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Attentional Spreading in Object-Based Attention

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The authors investigated 2 effects of object-based attention: the spread of attention within an attended object and the prioritization of search across possible target locations within an attended object. Participants performed a flanker task in which the location of the task-relevant target was fixed and known to participants. A spreading attention account predicts that object-based attention will arise from the spread of attention through an attended object. A prioritization account predicts that there will be a small, if any, object-based effect because the location of the target is known in advance and objects are not required to prioritize the deployment of attentional search. The results suggested that object-based attention operates via the spread of attention within an object.

Keywords: attention, object-based attention, attentional spreading, attentional prioritization

The control of attention and the effects of attention are two primary issues in the study of visual attention, and these issues are often explored independently of one another. The control of attention refers to mechanisms that direct attention to an item in the visual field. In visual search, in which an observer searches through a cluttered scene for a predetermined target, two attentional control parameters, or "modes," have been discussed: bottom-up and top-down control parameters. Bottom-up attentional control involves directing or capturing attention with an external event, such as an exogenous cue or an abruptly appearing object. Top-down control involves directing attention voluntarily, such as actively searching for keys on a cluttered desk.

Beyond these bottom-up and top-down control parameters, attentional control also involves different forms of attentional selection. One distinction in the attention literature is that attention can be either location-based, in which items are selected based on their spatial position, or object-based, in which items are selected based on shape properties. Location-based and object-based attentional control settings are likely to coexist and operate in different situations.

The control of attention by objects is supported by the multitude of studies demonstrating an object-based component of visual attention (see Mozer & Vecera, 2005; Scholl, 2001; Vecera, 2000, for recent reviews). This object-based component of attention has been clearly demonstrated in the popular cued spatial detection task developed by Egly, Driver, and Rafal (1994). In that study, participants viewed two rectangles, followed by a spatial cue that appeared at the end of one of the rectangles. A simple onset target followed the cue, and participants were to make a speeded response to the target onset. The target most frequently occurred at the validly cued location (75% of trials) and occasionally at an invalidly cued location (25% of trials). There were two types of invalidly cued targets: those appearing at the uncued end of the cued object and those appearing in the uncued object. Both of these invalid trial types were equidistant from the cued location. The results demonstrated a spatial cuing effect, in which participants detected validly cued targets faster than invalidly cued targets. More important, invalidly cued targets in the cued object were detected faster than those appearing in the uncued object, demonstrating an object-based component of the control of attention.

Object-based attention has also been demonstrated in other tasks, such as Eriksen's well-known "flanker" task (B. A. Eriksen & Eriksen, 1974; C. W. Eriksen & Hoffman, 1973). For example, Kramer and Jacobson (1991) demonstrated that responses to a central target were affected by task-irrelevant flankers that were connected to the target; flankers that did not connect to (i.e., group with) the target did not affect responses to this target. Similar results were reported by Baylis and Driver (1992), who found that responses to a target were affected by flankers that grouped with the target via either color similarity or good continuation.

Research on the effects of attention center on how an attended stimulus is processed differently from an unattended stimulus. Several studies have investigated the effects of spatial attention and have proposed several different effects for it. One effect involves the enhancement of the representation of an attended item relative to unattended items. Such sensory enhancement effects suggest that attended items are detected more readily than unattended items because attended items are more perceptible because of sensory enhancement (e.g., Carrasco, Penpeci-Talgar, & Eckstein, 2000; Carrasco, Williams, & Yeshurun, 2002; Cheal & Gregory, 1997; Hawkins et al., 1990; Henderson, 1996; Hillyard, Vogel, & Luck, 1998; Luck, Hillyard, Mouloua, & Hawkins, 1996; Yeshurun & Carrasco, 1999). Other effects have been proposed for spatial attention, including prioritization of visual search, in which attended items are searched or examined earlier than unattended items (e.g., Eckstein, Thomas, Palmer, & Shimozaki, 2000; C. W. Eriksen & Spencer, 1969; Palmer, Ames, & Lindsey, 1993; Pashler, 1998; Shiu & Pashler, 1994). No sensory enhancement

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need occur to explain how attended items are recognized more readily than unattended items. Yet another effect of spatial attention is to bind or integrate the features of objects (Treisman, 1988; Treisman & Gelade, 1980). The features of objects outside an attended region are misconjoined more often than features of objects within an attended region (Prinzmetal, Presti, & Posner, 1986).

Although there have been many studies of the effects of spatial attention, there have been fewer studies on the effects of object-based attention (see Chen & Cave, 2006; Shomstein & Yantis, 2002; 2004, for recent examples). As with spatial attention, there are differing accounts of object-based attentional effects, the most visible being attentional spreading accounts and search prioritization accounts. An attentional spreading view of object-based attention proposes that the rate and efficiency of perceptual processes are improved by spreading attention through an attended object. This spreading likely enhances the representation of the attended object relative to unattended objects (see Shomstein & Yantis, 2002). This view can explain many findings in the attention literature, such as results from cued detection tasks (e.g., Egly et al., 1994; Vecera, 1994). Attentional spreading explains object-based effects by proposing that targets appearing in an attended object are more likely to be attended because attention spreads readily within objects but not across objects. For other object-based attention tasks, such as the flanker tasks reviewed earlier, a spreading account would propose that attention would spread from the target to the distracters that grouped with the target; spreading would occur little, if at all, from a target to distracters that did not group with the target.

Other attentional effects can explain results from object-based attention tasks, however. As with spatial attention, another possible effect of object-based attention is prioritization. Prioritization has generally been discussed in terms of prioritizing visual search (e.g., Yantis & Johnson, 1990). Although prioritization could be construed as a broader attentional effect that does not operate solely within a visual search context, we follow the more narrow definition of *prioritization* throughout this article. Our usage of *prioritization* refers to determining how attention will search through a scene containing several objects; some objects are prioritized to be attended before others. We will return to the possibility of a broader definition of *prioritization* in the General Discussion. When applied to object-based attention, the prioritization account proposes that the main effect of attention is to order the analysis of attentional search. This view explains object-based attention by proposing that the attended object is processed ahead of unattended objects and, more specifically, that currently unattended portions of an attended object will be searched ahead of currently unattended portions of a different (unattended) object. In short, locations or features of attended objects have a higher processing priority than those of unattended objects, hence the term *prioritization.* One consequence of prioritization is that if a target location were certain (i.e., the target did not need to be searched for), then objects would be irrelevant to attention. Thus, target certainty should eliminate object-based attentional effects if objects serve to prioritize attentional search.

Prioritization can explain many of the findings from the object-based attention literature. In cuing tasks that summon attention to one region of an object (e.g., Egly et al., 1994; Vecera, 1994), attention would prioritize processing toward the cued location first, followed by the uncued location in the same (cued) object, and then toward the uncued location in the other (uncued) object. This strategy of searching different locations in the same object is supported by the finding that participants tend to direct attention from the cued location along contours to uncued locations, regardless of any incentive to search in such a manner (Avrahami, 1999). The prioritization view also explains results from matching tasks in which participants compare sets of task-relevant features. Several matching studies have found evidence that participants adopt an ordering strategy whereby they search features in one object before other objects (e.g., Behrmann, Zemel, & Mozer, 1998; Watson & Kramer, 1999), such as searching a single object before searching multiple (i.e., different) objects. Which of these two views, spreading attention or search prioritization, best accounts for effects of object-based attention? In a recent study, Shomstein and Yantis (2002) addressed this question using a flanker task. Displays contained three rectangles: one large rectangle and two smaller, adjacent rectangles. While participants attended the center of the display, three letters appeared, one in the center and two in flanking locations. These flankers appeared either on the same large rectangle as the target letter (same-object condition) or on the two smaller rectangles that did not contain the target letter (different-objects condition). Critically, participants knew that the target always appeared in the same location (fixation). The participants' task was to report the identity of the central letter. The basic flanker effect predicts that incompatible flankers (those associated with a different response from the target) will interfere with target recognition, and responses will be relatively slow. Compatible flankers (those associated with the same response as the target) will not interfere with target recognition, and responses should be relatively fast.

The attentional spread and prioritization accounts make different predictions for the outcome of this study. According to an attentional spreading view, attention should spread along the attended object, altering the perceptual representation of that object and allowing targets on that object to be processed efficiently. Therefore, flankers on the same object as the target should produce a greater influence on reaction times (RTs) than when they appear on different objects from the target. In contrast, the prioritization account predicts that regions of the display will be ordered in search. Because the location of the target is always known and search is not required, a prioritization account predicts that there should be little effect of whether the flankers appear on the same object or on different objects as the target.[1] As previously stated, the prioritization account has been utilized to explain priority in visual search. In a flanker paradigm, the objects should be irrelevant to a prioritization process because the target location is fixed and no search is required. Thus, if objects serve to prioritize attention, then object-based attentional effects should not be observed in a flanker task.

Shomstein and Yantis (2002) found that the flanker effect was not affected by whether the flankers appeared on the same or different objects as the target. These results were taken as evidence of a prioritization account in which the target location was given

[1] Under a prioritization account, one might ask why flanker effects appear at all in standard flanker tasks, because the target location is known and a search is not required. The abrupt appearance of the display might prioritize attention to the target and flankers, producing a flanker effect.

priority. Because the target location was known, no object-based advantage was found because search was not required to find the task-relevant stimuli. More generally, Shomstein and Yantis (2002) concluded that the commonly found object-based advantage is likely due to an object-specific prioritization rather than a perceptually driven mechanism, such as attentional spreading. That is, attended objects are searched before unattended objects, and attention does not need to spread within an attended object.

Although a prioritization effect of object-based attention appears supported in the literature, this support may be equivocal when a broader range of studies is considered. For example, both behavioral (e.g., Cheal & Gregory, 1997; Henderson, 1996; Henderson & Macquistan, 1993; Luck et al., 1996, 1994; Yeshurun & Carrasco, 1999) and electrophysiological (e.g., Hillyard et al., 1998; Luck, Woodman, & Vogel, 2000) results from the spatial attention literature support nonprioritization effects, which could include attentional spreading accounts. Because many theoretical accounts of object-based attention, such as the *grouped array* (Vecera, 1994; Vecera & Farah, 1994), explain object-based attention as arising from selecting the locations occupied by objects, object-based attention might be expected to spread within attended objects and enhance the representations of those objects. Moreover, the results that support a prioritization effect used a paradigm that might have favored a prioritization effect. For example, in the Shomstein and Yantis (2002) study, the target was in a single, fixed location. Some studies have suggested that object-based attention is observed only within a larger spatially attended region (e.g., Lavie & Driver, 1996); when a target appears at a single location, the stimulus components that distinguish same-object groupings from different-objects groupings might fall outside the spatial scope of attention, producing results that appear to be due to a prioritization mechanism. Additionally, in the previous studies, the task-relevant stimuli were highly familiar letters, and these stimuli might not require perceptual-level attention to spread to these stimuli for them to be distinguished from one another. These task-relevant letters also appeared abruptly and were presented after the task-irrelevant objects (rectangles). Such displays give the impression of stimuli occurring at two depth planes—a near surface of letters and a more distant surface of the background objects. Because the letters do not group perceptually with the objects, attention might be optimized to reduce the interference among the letters and disregard the irrelevant background items. Finally, Shomstein and Yantis's (2002) results appear at odds with other object-based attention tasks that have used variants of the flanker paradigm and reported object-based effects (e.g., Baylis & Driver, 1992; Kramer & Jacobson, 1991).

Based on the foregoing considerations, there may be situations in which object-based attention might exhibit spreading effects. To explore further the effects of object-based attention and to distinguish attentional spreading and prioritization effects, we developed stimuli that should not favor prioritization effects. It is important to clarify that we are not proposing that perceptual organization is independent from object-based attention. Rather, we propose that the outputs from perceptual organization processes guide spatial attention (Vecera, 1994; Vecera & Farah, 1994). This guidance could occur as either a prioritization of search or a spread of spatial attention that produces sensory enhancement, and the current experiments are aimed at distinguishing these alternatives. Specifically, we used stimuli in which target locations were known and fixed, but where the targets were perceptually similar to one another, a situation that might be more likely to require perceptual-level processing to distinguish the alternatives. In addition, the task-relevant stimuli—not stimuli that were superimposed on the objects that might not group perceptually with the objects—were integral components of the objects (i.e., they contributed to the objects' shape).

Participants in the following studies performed a flanker task on objects that contained "bites" (concavities) similar to those shown in Figure 1A. The central bite was the target, and participants were asked to report whether the target was a circular or rectangular bite. There were two flanking bites, and these flankers could appear on the same object as the target or on different objects from the target. The spreading and prioritization accounts make different predictions across all of our experiments. Specifically, because the target position is fixed in all of our studies, a prioritization account would predict that we should observe no object-based attentional effects. Because search for the target is not required, no object-based prioritization of search would be required. Consequently, flankers on the same object as the target should influence responses approximately as much as flankers on different objects, and no object effects should be observed. In contrast, an attentional spreading account would predict that object-based attention would select and enhance the attended object, allowing flankers on the same object as the target to affect responses more than would flankers on different objects from the target.

Experiment 1

Method

Participants. Twenty University of Iowa undergraduates with normal or corrected vision volunteered for course credit.

Stimuli. Displays contained either one large rectangle (same-object condition) or three small rectangles (different-objects condition). The large rectangle extended 1.5° by 10° of visual angle and the small rectangles extended 1.5° by 3° from a viewing distance of 60 cm. The rectangles were aligned either horizontally or vertically. The small rectangles were separated by gaps measuring 1.5° by 0.5°. The inner edge of the gaps was 1.5° from the center fixation point. The target pair and flanker pairs were either rectangular or circular bites measuring 1° wide by 0.5° deep. The target bites were always presented at the center of the display. The far edges of the flanker bites were 4° from the center of the screen.

Procedure. Each trial began with a 500-ms presentation of a fixation cross, followed by one large rectangle or three small rectangles that were visible until response. The task was to determine whether the center bite was rectangular or circular, and participants pressed the *N* key if the bite was circular and the *M* key if bite was rectangular. The probability of a circular or rectangular target response was equal, as was the probability of circular or rectangular flankers. Thus, on half of the trials, the target and flankers were identical (compatible trials), and on the other half the target and flankers were different from each other (incompatible trials). Following a response, participants received feedback that indicated whether the response was correct or incorrect. The word *correct* or *incorrect* was presented at fixation for 800 ms. Rectangle orientation, object condition, and target/distractor compatibility appeared intermixed within a block of trials. There

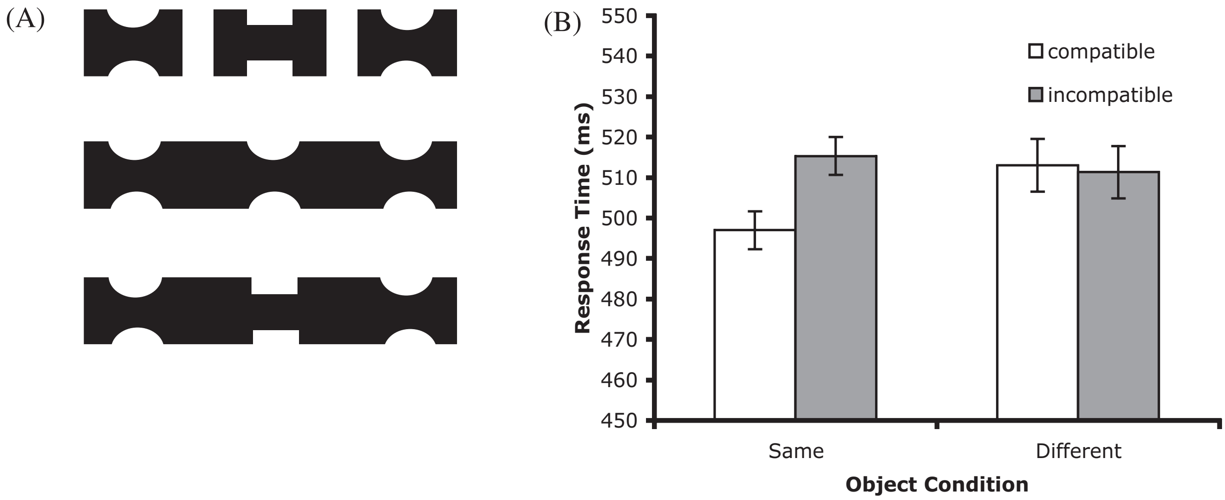


Figure 1. A: Sample stimuli used in Experiment 1. Top stimulus depicts an incompatible, different-objects trial; bottom stimulus depicts a compatible, same-object trial. B: Results from Experiment 1. Participants exhibited a flanker effect when the target and flankers appeared in a single object but not when they appeared in different objects. In all of the graphs the error bars are within-subject 95% confidence intervals on the same-object versus different-objects comparisons (Cousineau, 2007; Loftus & Masson, 1994).

were four blocks with 64 trials each. Each participant received 20 unanalyzed practice trials at the beginning of the experiment.

Results and Discussion

RTs less than 150 ms or greater than 2,000 ms were excluded from the analyses; this trimming eliminated less than 1% of the data. We conducted a preliminary analysis on display orientation (vertical vs. horizontal). There was a main effect of display orientation, with faster responses to vertical displays (504 ms) than to horizontal displays (515 ms), but orientation did not interact with target/flanker compatibility and object condition, so we collapsed across display orientation.

Participants' mean RTs were analyzed with a within-subject analysis of variance (ANOVA), with target/flanker compatibility (compatible or incompatible) and object condition (same or different objects) as factors. The mean RTs from the target discrimination task appear in Figure 1B. There was a main effect of target/flanker compatibility, $F(1, 19) = 4.7$, $p < .05$, with faster responses on compatible trials (505 ms) than on incompatible trials (513.3 ms). There was no main effect for object condition, $F(1, 19) = 2.5$, *ns*. There were similar RTs between same-object trials (506 ms) and different-objects trials (512 ms). Most important, the interaction between target/flanker compatibility and object condition was significant, $F(1, 19) = 6.3$, $p < .05$. Planned comparisons revealed that target/flanker compatibility was significant only in the same-object condition, $t(19) = 4.0$, $p < .01$; the compatibility effect was not significant in the different-objects condition, $t(19) < 1$.

The accuracy data for all of our experiments appear in Table 1. For Experiment 1, accuracy was high (97.8% correct on average), but the pattern of results paralleled the RT data: Compatible trials were more accurate than incompatible trials in the same-object condition (98.6% and 97.4%, respectively), but compatible and incompatible trials had similar accuracy in the different-objects condition (97.3% and 97.9%, respectively).

These results support an attentional spreading account of object-based attention. Even though participants knew that the target would always appear at fixation, the results nevertheless demonstrated a larger flanker effect when the target and flankers appeared in a single object than when they appeared across objects (also see Baylis & Driver, 1992; Kramer & Jacobson, 1991). Presumably, object-based attention spread across the object con-

Table 1
Mean Accuracy (in Percentages) for Each Experiment

	Same object			Different object		
Experiment	Compatible	Neutral	Incompatible	Compatible	Neutral	Incompatible
1	98.6		97.3	97.3		97.9
2	97.8		97.0	96.7		97.0
3	98.6	98.4	97.7	97.5	97.6	98.0
4	97.2		95.1	97.0		94.9
5	96.4		94.1	95.2		93.1

taining the target, and this attentional spread included the flankers in the same-object condition, allowing the flankers to affect responses to the target feature. The results of Experiment 1 suggest that spreading-like effects can be observed when task-relevant features are part of an object and contribute to the shape of that object.

Although the results of Experiment 1 suggest a spreading account of object-based attention, a possible concern is that participants may have executed eye movements differently between the same-object and different-objects conditions. One could argue that knowing the target location and fixating that location on every trial might minimize the potential for eye movements. However, it remains possible that features (bites) that belong to an attended object might drive eye movements more strongly than would features that belong to another, unattended object. Thus, eye movements, not attentional spreading, might have produced the results observed in Experiment 1. We addressed this eye movement alternative in Experiment 2.

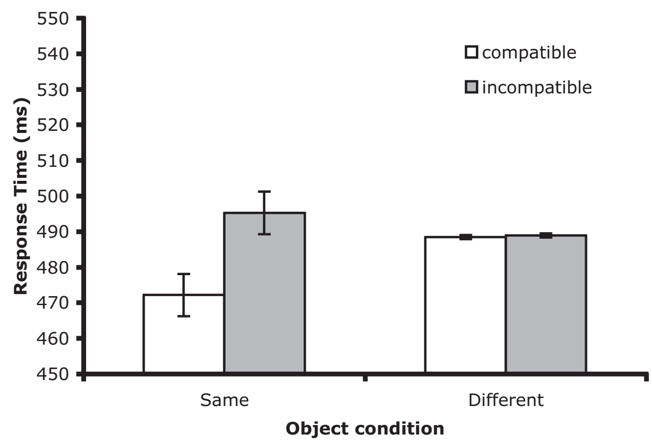


Figure 2. Results from Experiment 2. Participants exhibited a flanker effect in the same-object condition but not in the different-objects condition, despite being unable to execute eye movements to the flanker locations.

Experiment 2

To ensure that participants maintained central fixation, we monitored their right eye while they performed the flanker task used in Experiment 1 and eliminated trials during which eye movements were made.

Method

Participants. Twelve University of Iowa undergraduates with normal or corrected vision volunteered for course credit.

Stimuli and procedure. The stimuli and procedure were identical to those used in Experiment 1, except for the eye movement monitoring. We used a video-based ISCAN ETL-400 eye tracker (ISCAN, Burlington, MA) to monitor eye position. Participants used a chin and forehead rest to maintain viewing distance and to restrict head movement. A real-time image of the participants' right eye was projected onto a monitor facing the research assistant. Eye movements were directly visible in this image. The experimenter was trained to monitor the image and recorded trials in which a participant made an eye movement. The experimenter indicated the presence or absence of an eye movement by pressing a button at the end of the trial. The next trial would not begin until the experimenter recorded the presence or absence of an eye movement. Trials in which an eye movement occurred were later removed from analysis.

Results and Discussion

RTs less than 150 ms or greater than 2,000 ms were excluded from the analyses; this trimming eliminated less than 1% of the data. Eye movements occurred during less than 1% of the trials. Participants' mean RTs were analyzed with a within-subject ANOVA, with target/flanker compatibility (compatible or incompatible) and object condition (same or different objects) as factors. The mean RTs from the target discrimination task appear in Figure 2.

The main effect of target/flanker compatibility was significant, $F(1, 11) = 9.4$, $p < .05$, with faster responses on compatible trials (480 ms) than on incompatible trials (492 ms). The main effect for object condition was not significant, $F(1, 11) = 1.5$; there were similar RTs for both same-object trials (484 ms) and different-objects trials (489 ms). Most important, the interaction between target/flanker compatibility and object condition was significant, $F(1, 11) = 8.4$, $p < .05$. Planned comparisons revealed that target/flanker compatibility was significant only in the same-object condition, $t(11) = 4.2$, $p < .01$; the compatibility effect was not significant in the different-objects condition, $t(11) < 1$. The accuracy data (see Table 1) parallel the RT results. The results of Experiment 2 also support an attentional spreading account of object-based attention while ruling out the possibility of eye movements to flankers within the same object as the target.

The current results suggest that attention spreads within the object containing the target feature. In the same-object condition, attention spreads to include the flankers, resulting in a flanker effect. In the different-objects condition, attention is confined to the small central object, and the flankers receive little, if any, attention, resulting in a small, or absent, flanker effect. Experiment 2 ruled out the possibility of overt shifts of attention and the eyes to the flanker positions. One might argue that covert attention, but not overt attention, continued to be captured by the flankers in our stimuli and that this capture was greater in the same-object condition than in the different-objects condition. Such a scenario would explain our results within a prioritization framework. However, the very purpose of using a flanker task in the first place is to eliminate the need for shifts of attention to search for the target.

At first blush, one might think to rule out a shift of attention in our task by presenting stimuli briefly and masking the displays. With sufficiently short exposure durations, attention could not be shifted to the flanker locations. Unfortunately, an attentional spread could also be eliminated by such an experiment if the spread of attention were time-dependent, with a greater extent of spread with increased time. The use of a flanker task, along with eye movement monitoring (Experiment 2) seems the most straightforward way to distinguish the prioritization and spread accounts.

Having investigated the possibility that overt attentional shifts to the flanker locations produced our findings, we considered another account of our results: Because the target and flankers were identical on compatible trials, our flanker effects in the same-object condition might reflect grouping via shape similarity, not an attentional spread. In the compatible same-object condition, the flankers might group more strongly with the target, producing the fastest responses of all conditions (see Figure 1A). Our current results cannot distinguish this similarity grouping account from an attentional spread because there is no baseline against which to measure benefits of compatible flankers and potential costs of incompatible flankers.

To address the role of similarity grouping on our results, we included neutral flankers in Experiment 3. Neutral flankers allow us to examine both benefits (compatible vs. neutral trials) and costs (neutral vs. incompatible trials) in our task. If similarity grouping, not attentional spreading, underlies our findings, then on same-object trials we would expect to find benefits but not costs, because similarity grouping occurs only in the compatible conditions. In contrast, if a spread of attention across an object produces our results, then we should find both benefits and costs, because attention would spread to the flanker locations, allowing (a) compatible flankers to speed responses relative to neutral flankers and (b) incompatible flankers to slow responses relative to neutral flankers.

Experiment 3

Method

Participants. Twenty University of Iowa undergraduates with normal or corrected vision volunteered for course credit.

Stimuli and procedure. The stimuli and procedure were identical to those used in Experiment 1, except for the addition of a neutral flanker. Neutral flankers were triangle-shaped bites that measured 1° wide by 0.5° deep. The three flanker types appeared equally often. Participants performed 384 trials, and there were 20 practice trials at the beginning of the experiment that were not analyzed.

Results and Discussion

As with our previous experiments, RTs less than 150 ms or greater than 2,000 ms were excluded from the analyses; this trimming eliminated less than 1% of the data. Participants' mean RTs were analyzed with a within-subject ANOVA, with target/flanker compatibility (compatible, neutral, or incompatible) and object condition (same or different objects) as factors. The mean RTs from the target discrimination task appear in Figure 3, and the accuracy data appear in Table 1.

The main effect of target/flanker compatibility was not significant, $F(1, 19) = 1.5$, with similar responses across compatible (495 ms), neutral (495 ms), and incompatible (499 ms) trials. There was, however, a main effect for object condition, $F(1, 19) = 29.3$, $p < .0001$. RTs were faster on same-object trials (487 ms) than on different-objects trials (505 ms). Most important, the interaction between target/flanker compatibility and object condition was significant, $F(1, 19) = 6.7$, $p < .005$. As in Experiments 1 and 2, there were larger flanker effects in the same-object condition than in the different-objects condition.

We conducted planned comparisons to investigate the costs and benefits for compatible and incompatible flankers. Because flanker effects appeared only in the same-object condition, we restricted the planned comparisons to this condition. There was a benefit for compatible flankers (478 ms) over neutral flankers (487 ms), $t(19) = 2.4$, $p < .05$. There was a marginal cost, with slower responses on incompatible trials (495 ms) than on neutral trials, $t(19) = 1.7$, $p = .10$. This latter effect was marginal because of one outlying participant, who exhibited no flanker effect and whose attentional cost was over 2.5 standard deviations below the cost of the other participants. When this participant is removed from the analyses, there is a significant difference between incompatible and neutral trials, $t(18) = 2.4$, $p < .05$, and the benefit for compatible flankers remains significant.[2]

The current results replicate those from Experiments 1 and 2: Flanker effects are observed in the same-object condition but not in the different-objects condition, consistent with a spread of attention. Furthermore, in the same-object condition, we observed both benefits for compatible flankers and costs for incompatible flankers, a pattern that is not readily explained by a similarity grouping account. Instead, results from our flanker task and stimuli appear to reflect a spread of attention through an object.

Given our evidence for a spreading effect for object-based attention, one lingering issue remains: Why have previous studies found clear evidence supporting a prioritization effect? We do not dismiss the possibility that object-based attention might have different effects, consistent with the idea that there are multiple attentional processes (Allport, 1993; Luck & Vecera, 2002). Nevertheless, it is important to understand when these different effects arise. We explored the causes of prioritization effects in Experiments 4 and 5.

A close comparison between our paradigm and Shomstein and Yantis's (2002) paradigm reveals two main differences that could produce different attentional effects: First, as noted earlier, the target and flankers in the Shomstein and Yantis (2002) experiments were letters placed on top of objects (filled rectangles). These letters may not have been perceived as intrinsic parts of the objects. Second, the rectangles used to assess object-based attention were presented for 1,000 ms before the target and flankers appeared. This may be enough time for the participants to constrict their focus of attention to the target location only, after an initial spread of attention across the entire object. Both of these differences suggest that participants may have been able to prioritize the processing of the target letter based on its location alone. Object information may have been discarded, either because the letters and objects formed separate events to which attention could be directed or because an initial spread of attention could be overcome given the ample time delay between the objects and letters.

In Experiment 4, we first replicated the Shomstein and Yantis (2002) paradigm using our objects with superimposed letter stimuli. In Experiment 5, we eliminated the timing gap between the rectangles and the letters to determine whether attention initially spread across within an object before it was later constricted to prioritize processing. In contrast to the results from Experiments 1–3, those from Experiments 4 and 5 support a search prioritization effect. Specifically, we found no effect of object condition, suggesting that object information can be discarded when task-

[2] This significant attentional cost is not skewed by the participant who exhibited the largest cost; when the largest attentional cost is also excluded from the analyses, the difference between the neutral and incompatible conditions remains statistically significant, $t(17) = 2.3$, $p < .05$.

(A) (B)

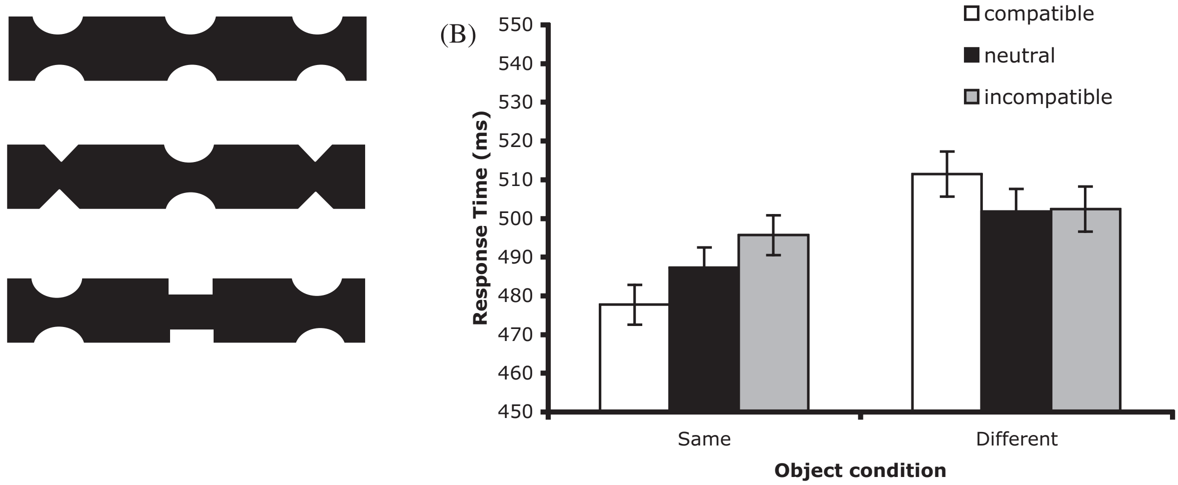


Figure 3. A: Stimuli from Experiment 3; the top panel depicts a compatible trial, the middle panel depicts a neutral stimulus, and the bottom panel depicts an incompatible stimulus. B: Results from Experiment 3. Both benefits and costs for flankers appear in the same-object condition.

relevant targets are not integral to (i.e., contribute to the shape of) an object.

Experiment 4

Method

Participants. Twenty University of Iowa undergraduates with normal or corrected vision volunteered for course credit.

Stimuli. Displays were similar to those used in the previous experiments, with the following exceptions. The bites were removed to create rectangular objects, and the task-relevant stimuli were now letters that appeared within the objects; however, the dimensions of the objects remained the same. The target and flankers were the letters *H, V, U,* and *X*. Each letter measured 1.5° by 1.5°. The far edges of the flanker letters were 3.75° from the center of the screen.

Procedure. The procedure was identical to that in Experiment 1 with the following exceptions. The background objects were presented for 1 s following the 500-ms fixation cross. Then three letters appeared on the background objects until response. The target letter always appeared in the center of the display, with two flanking letters on either side. If the target was *H* or *V*, participants responded by pressing the *Z* key, and if the target was *U* or *X*, participants responded by pressing the / key on the keyboard. In the compatible condition, the targets and flankers were always different letters from the same response category (e.g., *H* target and *V* flankers). The stimuli and timing are portrayed in Figure 4A.

Results and Discussion

RTs less than 150 ms or greater than 2,000 ms were excluded from the analyses; this trimming eliminated less than 1% of the data. Participants' mean RTs were analyzed with a within-subject ANOVA, with target/flanker compatibility and object condition as factors. The mean RTs from the target discrimination task appear in Figure 4B, and the accuracy data appear in Table 1.

There was a main effect of target/flanker compatibility, $F(1, 19) = 17.0$, $p < .01$, with faster responses to compatible trials (601 ms) than to incompatible trials (629 ms). There also was a main effect of object condition, $F(1, 19) = 7.6$, $p < .05$, but in the direction opposite that predicted by object-based attention results: Responses were faster to different-objects trials (605 ms) than to same-object trials (625 ms). We have no theoretical interpretation for this result; interestingly, Shomstein and Yantis (2002) observed similar trends in their results (although these trends were not statistically significant). Most important, the interaction between target/flanker compatibility and object condition was not significant, $F(1, 19) < 1$. The accuracy data parallel the RT data. These results replicate the previously reported prioritization effects.

Having replicated a prioritization effect using our stimuli, we next explored the factors that influence whether one observes an attentional spreading effect or a prioritization effect. Recall that there are at least two possible reasons why prioritization effects may have been evident in the current experiment: First, because the letters were not integral to the objects but instead appeared on top of (and monocularly in front of) the objects, the letters and objects may have been perceptually segregated from one another, allowing the objects to be effectively ignored; thus, attentional priority may have been given to the visual surface of the letters, not the background objects. Second, because the background objects were presented for a long duration, object-based attention may have initially spread through the object at fixation and enhanced the representation of this object. However, top-down attentional control may have operated to refocus, constrain, or rein in attention around the prioritized location (fixation). In Experiments 1 and 2, this top-down control may not have had time to operate because the displays were response-terminated and the response times were well below 1,000 ms, the duration of the objects in the Shomstein and Yantis (2002) studies. To tease apart these two accounts, in Experiment 5 we eliminated the time lag between the presentation of the rectangles and the letters. If segregation of the letters and objects allows attention to be prioritized to the near surface of the letters, then we should replicate the results of Experiment 4 because the letters and

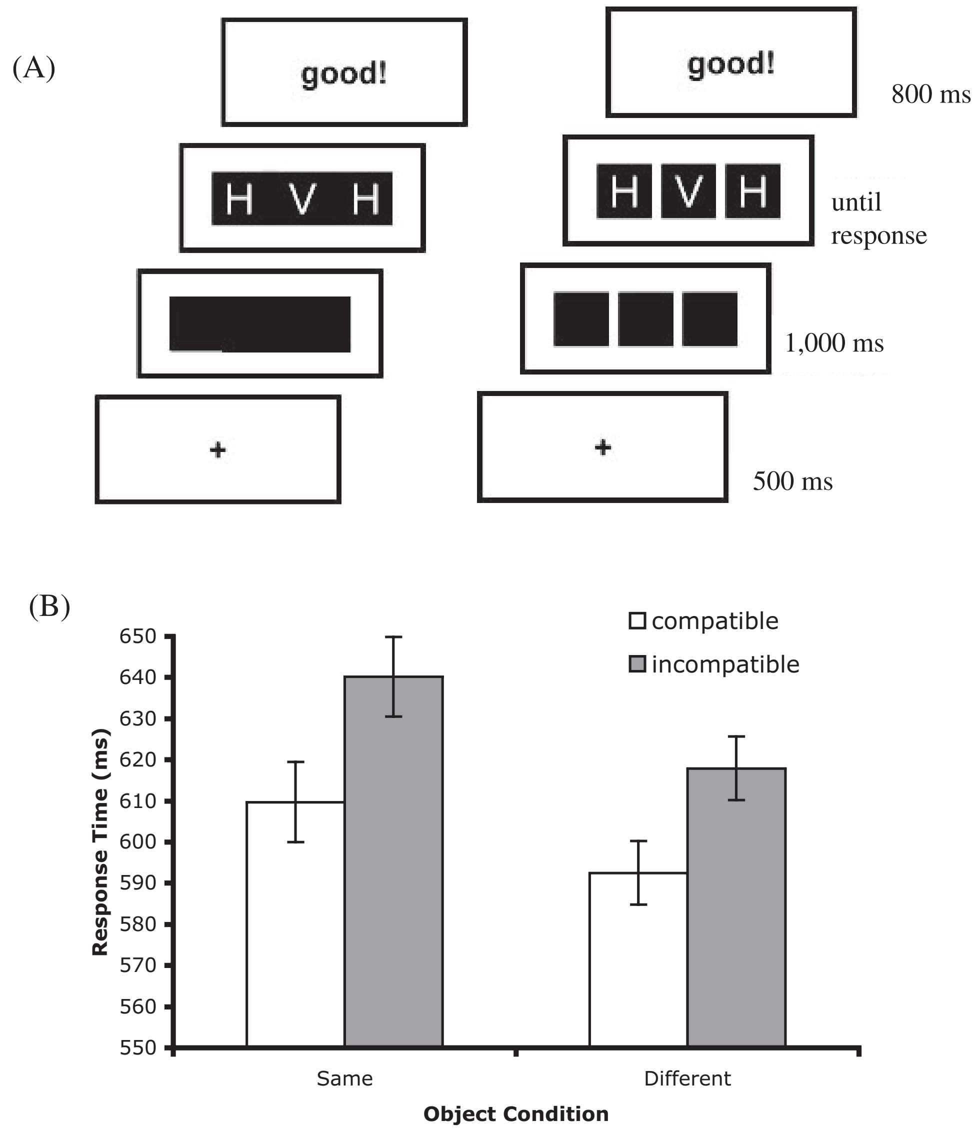


Figure 4. A: Order of events in Experiment 4. The left side depicts a same-object trial, and the right side depicts a different-objects trial. B: Results from Experiment 4. Participants exhibited a flanker effect in both same-object and different-objects conditions, but there was no object-based modulation of the flanker effect, consistent with a prioritization account.

objects remain segregated as two surfaces at different monocularly defined depth planes. If, however, top-down control processes operate to refocus attention after an initial spread of attention across an object, then we should find results similar to those observed in Experiments 1 and 2. Top-down control processes make this prediction because, as in Experiments 1 and 2, these processes do not have sufficient time to refocus attention at the target location following the initial distribution of attention across the object.

Experiment 5

Method

Participants. Twenty-one University of Iowa undergraduates with normal or corrected vision volunteered for course credit.

Stimuli and procedure. Displays and procedure were identical to those in Experiment 4 except for the time gap between the presentation of the rectangles and the letters. In Experiment 5, target letters and rectangles were presented simultaneously.

Results and Discussion

Data from one participant was collected but not included in the analysis because the person's accuracy was below 80% correct. RTs less than 150 ms or greater than 2,000 ms were excluded from the analyses; this trimming eliminated less than 1% of the data. Participants' mean RTs were analyzed as in Experiment 4. The mean RTs from the target discrimination task appear in Figure 5, and the accuracy data appear in Table 1.

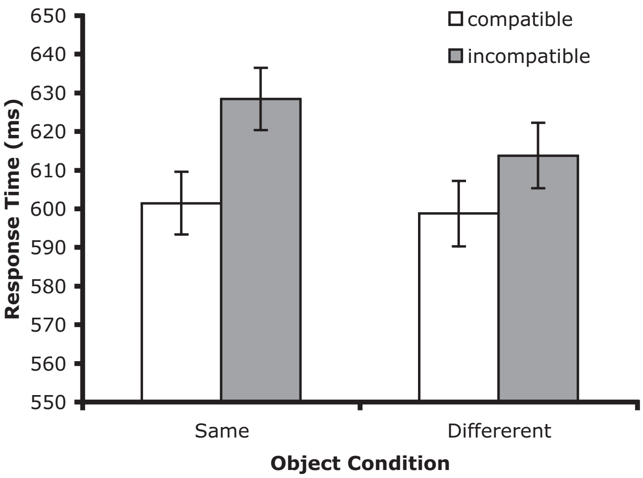


Figure 5. Results from Experiment 5. As in Experiment 4, participants exhibited a flanker effect in both same-object and different-objects conditions, but there was no object-based modulation of the flanker effect.

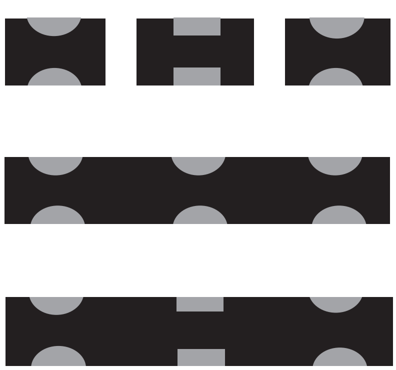
The analyses revealed a main effect of target/flanker compatibility, $F(1, 19) = 10.1$, $p < .01$, with faster RTs to compatible trials (600 ms) than to incompatible trials (621 ms). The main effect of object condition was not significant, $F(1, 19) = 1.1$; responses to same-object trials (615 ms) were similar to those for different-objects trials (606 ms), a trend toward faster RTs in the different-objects condition than in the same-object condition, as reported in Experiment 4 and in some of the Shomstein and Yantis (2002) experiments. Most important, there was no interaction between target/flanker compatibility and object condition, $F(1, 19) = 1.7$, *ns.*

This pattern of findings replicates those observed in Experiment 4, suggesting a prioritization effect. Specifically, we found no interaction between object condition and compatibility, suggesting that the stimulus objects did not influence the compatibility effect. There also was a slight trend for different-objects trials to be faster than same-object trials, although this was not statistically significant. Overall, the current pattern of results is very different from what we observed in Experiments 1 and 2, in which object condition clearly influenced the compatibility effect, consistent with an attentional spreading account of object-based attention.

The results of the current experiment suggest that a prime determinant of prioritization effects is the separation of the task-relevant flanker stimuli and the objects used to assess object-based attention. When the flanker stimuli are not integral parts of the objects and do not contribute to the objects' shape, prioritization effects emerge (Experiments 4 and 5). In contrast, when the features contribute to the objects' shape, spreading-like results emerge (Experiments 1 and 2) in which object-based attention spreads within attended objects, even when a target feature's location appears at a known location.

One lingering issue from the comparison of Experiments 1 and 2 and Experiments 4 and 5 is that the physical stimuli differ across these experiments. Results favoring an attentional spread could be biased because of the bites used in the first two experiments, and results favoring prioritization could result from letter stimuli. To rule out this potential concern, we asked an additional 6 participants to perform a flanker task in which the bites were red and appeared to fall on top of the rectangles, such as the stimuli shown in Figure 6A. The procedure was identical to that used in Experiment 4 except that instead of letter stimuli being presented, red shapes (rectangles and half circles) appeared abruptly on top of the black rectangle(s). The results, shown in Figure 6B, paralleled those from Experiment 4: The participants exhibited a flanker effect, with faster RTs to compatible trials (430 ms) than to incompatible trials (440 ms), $F(1, 5) = 16.3$, $p < .01$. However, there was neither an object-based effect (438 ms vs. 433 ms for same-object and different-objects conditions, respectively), $F(1, 5) = 1.1$, $p > .30$, nor an interaction, $F(1, 5) < 1$, *ns.* Because we found prioritization-like results with the bite stimuli used in Experiments 1–3, we could rule out any stimulus confound as an alternative account of our findings.

(A)



(B)

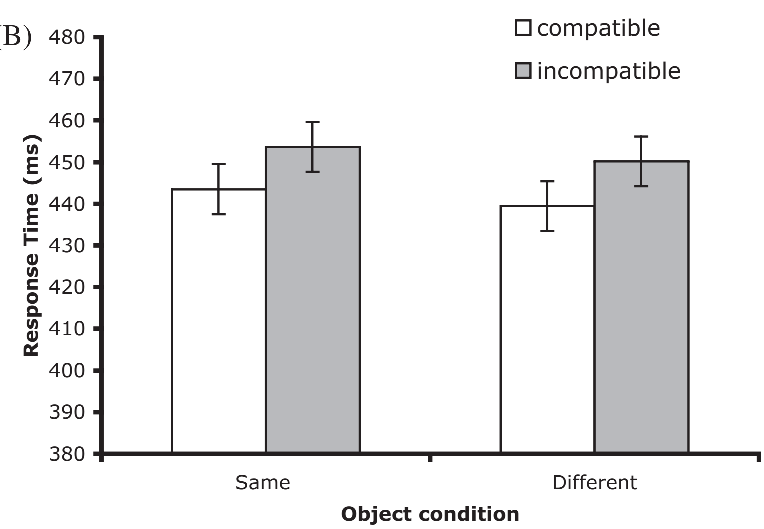


Figure 6. A: Stimuli from a control experiment in which filled rectangular and circular shapes appeared to fall on top of the background rectangle(s). B: Results from 6 participants. See text for discussion.

General Discussion

On the basis of the five experiments we have reported, we provide evidence in favor of an attentional spreading effect in which attention appears to fill an attended object. Even when participants knew where to attend in advance of a display and were not required to search for the target, we found object-based attention effects, provided that the to-be-reported features were part of the object (i.e., they contributed to the object's shape). A strong search prioritization view would predict no object-based effects in such conditions because attention would have already been prioritized due to the target's fixed location. We found object effects when eye movements to the flanker locations were prevented (Experiment 2). We also found object-based effects when comparing neutral flankers to compatible and incompatible flankers (Experiment 3), ruling out a similarity grouping interpretation of our findings. In addition to finding object-based effects, we replicated prioritization-like effects when task-relevant features were perceptually segregated from objects (Experiments 3 and 4), suggesting that previous prioritization findings might have been a byproduct of this segregation (also see Chen & Cave, 2006). Specifically, attention might have selected the task-relevant stimuli based on their monocularly defined depth plane, allowing the background objects to be effectively ignored.

This constellation of results is relevant for accounts of object-based attention specifically and attention more generally. In regard to object-based attention, the current findings suggest that results from cuing paradigms (e.g., Egly et al., 1994; Vecera, 1994) may be due to attention spreading throughout an attended object and perhaps enhancing the perceptual representation of that object rather than to prioritization of regions to be searched. The natural question is why our results appear at odds with previous results that support a prioritization account. To address this issue, we suggest an "integrality hypothesis" in which different effects result from the relationship between objects and the features used in object-based attention tasks. When task-relevant features are integral to the objects in a display—that is, when the features contribute to the shape or surface structure of the objects (e.g., Baylis & Driver, 1992; Behrmann et al., 1998; Kramer & Jacobson, 1991)—then object-based attention may be more highly constrained to select the object via an attentional spread because the features cannot be selected independently of the object. In contrast, when features are not integral to objects—as when a target appears superimposed on the object (e.g., Egly et al., 1994; Shomstein & Yantis, 2002, 2004; Vecera, 1994)—then object-based attention may be prioritized toward some features over others because the features are readily separated from the objects used to assess object-based attention.

Although our current results support a spread of object-based attention, we would not want to argue that such a spread explains all attentional effects (or even all object-based attentional effects). If there are multiple attentional systems as suggested by some reviews of the literature (Allport, 1993; Luck & Vecera, 2002), then it is logically possible that some of these systems produce different attentional effects. Furthermore, there may be a broader conceptualization of prioritization that could explain the current results. The current experiments conceptualize prioritization as ordering the attentional search across several items. It is possible, however, that prioritization may be defined more broadly to include situations in which areas within attention spreads are given an ordered processing priority. If the notion of prioritization is broadened to include prioritizing the spread of attention, then the current results could be explained by such a broadened account. However, this broader definition of prioritization has not been well developed, and it would be difficult to distinguish from spreading effects that did not require prioritization.

In addition to remaining open to broader conceptualizations of prioritization, we should also acknowledge methodological issues that arise when studying attentional effects. Previous studies of the effects of spatial attention have had difficulty inferring the underlying effects because of potential speed–accuracy tradeoffs. Shiu and Pashler (1994) advocated for using masked displays and measuring accuracy to overcome the limitations of previous studies. Being mindful of Shiu and Pashler's points, we attempted a masked-accuracy flanker experiment similar to Experiment 1, with the hope of demonstrating an object-based flanker effect. Unfortunately, not only could we not observe object-based effects, but we also failed to see reliable flanker effects. Our attempts leave open the need to examine the effects of object-based attention using procedures that would address issues raised in the spatial attention literature.

One lingering question from the current studies is the effect that attention has on the flankers. That is, once attention has spread to the flankers in the same-object condition, how does attention alter the processing of the flankers? Based on the attentional effects that have been proposed in the spatial attention literature, we hypothesize that attention is enhancing the perceptual representations of the flankers, allowing the flankers to be more perceptible and, therefore, to influence responses to the target. However, we acknowledge that our evidence for perceptual enhancement is indirect; future studies should follow findings from the spatial attention literature to demonstrate increased perceptibility for targets appearing within an attended object (e.g., Carrasco et al., 2000, 2002; Cheal & Gregory, 1997; Hawkins et al., 1990; Henderson, 1996; Hillyard et al., 1998; Luck et al., 1996; Yeshurun & Carrasco, 1999).

There is evidence that a spread of attention within an object can enhance the perceptual representation of that object. For example, we have evidence suggesting that a single integral target can produce an enhancement effect in a cued discrimination task that does not require visual search (Vecera, Richard, & Hollingworth, 2005). A study by Han, Dosher, and Lu (2003) is also consistent with an attentional enhancement effect. Han et al. (2003) reported that directing attention toward an object had the effect of reducing the deleterious effects of random masking noise that was superimposed over the object, consistent with a perceptual-level effect of attention.[3] Finally, there is strong evidence for a sensory enhancement effect from electrophysiological measures of object-based attention. Valdes-Sosa, Bobes, Rodriguez, and Pinilla (1998) used an attribute report task and measured event-related potentials (ERPs) to irrelevant changes that occurred on an attended object or an unattended object. These irrelevant changes, a shift in an object's position, elicited early ERP components, namely the P1 and N1. The P1 and N1 components generated were

[3] However, these results come from stimulus displays containing two spatially separated objects (i.e., the objects appeared to the left and right of fixation and were separated by 14.6°), and consequently the effects of object-based attention could have been due to spatial attention, not object-based attention.

larger when the attended object shifted than when the unattended object shifted. Because the P1 and N1 are thought to reflect early sensory enhancement mechanisms (see Hillyard et al., 1998), Valdes-Sosa et al.'s findings strongly support a sensory enhancement effect of object-based attention.

The conclusion of the current experiments is that object-based attention can be the result of an attentional spread through the representation of the attended object. This conclusion, and our integrality hypothesis for explaining when various object-based attentional effects might be observed, make testable predictions for future research. Furthermore, the specific consequences of an attentional spread through an object, such as enhancing the representation of the object, awaits further investigation.

References

Allport, A. (1993). Attention and control. Have we been asking the wrong questions? A critical review of twenty-five years. In D. E. Meyer & S. Kornblum (Eds.), *Attention and performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience* (pp. 183–218). Cambridge, MA: MIT Press.

Avrahami, J. (1999). Objects of attention, objects of perception. *Perception & Psychophysics, 61*(8), 1604–1612.

Baylis, G. C., & Driver, J. (1992). Visual parsing and response competition: The effect of grouping factors. *Perception & Psychophysics, 51*(2), 145–162.

Behrmann, M., Zemel, R. S., & Mozer, M. C. (1998). Object-based attention and occlusion: Evidence from normal participants and a computational model. *Journal of Experimental Psychology: Human Perception and Performance, 24*(4), 1011–1036.

Carrasco, M., Penpeci-Talgar, C., & Eckstein, M. (2000). Spatial covert attention increases contrast sensitivity across the CSF: Support for signal enhancement. *Vision Research, 40*(10–12), 1203–1215.

Carrasco, M., Williams, P. E., & Yeshurun, Y. (2002). Covert attention increases spatial resolution with or without masks: Support for signal enhancement. *Journal of Vision, 2*(6), 467–479.

Cheal, M., & Gregory, M. (1997). Evidence of limited capacity and noise reduction with single-element displays in the location-cuing paradigm. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 51–71.

Chen, Z., & Cave, K. R. (2006). Reinstating object-based attention under positional uncertainty: The importance of subjective parsing. *Perception & Psychophysics, 68*(6), 992–1003.

Cousineau, D. (2007). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorials in Quantitative Methods for Psychology, 1,* 42–45.

Eckstein, M. P., Thomas, J. P., Palmer, J., & Shimozaki, S. S. (2000). A signal detection model predicts the effects of set size on visual search accuracy for feature, conjunction, triple conjunction, and disjunction displays. *Perception & Psychophysics, 62,* 425–451.

Egly, R., Driver, J., & Rafal, R. D. (1994). Shifting visual attention between objects and locations: Evidence from normal and parietal lesion subjects. *Journal of Experimental Psychology: General, 123,* 161–177.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16,* 143–149.

Eriksen, C. W., & Hoffman, J. E. (1973). The extent of processing of noise elements during selective encoding from visual displays. *Perception & Psychophysics, 14,* 155–160.

Eriksen, C. W., & Spencer, T. (1969). Rate of information processing in visual perception: Some results and methodological considerations. *Journal of Experimental Psychology Monographs, 79*(2 Pt. 2), 1–16.

Han, S., Dosher, B. A., & Lu, Z.-L. (2003). Object attention revisited: Identifying mechanisms and boundary conditions. *Psychological Science, 14*(6), 598–604.

Hawkins, H. L., Hillyard, S. A., Luck, S. J., Mouloua, M., Downing, C. J., & Woodward, D. P. (1990). Visual attention modulates signal detectability. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 802–811.

Henderson, J. M. (1996). Spatial precues affect target discrimination in the absence of visual noise. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 780–787.

Henderson, J. M., & Macquistan, A. D. (1993). The spatial distribution of attention following an exogenous cue. *Perception & Psychophysics, 53,* 221–230.

Hillyard, S. A., Vogel, E. K., & Luck, S. J. (1998). Sensory gain control (amplification) as a mechanism of selective attention: Electrophysiological and neuroimaging evidence. *Philosophical Transactions of the Royal Society: Biological Sciences, 353,* 1257–1270.

Kramer, A. F., & Jacobson, A. (1991). Perceptual organization and focused attention: The role of objects and proximity in visual processing. *Perception & Psychophysics, 50,* 267–284.

Lavie, N., & Driver, J. (1996). On the spatial extent of attention in object-based visual selection. *Perception & Psychophysics, 58,* 1238–1251.

Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subjects designs. *Psychonomic Bulletin & Review, 1,* 476–490.

Luck, S. J., Hillyard, S. A., Mouloua, M., & Hawkins, H. L. (1996). Mechanisms of visual-spatial attention: Resource allocation or uncertainty reduction? *Journal of Experimental Psychology: Human Perception and Performance, 22,* 725–737.

Luck, S. J., Hillyard, S. A., Mouloua, M., Woldorff, M. G., Clark, V. P., & Hawkins, H. L. (1994). Effects of spatial cuing on luminance detectability: Psychophysical and electrophysiological evidence for early selection. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 887–904.

Luck, S. J., & Vecera, S. P. (2002). Attention: From tasks to mechanisms. In S. Yantis (Ed.), *Stevens' handbook of experimental psychology, Vol. 1: Sensation and perception* (pp. 235–286). New York: Wiley.

Luck, S. J., Woodman, G. F., & Vogel, E. K. (2000). Event-related potential studies of attention. *Trends in Cognitive Sciences, 4,* 432–440.

Mozer, M. C., & Vecera, S. P. (2005). Object-based and space-based attention. In L. Itti, G. Rees, & J. K. Tsotsos (Eds.), *Neurobiology of attention* (pp. 130–134). New York: Elsevier.

Palmer, J., Ames, C. T., & Lindsey, D. T. (1993). Measuring the effect of attention on simple visual search. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 108–130.

Pashler, H. E. (1998). *The psychology of attention.* Cambridge, MA: MIT Press.

Prinzmetal, W., Presti, D. E., & Posner, M. I. (1986). Does attention affect visual feature integration? *Journal of Experimental Psychology: Human Perception and Performance, 12,* 361–369.

Scholl, B. J. (2001). Objects and attention: The state of the art. *Cognition, 80*(1–2), 1–46.

Shiu, L., & Pashler, H. (1994). Negligible effect of spatial precuing on identification of single digits. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 1037–1054.

Shomstein, S., & Yantis, S. (2002). Object-based attention: Sensory modulation or priority setting? *Perception & Psychophysics, 64,* 41–51.

Shomstein, S., & Yantis, S. (2004). Configural and contextual prioritization in object-based attention. *Psychonomic Bulletin & Review, 11,* 247–253.

Treisman, A. (1988). Features and objects: The Fourteenth Bartlett Memorial Lecture. *Quarterly Journal of Experimental Psychology, 40,* 201–237.

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12,* 97–136.

Valdes-Sosa, M., Bobes, M. A., Rodriguez, V., & Pinilla, T. (1998). Switching attention without shifting the spotlight: Object-based attentional modulation of brain potentials. *Journal of Cognitive Neuroscience, 10,* 137–151.

Vecera, S. P. (1994). Grouped locations and object-based attention: Comment on Egly, Driver, and Rafal (1994). *Journal of Experimental Psychology: General, 123*(3), 316–320.

Vecera, S. P. (2000). Toward a biased competition account of object-based segregation and attention. *Brain and Mind, 1,* 353–384.

Vecera, S. P., & Farah, M. J. (1994). Does visual attention select objects or locations? *Journal of Experimental Psychology: General, 123*(2), 146–160.

Vecera, S. P., Richard, A. M., & Hollingworth, A. (2005). The spatial distribution of object-based attention. *Abstracts of the Psychonomic Society, 10,* 13.

Watson, S. E., & Kramer, A. F. (1999). Object-based visual selective attention and perceptual organization. *Perception & Psychophysics, 61*(1), 31–49.

Yantis, S., & Johnson, J. (1990). Mechanisms of attentional priority. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 812–825.

Yeshurun, Y., & Carrasco, M. (1999). Spatial attention improves performance in spatial resolution tasks. *Vision Research, 39,* 293–306.

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