. Thus, the attentional effects we observed in Kimchi et al. (2007) might be due to a mixture of attentional related processes and other processes that are not necessarily related to attention but to the actual processing of the object (e.g., grouping the elements into an object, extracting an element from an object, etc.). In this study we ask whether a similar automatic attraction of attention will be found even when the target is not a part of the object and task demands are not high. In a neurophysiological study, Senkowski and colleagues asked the participants to indicate whether a small triangle was pointing to the left or right (Senkowski, Rottger, Grimm, Foxe, & Herrmann, 2005). Prior to the target presentation a display of 23 inducers disks was presented, and on 2/3 of the trials this display included a Kanizsa triangle, appearing in one of two possible locations. On half of trials with a Kanizsa figure the target appeared within the Kanizsa figure, and on the other half it appeared at the other location. Hence, the Kanizsa figure did not predict the target location. The finding that response times were significantly faster when the target appeared within the Kanizsa figure than at the other location seems to suggest that the Kanizsa figure captured attention automatically to its location. This would imply that an automatic attraction of attention to an object occurs even when the target is not a part of the object. However, given that both the Kanizsa figure and the target were triangles it is possible that the attentional capturing by the Kanizsa figure reflects a controlled search for a triangle rather than a truly spontaneous deployment of attention to the object.

The current study was designed to examine whether attentional effects that are due to an automatic attraction of attention by the object can be found with displays in which the target is never a part of the object, has no figural resemblance to the object, and with simplified task demands. The color identification task employed in Kimchi et al. was replaced with a task that measures Vernier resolution. The target in this task was a Vernier target composed of two vertical lines with one line appearing above the other and was separated by a small horizontal offset. The observers had to indicate whether the upper line was displaced to the left or right of the lower line. We have chosen this task because it was already shown that when attention is directed to the location of a Vernier target, via onset precues, observers are faster and more accurate in this task (Yeshurun & Carrasco, 1999). Additionally, this task does not involve the relatively high memory load that was involved in the Kimchi et al.'s task. Prior to the presentation of the target, a matrix of 16 black L elements in various orientations was presented to the observers (Fig. 1a). On half of the trials, four elements were collinear, forming an object—a square