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Does the Object-Based Attention Effect Reflect a Benefit or a Cost?

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Object-based attention would result if target appearing at an invalid location on the same object is detected more quickly than target on an equidistant location on different object (e.g., Egly, Driver, & Rafal, 1994). Three experiments examined the form of object-based attention typical object-based attention paradigms elicit (object-based benefits from the spread of attention across objects or object-based costs for switching attention between objects). Without a measurement of the time to switch attention from one location to another in the absence of objects, it is not possible to assess the relative costs or benefits of objects on attention. By adding an object-absent condition to typical object-based attention paradigms, the present experiments found that object-based attention is best described in terms of the cost to switch attention between objects.

Keywords*: *benefit, cost, object-based attention

Introduction

Typical metaphors proposed for visual attention describe it as a roughly circular region of selective processing that is fixed (Broadbent, 1982; Posner, Snyder, & Davidson, 1980; Shulman, Remington, & McLean, 1979) or flexible in size (Eriksen & Eriksen, 1974; LaBerge, 1983; LaBerge & Brown, 1986). Although other experiments have suggested that attention may be more flexible than this simple account (including ring-like attention— McCalley, Bouwhuis, & Juola, 1995—or attention divided between multiple regions—Kramer & Hahn, 1995), descriptions of spatial attentional selection share the common notion that attention is selecting regions of the visual world that are agnostic with respect to the content of the region. Such metaphors stand in sharp contrast to object-based descriptions of visual attention (e.g., Duncan, 1984; Egly, Driver, & Rafal, 1994; Kramer & Jacobson, 1991) that describe attention as selecting not regions of visual space, but the objects within regions of visual space. This approach is consistent with the notion that vision rarely, if ever, operates without regard to objects and surfaces. Thus, in natural environments attention should spread along objects and the surfaces that comprise objects (Davis & Driver, 1997), and is perhaps biased toward surfaces of greatest affordance to the organism (McCarley & He, 2000).

Though there are numerous studies to

support both notions of attention, the question of the relationship between the two forms of visual attention remains open. The reader is directed to Lamy and Tsal (2000) for an excellent recent review of the research in this area. We will attempt to provide a simplified account here. One account is that attention is primarily object-based (e.g., Davis, Driver, Pavani, & Shepherd, 2000).Attention can spread to regions of an object that are irrelevant to the task, demonstrating that the spread of attention on objects is an obligatory process. In Egly, Driver, and Rafal (1994) for example, an invalid cue led to faster perception of a target on the same object than on a different object. The dominance of object-based representations is essentially an ecological stance, because it inevitably returns to the notion that attention operates in a world of objects, therefore attention might be expected to operate in an object-based fashion. Another account is that object-based attention is mediated by prior spatial selection (Lavie & Driver, 1996). When spatial attention is engaged, for example, when a spatial cue appears in empty space, the presence of objects does not override costs for shifting attention spatially. This account does not deny the existence of object-based attention, but it does propose that object-based selection follows and is thus derived from prior spatial selection. Recently, a possible mechanism of object-based attention was proposed as an attentional prioritization process (Avrahami, 1999; McCarley, Kramer, & Peterson, 2002; Shomstein & Yantis, 2002). Attention has the tendency to search locations within an already attended object because those locations have been assigned a higher priority. According to this view, when the task requires the observer to deploy attention to multiple locations, owing to an uncertain target location, locations within the already attended object have precedence for search (e.g., Duncan, 1984; Egly et al., 1994). Lamy and Egeth (2002) proposed that attentional shifting is a crucial factor for object-based attention. Using different paradigms such as spatial cuing (e.g., Egly et al., 1994) and same/different judgments (e.g., Lavie & Driver, 1996), they found when the task required attention to shift locations, object-based attention was obtained. In addition to these positions, a variety of other descriptions of spatial attention suggest that the object-based and space-based dichotomy may be largely artificial (e.g., Logan, 1996; Vecera, 1994).

The present study does not attempt to directly reconcile all of these positions. The present study examined one critical question related to the methodology of object-based attention experiments that may confound proper interpretation of object-based effects. The issue is whether object-based attention effects are due to a benefit of attention spreading along an object or a cost to switch attention between objects. This issue is highlighted by the basic paradigm of Egly, Driver, and Rafal (1994). In their paradigm, the task was to detect a luminance onset. The display contained two objects (rectangles). A cue that predicted the target location with greater than chance accuracy appeared at one end of one object prior to target onset. What the data showed was that, on invalid cue trials, responses were faster for targets appearing on the same object than on a different object. The conclusion, as has been noted, is that attention spreads along the object in an obligatory fashion, thus leading to a stronger attentional gradient at uncued locations on the same object. This conclusion is generally accepted, and used to bolster theories of object-based attentional selection (see Davis, Driver, Pavani, & Shepherd, 2000, but also see Vecera, 1994). However, recent evidence suggests that this effect may primarily be due to the cost to switch attention between objects. For example, in a study by Iani, Nicoletti, Rubichi, and Umlità (2001), the Egly et al. (1994) objects were joined at one end to form a “U” shaped figure to test the notion that switches of attention between objects incur a cost to RT. Targets could appear on the cued arm of the display (the vertical member) or the uncued arm (horizontal member), as well as at the cued location. They found the same RT’s on either arm, but greater RTs in the classic Egly et al. case (a horizontal switch with separate objects), which they suggested indicated a between-object switch cost. Recently Brown and Denney (2007) used one- and two-object (similar to Egly et al., 1994) displays to examine object-based attention related to disengaging and engaging attention within, between, into, and out of objects. They reported that object-based attention is primarily associated with disengaging operations.

In the current study, we investigated the issue of the same-object benefit or a different-object cost by adding an object-absent condition. Removing the objects eliminates any object-based benefits, providing a bias-free measure of the amount of time it takes to move attention from one location to another. To assess the effect on attention of objects, one simply looks for benefits (faster RTs) in the object-present case versus the object-absent case. If the effect of objects does not induce a cost for switching between them, then greater RTs would be expected in the different-object case versus the time to switch attention that distance in space. The lack of the object-absent condition creates methodological and therefore theoretical problems to account for Egly et al.'s (1994) findings. Because object-based attention is measured by a "same" versus "different" object comparison, it is not clear if differences are due to a same object benefit or a different object cost. An often assumed interpretation is that it reflects a same-object benefit (i.e., attention spreads along the object to facilitate target detection at uncued locations) as indicated by *faster* RTs in a same object case versus a different object case (either when features appear on the same or different objects or when attention is at a cue on the same object must be shifted to a different object). An equally possible account is that the difference is due to a cost for switching attention between multiple objects. In other words, the difference between same and different object conditions could be the result of *slower* RTs in the different object case. For example, consider hypothetical data from a task like Egly et al. (1994) used. As described, in their paradigm a target could appear at one of four locations (the end of one of two rectangles). A cue indicated the likely target location. Object-based attention would result if targets appearing at an invalid location on the same object were detected more quickly than targets on a different object. However, this could result from 1) observers taking more time to switch attention from one object to another than to move a similar distance in space, indicating an object-switching cost or 2) observers switching to the other object at the same speed as moving attention a similar distance in space, but switching attention to a different location on the cued object is faster than moving attention a similar distance in space. The latter effect would represent a same-object benefit. Without a measure of the cost for switching attention between the cued location and a new location when objects are not present, it is not possible to unequivocally distinguish between these two possibilities.

Experiment 1

The first experiment adds an object-absent condition to the Egly, Driver, and Rafal (1994) paradigm. The purpose is to more adequately describe possible costs and benefits of objects in a cued attention paradigm, as compared to the costs normally associated with movements of attention spatially. At this point it is appropriate to note that the "space only" condition that will be described is not meant to imply an object-free condition. Any structure, such as a cue or a target, can be considered an object. However, there will not be a prior object structure present that can serve to guide attention.

Method

Participants

Twenty-two observers from the University of Kansas participated for course credit. All participants had low false alarm rate (< 10%) and had normal or corrected-to-normal vision.

Materials

Stimuli were presented and data were collected on an IBM compatible PC using the MEL software package (Psychology Software Tools).

Design and Procedure

The design and procedure of this experiment replicates that of Egly, Driver, and Rafal (1994) with the addition of an object-absent condition. In addition, the color of the cue was changed to red, because a pilot experiment indicated that the white cue produced significantly slower RTs in the valid condition when the objects were present versus when they were absent, due to a difference in salience for the white cue appearing on a grey object, versus the white cue appearing against a black background. The task of the observer was to detect the presence of a luminance onset (square of 1.68 deg^2, MEL color white) in the display. Every trial began with a fixation point and two objects (outlines of rectangles, MEL color gray, subtending 1.68 deg by 11.11 deg, with orientation counterbalanced within blocks). A cue (consisting of an increase in the luminance, MEL color red, of the object outline at one end of the object) was presented with 75% validity after 1000 ms. On invalid trials, the target could appear on the same object (50%) or on a different object (50%). The SOA between the cue and the target was varied randomly (83, 100, 133 ms) to prevent anticipatory responses by the observers. In addition, catch trials (20% of trials) with no target were also presented. The primary difference in the current experiment is the inclusion of a condition in which no objects were present at the start of the display sequence. The cue consisted of an outline of the same brightness and dimensions as in the object present condition. All other aspects of the display sequence remained the same. For this and the following experiments, the target remained on until observer response or 2 sec, which was recorded as an error. All ISIs were 0 ms in this and the following experiments.

The experiment consisted of five blocks. The first block (50 trials) was a practice block. The remaining blocks contained 50 trials each. The variables of interest were object presence (present or absent) and cue validity (valid, invalid same-object, invalid-different object). For the "object-absent" condition, there were no same or different object cases. All factors were randomized within a block of trials.

Results and Discussion

Data from Experiment 1 are presented in Table 1. The average false alarm rate was 2.0%. As noted previously, there were no same and different object invalid conditions for the object absent case. There was no statistically reliable difference between these conditions ($F < 1.0$, *ns*). Planned comparisons (univariate F-tests) were performed to answer two questions. First, was there any evidence of object-based attention? To start, RTs when the cue was valid were the same with (mean RT = 308 ms) or without objects (mean RT = 306 ms). The classic metric of object-based attention is the presence of faster RTs in the invalid same object case versus invalid different object case. This experiment did produce evidence for object-based attention. RTs were significantly faster in the invalid-same object case (mean RT = 319 ms) than in the invalid-different object condition (mean RT = 341 ms), ($F(1, 18) = 8.86$, $MSE = 513.2$, $p < .05$). The magnitude of this difference (around 20 ms) is similar to other experiments using this method (such as Iani, et al., 2001). The second question concerned the source of the object-based effect. Was the object-based effect due to a benefit of moving attention within objects or a cost for moving attention between objects? To examine this question, we compared the time to switch attention in these conditions to the time to switch attention across the similar spatial extent. The time to switch attention within an object (11 ms) was not significantly different than switching attention between the same regions in space (18 ms), ($F < 1.0$, *ns*). However, it took more time to switch attention between objects (33 ms) than to switch attention between the same regions in space (18 ms), ($F(1, 18) = 5.31$, $MSE = 682.6$, $p < .05$).

The results of this experiment do not favor the idea that object-based attention is due to a benefit for detecting information that appears on a cued object. It took the same amount of time to detect a target that appeared on a cued object, but at a different location from the cue, as it did to detect a similar target that appeared a similar distance

Table 1 Mean RT (in ms) to detect the target for the conditions in Experiment 1

	Cue Type		
	Valid	Invalid-Same Object	Invalid-Different Object
Objects Absent	306	324	
Objects Present	308	319	341

away, but that was not on an object. However, when attention was switched to the uncued object from the cued object, RTs increased relative to the time to switch that distance in space. Thus, what has been called "object-based attention", at least using this often cited paradigm, reflects the cost of switching attention from one object to another, rather than the benefit for attending to a region on the same object.

Experiment 2

The cue employed in Experiment 1 may have a biasing structure; namely, the open end of this bracket-shaped cue may suggest the orientation of the rectangle. As a result, such a bracket-shaped cue might constrain attentional shift in the direction of the bracket points. In this and next experiments, an L-shaped cue was used to avoid such biasing constraint. An L-shaped cue was the bracket-shaped cue with the line on the interior side of rectangle (close to the central fixation) removed. Therefore, an L-shaped cue points to two invalidly-cued target locations.

Method

Participants

Twenty-three observers from the Chung-Shan medical university participated for course credit. All participants had low false alarm rate (< 10%) and had normal or corrected-to-normal vision.

Materials

Stimuli were presented and data were collected on an IBM compatible PC using the Eprime.

Design and Procedure

The design and procedure were similar to those in Experiment 1 except for the following changes. A cue was changed to an "L", in order not to bias attentional shift in the object-absent and object-present conditions. The experiment consisted of 288 trials where object-absent and object-present conditions were equally probable. There were 40 practice trials.

Results and Discussion

The average false alarm rate was 5.0 %. RTs smaller than 150 ms were excluded from further analysis, resulting in loss of 1.1 % of the trials. Data are shown in Table 2. As Experiment 1, there were no RT differences between same and different object invalid conditions for the object absent case (F = 1.25, *ns*). RTs when the cue was valid were the same with (mean RT = 343 ms) or without objects (mean RT = 345 ms). As Experiment 1, this experiment also provided evidence for the object-based effect. Namely, RTs were significantly faster in the invalid-same object case (mean RT = 354 ms) than in the invalid-different object condition (mean RT = 375 ms), ($F(1, 22) = 9.09$, $MSE = 572.9$, $p < .01$). To examine whether the object-based effect is due to a within-objects benefit or a between-object costs, we compared the RT to switch attention in the object-present condition to the RT to switch attention across the similar spatial extent. The time to switch attention within an object (11 ms) was not significantly different than switching attention between the same regions in space (18 ms), (F = 1.57, *ns*). Nonetheless, it took more time to shift attention between objects (32 ms) than to shift attention between the same regions in space (18

Table 2 Mean RT (in ms) to detect the target for the conditions in Experiment 2

	Cue Type		
	Valid	Invalid-Same Object	Invalid-Different Object
Objects Absent	345	363	
Objects Present	343	354	375

ms), ($F(1, 22) = 4.33$, $MSE = 544.2$, $p < .05$). The results of this experiment again provided evidence that object-based effect was the RT cost of switching attention from one object to another.

Experiment 3

In Experiments 1 and 2, the object-present and object-absent trials were intermixed. It is possible that some object structure could be carried over from a previous object-present trial to a current object-absent trial. In the present experiment, the object-present and object-absent conditions were blocked to rule out this possibility.

Participants

Eighteen observers from the Chung-Shan medical university participated for course credit. All participants had low false alarm rate (< 10%) and had normal or corrected-to-normal vision.

Materials

Same as Experiment 2.

Design and Procedure

The design and procedure were similar to those in Experiment 2 except that the object-absent and object-present conditions were blocked and counterbalanced across participants.

Results and Discussion

The average false alarm rate was 4.0 %. RTs smaller than 150 ms were excluded from further analysis, resulting in loss of 0.3 % of the trials. Data from Experiment 3 are presented in Table 3. When the objects were absent, there were no RT differences between same and different object invalid conditions ($F < 1$, *ns*). When the cue was valid, RTs when the objects were present (mean RT = 349 ms) were longer than those when they were absent (mean RT = 325 ms) ($F(1, 17) = 11.92$, $MSE = 439.9$, $p < .01$). The object-based effect was again observed; that is, RTs were significantly faster in the invalid-same object case (mean RT = 363 ms) than in the invalid-different object condition (mean RT = 378 ms), ($F(1, 17) = 5.68$, $MSE = 352.9$, $p < .05$). We found that the time to switch attention within an object (14 ms) was not significantly different than switching attention between the same regions in space (9 ms), ($F < 1$, *ns*). On the other hand, it took more time to shift attention between objects (29 ms) than to shift attention between the same regions in space (9 ms), ($F(1, 17) = 6.95$, $MSE = 521.8$, $p < .05$). As Experiments 1 and 2, the results of current experiment indicated that object-based effect was a between-object RT cost, rather than a within-object RT benefit.

Table 3 Mean RT (in ms) to detect the target for the conditions in Experiment 3

	Cue Type		
	Valid	Invalid-Same Object	Invalid-Different Object
Objects Absent	325	334	
Objects Present	349	363	378

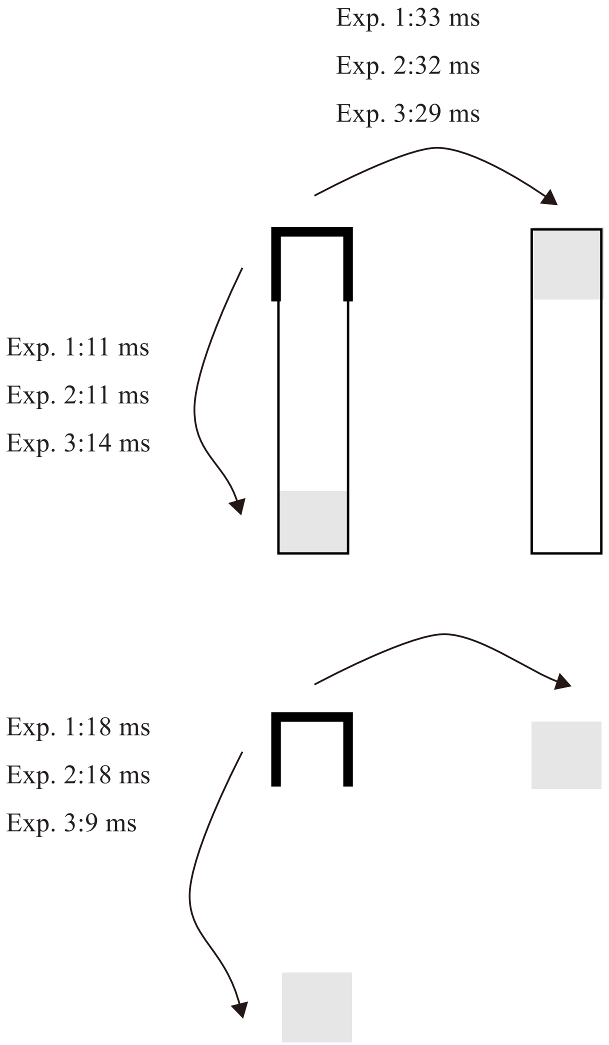

Figure 1. Summary of the time to switch attention in the object present (top) versus object-absent conditions (bottom) for Experiments 1, 2, and 3. Note that the bracket-shaped cue shown in this figure was used only in Experiment 1. An L-shaped cue (not shown) was used in Experiments 2 and 3.

General Discussion

The purpose of the present study was to determine if typical object-based effects are best described in terms of an object-based benefit or an object-based cost (due to the cost of switching attention from one object to another). Previous research, such as Egly, Driver, and Rafal (1994) has discussed object-based attention in terms of the difference between same-object and different-object invalid cueing conditions. Without a measurement of the time to switch attention from one location to another in the absence of objects, it is not possible to assess the relative costs or benefits of objects on attention. In the present study, the addition of an object-absent condition revealed that object-based effects, at least with the paradigms used here, are best described in terms of the cost associated with switching attention from one object to another. In three experiments, we replicated the object-based effect of Egly et al. (1994). However, in these experiments we found that switching attention between locations on the same object was equivalent to switching attention, in the absence of objects, between spatial locations of the same distance. Switching attention between objects took more time than switching attention, in the absence of objects, between spatial locations of the same distance.

One might infer from these results that object-based attention is nothing more than a special cost associated with moving attention in space when attention must be disengaged from objects (e.g., Brown & Denney, 2007). This is consistent with models of attention that have sought to unify the concepts of spatial and object-based attention (e.g., Logan, 1996) or with viewpoints that suggest that the definition of objects has been confused with other organizing principles that might guide spatial attention in visual space in a non-uniform fashion (e.g., Vecera, 1994). It is possible that many paradigms that have been used to study object-based attention may not adequately specify the nature of object-based attention. But, the position that there is no object-based attention would be an inaccurate view. It is clear that objects are having an influence on the deployment of attention. Consider the data from Experiment 1. When no objects were present, there was an 18 ms cost to move attention spatially from a cued location to a target location. When objects were present, a switching cost (33 ms) from a cued object to an uncued one was incurred. It appears, therefore, that the presence of an object "constrains" the distribution of attention in a way that is qualitatively different than purely spatial distributions.

In the current study, although we found that object-based effects were based upon a RT cost when attention switches between different objects (Brown & Denney, 2007; Lamy & Egeth, 2002), we do not reject the possibility that attention can spread over objects. There have been other methods that have manipulated the shape of objects (Avrahami, 1999; Kramer & Watson, 1996, Watson & Kramer, 1999) that have found that object shape also plays a role, consistent with the spreading attention model. In the Avrahami paradigm, manipulation of object curvature led to declines in same-object benefits. In the Watson and Kramer paradigm, bends at the ends of wrenches or wrench "handles" (locations of color discontinuity) reduced a same-object (wrench) benefit of extracting critical features on the objects. Watson and Kramer proposed a spreading attention model in which object shape as influenced by areas of continuity or uniform connected regions (Hoffman & Richards, 1984) constrains the spread of attention. This proposal has also received support from the work of Lamy and Egeth (2002). Although the strongest effects in the current work and other recent work (Iani, Nicoletti, Rubichi, & Umlità, 2001) seem to be due to the cost to switch attention from one object to another, these positions are not mutually exclusive. For example, attention may spread along an object, giving priority of processing to information on that object, and which would also cause a cost to switch attention to a different object.

Because the current experiments are cue-based target detection experiments, they are not necessarily comparable to other paradigms in which observers extract multiple features from an object or multiple objects (e.g., Duncan, 1984; Kramer & Watson, 1996; Watson & Kramer, 1999). It is possible that cuing an object constrains attention to that object in a way that the absence of cues does not, thereby enhancing object-switching costs. The requirement to detect multiple features may also change the way in which attention is distributed along objects. Recent work by Lamy and Egeth (2002) showed that the conditions under which object-based effects occur vary as a result of task. Ben-Shahar, Scholl, and Zucker (2003) report that divided attention paradigms are much more effective for detecting object-based effects. More research which compares various methods of assessing object-based attention is warranted to resolve this issue. Clearly object-based attention is not a singular mechanism. It remains to be determined how we can best classify the variety of object-based attentional effects.

To conclude, previous studies employing the cued-based task and demonstrating object-based attention have assumed that the mechanism is a benefit due to the spread of attention along an object. By including the object-absent condition, the present study showed that object-based attention is best described in terms of the cost to switch attention between objects. Future studies can investigate the boundary conditions in which the within-object benefits could be observed.

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物體爲基注意力作用是否反射優勢或代價？

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在無效線索的情況下，當目標與線索的距離維持相同時，如果目標與線索出現在相同物體時，目標偵測所需的時間，比當目標與線索出現在不同物體，還要來得快（例如Egly, Driver, & Rafal, 1994），稱之爲物體爲基注意力效果。我們以三個實驗來檢驗導致物體爲基注意力效果之兩個可能性：注意力分佈在與線索相同之物體的優勢，抑或是注意力在兩個物體間移動所產生的代價。我們採用Egly、Driver及 Rafal (1994)的實驗典範，並加入了無物體的情境，藉由比較有物體與無物體兩個情境，來區分代價與優勢這兩種可能。本研究發現物體爲基注意力主要導因於注意力在兩個物體間移動所產生的代價。

關鍵詞：代價、物體爲基注意力、優勢