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Is Object-Based Attention Mandatory? Strategic Control Over Mode of Attention

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Is object-based attention mandatory or under strategic control? In an adapted spatial cuing paradigm, participants focused initially on a central arrow cue that was part of a perceptual group (Experiment 1) or a uniformly connected object (Experiment 2), encompassing one of the potential target locations. The cue always pointed to an opposite, different-object location. By varying cue validity, the strategic incentive to prevent the spread of attention to the entire cue object, and consequently to the same-object location, was manipulated: With invalid cuing and (consequently) equal probability of targets at same-object and different-object locations, a same-object target identification advantage was observed. With highly valid cuing and targets much more probable at the different-object location than at the same-object location, the same-object advantage disappeared. Object-based attention appears to be a default mode that may be ecologically adaptive but can be overridden by strategic control when there is a strong immediate benefit in doing so.

Keywords: visual attention, object based versus space based, perceptual organization, strategic control, default mode

A large body of literature on visual attention has emphasized the spatial nature of attentional selection, promoting a space-based view in which the basic units of selection are unparsed regions of space (e.g., Eriksen & Hoffman, 1972; Posner, 1980). At the same time, substantial evidence exists that attentional selection is constrained by organizational factors such as gestalt grouping (Wertheimer, 1923) and uniform connectedness (Palmer & Rock, 1994). For example, all else (e.g., spatial separation) equal, the amount of interference from distractor stimuli in selective attention tasks is increased when the target and distractors are strongly grouped (e.g., Baylis & Driver, 1992; Kramer & Jacobson, 1991; Pomerantz, 1981) or perceived as composing a single object (e.g., Pomerantz & Pristach, 1989; Treisman, Kahneman, & Burkell, 1983). Conversely, dividing one's attention between stimulus features that are strongly grouped or that pertain to the same object is more efficient than dividing attention between weakly grouped stimuli or between features of different objects (e.g., Baylis & Driver, 1993; Behrmann, Zemel, & Mozer, 1998; Duncan, 1984; Goldsmith, 1998; Treisman et al., 1983). Further evidence comes from Egly, Driver, and Rafal's (1994) influential adaptation of the spatial-cuing paradigm, in which two objects (e.g., rectangles) are added to the display and targets are presented either within the same object or in a different object than the immediately preceding spatial cue. In addition to the expected space-based advantage in responding to targets at cued versus uncued locations, organizational influences on attention are generally evidenced by faster and more accurate responses to targets presented at an uncued location within the cued object than to targets presented at an equally distant uncued location within the other object (e.g., Atchley & Kramer, 2001; Behrmann et al., 1998; Goldsmith & Yeari, 2003; Lamy & Egeth, 2002; Moore, Yantis, & Vaughan, 1998).

Thus, challenging the view that attentional selection is based solely on spatial parameters, the object-based view (e.g. Duncan, 1984; Treisman et al., 1983) holds instead that attention is directed to discrete perceptual objects (or groups of objects) that emerge from a preattentive segmentation of the visual field in accordance with Gestalt principles of perceptual organization (Neisser, 1967). A central tenet of this view is that the organizational constraints on attentional selection are mandatory: The attempt to select any part or feature of an object necessarily yields a processing advantage for all parts and features of the selected object (Chen & Cave, 2006b; Duncan, 1984; Kahneman & Henik, 1981; Kahneman & Treisman, 1984; Kahneman, Treisman, & Burkell, 1983; Kramer & Jacobson, 1991). In the original, strong version of the object-based view, all features of the selected object enjoy an equal processing benefit. As stated by Kahneman and Henik (1981),

> Attention operates on perceptual units, or objects, that are organized by a prior (preattentive) process . . . to the degree that an object is attended, however, all its aspects and elements receive attention. An irrelevant element of an attended object will therefore attract—and waste—its share of attention. (p. 183)

In somewhat weaker versions based on later findings, the object-based processing of irrelevant object parts or features is differential, with same-object benefits decreasing at locations that are distant from the initially attended object region (e.g., Egly et al., 1994). Thus, attention is often assumed to spread throughout the attended object in a graded manner, depending on both object-

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based (e.g., contours) and space-based (e.g., distance) parameters (e.g., Abrams & Law, 2000; Arrington, Carr, Mayer, & Rao, 2000; Egly et al., 1994; Kramer & Jacobson, 1991; Vecera, 1994). Nevertheless, both strong and weak versions of the object-based view agree that the distribution of attentional resources throughout the object is automatic and nonoptional (but see Shomstein & Yantis, 2002, 2004).

Is Object-Based Attention Mandatory?

Our goal in these experiments was to examine this central claim: Is attention to all parts of an attended object indeed mandatory, or rather, is the spread of attention throughout an object under strategic control? More specifically, under conditions in which it is strategically advantageous to avoid allocating attention to irrelevant parts of an attended object or group, will attention nonetheless conform to object boundaries and perceptual groupings, or will perceivers be able to resist the influence of such organizational factors? Surprisingly, despite a large amount of related research, there is still no clear answer to this question.

The idea that object-based attention is mandatory has been supported implicitly by the many studies in which object-based effects were observed even though object-based allocation was neither strategically expedient nor explicitly required by the task. For example, in the Egly et al. (1994) double-rectangle task, in which targets are no more likely to appear in uncued same-object locations than in uncued different-object locations, there is no strategic incentive to allocate attentional resources preferentially to the former at the expense of the latter. Hence, the finding of a same-object advantage in that paradigm might be taken as indicating that the object-based allocation was automatic and involuntary. However, although such findings might reflect a mandatory mode of allocation that is impervious to strategic control, they might rather merely reflect a general tendency or default mode (cf. Shomstein & Yantis, 2004) that is used unless there is some special (strategic) reason to do otherwise.

Evidence against the claim of mandatory object-based attention is similarly inconclusive. It is now well established that object-based effects on attention are not observed under all conditions (e.g., Goldsmith & Yeari, 2003; Lamy & Egeth, 2002), implying that object-based selection is not universal. It is still quite possible, however, that object-based selection is mandatory whenever the "boundary conditions" for such selection are met. To refute the claim that object-based attention is mandatory (nonoptional), one must show that object-based selection can be avoided when it is strategically worthwhile to do so, under the same conditions in which it would otherwise be observed.

One way of achieving this goal is to manipulate the relative expediency of space-based versus object-based attention, holding all other factors constant. Beck and Palmer (2002), for example, had participants search a row of items for a target defined as any adjacent pair of identical shapes (e.g., two adjacent squares or circles), while manipulating the probability (25%, 50%, or 75%) that both elements of the adjacent target pair would be part of the same rather than different perceptual groups. Overall, search latencies were faster when the target elements were presented within the same group than between groups, with this difference decreasing as the probability of different group targets increased. Nevertheless, attention to perceptual objects or groups may still be mandatory because the same-group advantage was not negated entirely, even in the 25% same-group condition.

In a second study, Shomstein and Yantis (2004) examined control over attentional scanning strategies in the Egly et al. (1994) double-rectangle paradigm, described earlier. The critical manipulation involved the probability that the target would appear in a particular location on invalid-cue trials: Although invalidly cued targets were equally as likely to appear in same-object and different-object locations, such targets appeared in only two of the four possible locations throughout the experiment (e.g., upper right and bottom left corners) and were much more likely to appear in one of these two locations (83% of the invalid-cue trials) than in the other. Shomstein and Yantis's results indicated that at short to moderate cue–target stimulus onset asynchronies (SOAs; 200 ms and 400 ms), both the spatial probabilities and the rectangle objects were influencing performance on invalid-cue trials in an additive manner: Response times were faster to high-probability targets than to low-probability targets and to same-object targets than to different-object targets. At the longest cue–target SOA (600 ms), however, the same-object advantage disappeared, and the spatial-probability effect remained.

These results were interpreted within an "attentional prioritization" framework (Shomstein & Yantis, 2002), in which object-based effects are assumed to reflect a default tendency to scan same-object locations before different-object locations on invalid-cue trials. On the basis of the results just described, Shomstein and Yantis (2004) concluded that it might take as long as 600 ms to override this tendency. Alternatively, adhering to the more traditional object-based view mentioned earlier, in which attention is assumed to spread or "radiate" from the cued location throughout the attended object, 600 ms may just be the time it takes for the object-based radiation to dissipate. Without the inclusion of a control condition in which there is no special target-location probability manipulation and in which an object-based effect is observed at an SOA of 600 ms, one cannot know whether the absence of an object-based effect at an SOA of 600 ms in Shomstein and Yantis's (2004) study was in fact a consequence of strategic control. (For a related discussion regarding the possible weakening of object representations at long cue–target SOAs, see Goldsmith & Yeari, 2003, and see footnote 7, later). In any case, conclusive evidence that object-based attention is optional (i.e., that it can be completely avoided) requires the elimination of object-based attention at short and long SOAs.

Present Research

As just discussed, although there is some evidence to indicate a limited degree of strategic control over object-based attention when the expediency of such control is manipulated, whether the effects of perceptual organization on attention can be completely avoided through such control is unclear.[1] In addition, whether resisting object-based influences on attention might incur a residual cost in the effectiveness of the ensuing space-based attentional

[1] A recently published study by Shomstein and Behrmann (2008), conducted in parallel with the current research, demonstrated that the object-based effects in Shomstein and Yantis's (2004) task can be eliminated even at a short cue–target SOA under specific conditions. A discussion of their results and conclusions, in light of our own, is deferred to the General Discussion.

allocation is unknown. To examine these questions, in this research we used a very strong expediency manipulation to induce participants to avoid an object-based mode of attentional allocation: Targets were presented in the different-object location on 75% or 80% of the trials, and this different-object location was pointed to by a highly valid arrow cue on all of the trials. Essentially, this manipulation combines the manipulation of different-object target probability used by Beck and Palmer (2002) with the manipulation of spatial information used by Shomstein and Yantis (2004).

We used the same basic paradigm in two experiments: Experiment 1 examined the ability to avoid the attentional influence of perceptual grouping (cf. Beck & Palmer, 2002), and Experiment 2 examined the ability to avoid the attentional influence of a uniformly connected object (cf. Shomstein & Yantis, 2004). In a specially designed discrimination task with a spatial precue, participants fixated attention on a central cue that was part of a perceptually grouped object (Experiment 1; Figure 1A) or uniformly connected object (Experiment 2; Figure 1C). The cue always pointed to an opposite, different-object location. By varying cue validity, the strategic incentive to avoid the spread of attention to the entire cue object was manipulated: When the cue was uninformative of target location (chance validity), such that targets were equally likely to appear in same-object (connected or grouped with arrow cue) and different-object (not connected or grouped with arrow cue) locations, we expected to find a same-object advantage, with same-object targets identified faster than different-object targets. This assumes that object-based attention is a default tendency (Shomstein & Yantis, 2004), a generally preferred mode of selection that is used unless there is a strong and clear reason to avoid it. In contrast, when the cue was highly informative, such that cued different-object targets were much more probable than uncued same-object targets, a strong strategic advantage in avoiding object-based attention to the entire cue object should exist. We hypothesized that under these conditions, participants would attempt to attend to the central arrow cue and subsequently orient attention to the cued peripheral location in a space-based manner, that is, without attention being drawn involuntarily, either by gestalt grouping (Experiment 1) or by uniform connectedness (Experiment 2), to the opposite, same-object peripheral location. The critical question was whether they would be successful. If they were, would they be equally successful at both short and long cue–target SOAs? Finally, if they were successful in negating object-based effects, would there nevertheless be a "residual cost" of avoiding object-based attention in comparison to a control condition in which there was no perceptual group or uniformly connected object whose influence needed to be avoided?

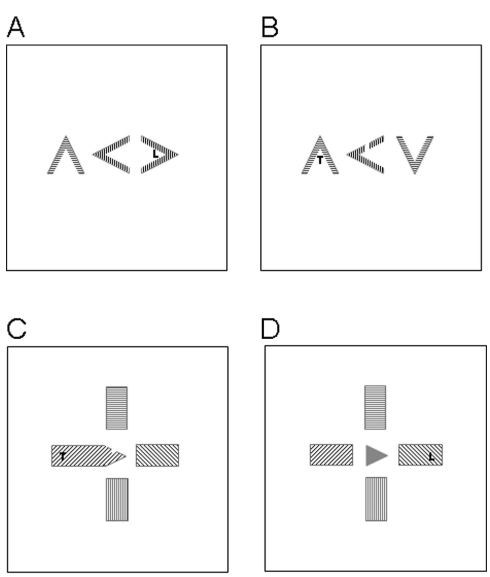

Figure 1. Examples of the visual displays used in the two studies and their control conditions. The central arrow shape is a spatial precue that points to the target location with either high or low validity, and either two or four peripheral shapes mark the potential target locations. A: Experiment 1—cue and one peripheral location marker are perceptually grouped. B: Experiment 1 control—no grouping between cue and peripheral location marker. C: Experiment 2—cue and one peripheral location marker form a uniformly connected object. D: Experiment 2 control—cue and peripheral location marker do not form a uniformly connected object. Examples of the no-go cue, a small gap or notch in the central arrow cue, appear in Panels B and C. Examples of the target letters, *L* or *T*, appear in uncued same-object locations in Panels A and C and in cued different-object locations in Panels B and D. Different textures in the figure represent different colors of approximately equal luminance in the actual displays.

Experiment 1

In the first experiment, we examined the mandatory versus strategic nature of object-based attention to perceptual objects formed by gestalt grouping. In particular, we examined whether the effects of gestalt grouping on the allocation of attention can be avoided when there is a strong strategic advantage in doing so. In this experiment, the visual display consisted of a row or column of three arrowlike elements (<), with each element appearing in a different orientation (see Figure 1A). One such element, presented at the center of the screen, served as an endogenous spatial cue, with the two peripheral elements serving as potential target location markers. Critically, on each trial the central arrow element and one of the peripheral elements (same-group element) were oriented 180° with respect to each other, such that they perceptually grouped to form an unconnected diamondlike object, whereas the other peripheral element (different-group element), pointed to by the vertex of the central arrow element, was oriented such that it would not group with either of the other two elements (with an orientation difference of 90° or 270°). To strengthen the phenomenal impression of grouping between the central cue and the same-group peripheral element, these two elements were also presented in a different color than the different-group element. Then 100, 200, 300, or 400 ms after this initial display, a target letter (*L* or *T*) was presented within one of the two peripheral elements. The participants' task was to identify the target as quickly and as accurately as possible.

Cue validity was manipulated by varying the percentage of trials on which the target appeared within the different-group peripheral element pointed to by the central cue: 50% in Experiment 1A (uninformative cue) and 80% in Experiment 1B (informative cue). To ensure that participants would focus attention on the central arrow-cue element, regardless of whether it was informative of target location, a "no-go" cue, instantiated as a small gap in one of the central element's line segments, appeared on 20% of the trials. Participants were instructed to refrain from responding on trials in which the no-go cue was present.

To examine systematically the strategic control over object-based attention in this experiment (and in the next), we performed several types of analyses and comparisons: First, we examined performance in the uninformative-cue condition to ensure that a same-object advantage was in fact observed under such conditions. Second, after establishing the existence of "default" object-based attention, we examined whether such attention could be completely avoided: (a) whether the same-object advantage would be eliminated in the informative-cue condition, (b) whether the elimination of the same-object advantage in the informative-cue condition would be observed at both short and long SOAs, and (c) whether there would be any residual cost of avoiding object-based attention in the informative-cue condition, when comparing response latencies to validly cued targets in that condition to the corresponding latencies in a control condition in which the informative central cue was not grouped with any of the peripheral location markers (Figure 1B).

Method

Participants. Forty undergraduate students at the University of Haifa, 20 in the uninformative-cue condition (Experiment 1A) and 20 in the informative-cue condition (Experiment 1B), participated for payment. All participants had normal or corrected-to-normal vision and normal color vision.

Apparatus and stimuli. The experiments were run using an IBM PC–compatible computer and a super-VGA, high-resolution color monitor. Participants viewed the monitor from a distance of 120 cm with the head placed on a chin rest in a dimly lit room.

The fixation cross subtended 0.4° × 0.4°. The stimuli were three colored (red or blue) arrowlike elements (>), presented on a white background at different orientations. Each element was composed of two line segments, each 3° in length, forming a 60° angle. The three elements were positioned in either a horizontal or a vertical configuration, with the middle element centered at the center of the display and the two peripheral elements centered 3.5° to either side. On no-go trials, a small gap subtending 0.14° × 0.72° dissected one of the central element's line segments. The target stimulus, a capital letter *L* or *T*, subtending 0.3° × 0.4°, was presented at the center of one of the peripheral elements (in the open space between the line segments). Two types of element displays were used, grouped object and no grouped object.

Experiment 1A and Experiment 1B, grouped-object condition. In Experiment 1A and in the grouped-object condition of Experiment 1B, the central arrow element and one of the peripheral elements (same-group element) were perceptually grouped by presenting them in the same color and orienting them 180° relative to each other to form an unconnected diamond shape (< >). The other peripheral element (different-group element) was presented in a different color and oriented either 90° or 270° relative to the other two elements.

Experiment 1B, no-grouped-object condition. In the no-grouped-object condition of Experiment 1B, perceptual grouping between the central cue element and the peripheral elements was prevented by orienting each peripheral element either 90° or 270° with respect to the central element (180° with respect to each other) and by presenting the two peripheral elements in a different color than the central element.

Procedure. Participants were run individually. The procedures for the two experiments (and for the grouped-object and no-grouped-object conditions within Experiment 1B) were identical except as noted. On arriving at the experiment, participants read a description of the task, and any questions that they had were answered. The importance of maintaining eye fixation throughout each trial was stressed. Participants were then given a block of practice trials that were identical to the experimental trials, during which the experimenter was seated where he could observe the participant's eyes to verify that the participant had completed at least 20 consecutive practice trials without eye movements. This was followed by several blocks of experimental trials, as specified for each experiment.

Each trial began with a blank screen for 0.5 s, and then the fixation cross appeared at the center of the screen. After 1.5 s, the three colored elements were presented in either a vertical or a horizontal configuration, remaining on the screen until the end of the trial. After a cue–target SOA of 100, 200, 300, or 400 ms, the target letter appeared for 50 ms at one of the two peripheral locations. Participants then indicated whether the target was a *T* or an *L* by pressing a key. They were instructed to respond as quickly as possible but to avoid making errors. Errors were signaled by a short beep. Element configuration, cue-element coloring, different-group element orientation, target position, and cue–target SOA were randomly intermixed within blocks. The no-go cue was present on a randomly chosen 20% of the trials; participants were instructed to refrain from responding on these trials. The two experiments differed with respect to the informativeness of the central cue and with respect to the manipulation of element grouping.

Experiment 1A: Uninformative cue. In Experiment 1A, the target letter was equally as likely to appear within either of the two peripheral shapes, regardless of the direction (or grouping) of the cue. That is, the central arrow cue provided no information regarding the target's subsequent location. All of the displays were grouped-object displays in which one peripheral element was perceptually grouped with the central cue element. One practice block of 100 trials was followed by four blocks of 200 trials. These were performed in a single session of about 45 min.

Experiment 1B: Informative cue. Experiment 1B differed from Experiment 1A in two essential respects: First, the central arrow cue was highly informative regarding the upcoming target location, with targets appearing in the cued peripheral location 80% of the time versus 20% in the uncued location. Second, the type of element display, grouped object versus no grouped object, was manipulated within participants in two sessions in counterbalanced order, separated by about 1 week. Each 45-min session consisted of one practice block of 100 trials, followed by four blocks of 200 trials.

Results and Discussion

We calculated mean correct response latencies and error rates on go trials only for each participant separately for cued (different-group) and uncued (same-group) targets at each of the four cue–target SOAs. In Experiment 1B, these calculations were performed separately for the grouped-object and no-grouped-object conditions. Latency means were trimmed by omitting any observation more than 2.5 standard deviations above or below the mean for a particular cell (2.8% for Experiment 1A and 2.9% for Experiment 1B). We also calculated the rate of no-go errors (i.e., the rate of responding on no-go trials) for each participant. Overall, the no-go error rate averaged only 3.7% ($SD = 3.8$), indicating that the participants were in fact focusing their attention initially on the central cue element to detect the no-go cue.

The trimmed mean latencies for all experiments and conditions are presented in Figure 2. The error rates are presented in Table 1. Both experiments yielded statistically significant main effects of cue–target SOA on response latency, indicating a general decrease in response time with increasing SOA. This effect of SOA across the other conditions is not of current interest and, although included in the analyses, is not reported further.

Experiment 1A: Uninformative cue. As a precondition for examining whether object-based attention to the central cue group can be avoided when there is a strong strategic advantage in doing so (under informative cuing in Experiment 1B), we first examined whether object-based attention was observed in the baseline condition of uninformative cuing in Experiment 1A. A two-way repeated measures target position (cued–different group vs. uncued–same group) × cue–target SOA analysis of variance (ANOVA) conducted on the response latencies revealed that, indeed, same-group targets were identified faster (565 ms) than different-group targets (576 ms), $F(1, 19) = 14.7$, $MSE = 356$, $p < .001$. There was no interaction between target position and cue–target SOA ($F < 1$). Nonetheless, it is worth noting that the same-group advantage was statistically significant at SOAs of 200 ms, 300 ms, and 400 ms, but not at an SOA of 100 ms; for the latter comparison, $t(19) = 0.93$, *ns*.

We conducted a similar analysis on the error rates, primarily to ensure that the latency results did not stem from a speed–accuracy trade-off. In line with the latency results, the overall error rate for same-group targets (3.0%) was lower than that for different-group targets (3.8%), $F(1, 19) = 5.0$, $MSE = 0.6$, $p < .05$. The interaction with cue–target SOA was again not significant, $F(1, 19) = 1.3$, $MSE = 0.4$, *ns*. Unlike in the latency results, however, we observed a same-group advantage on error rates at an SOA of 100 ms as well (3.8% vs. 4.3%), $t(1, 19) = 2.0$, $p < .05$ (one-tailed). Thus, the accuracy results generally reinforce the latency results, indicating an automatic or default tendency to allocate attention to the peripheral location that is grouped with the central cue element, under conditions in which there is no strategic reason to do so (or not to do so). There was no indication of a speed–accuracy trade-off.

Experiment 1B: Informative cue, grouped-object condition. We now turn to the grouped-object condition of Experiment 1B, in which the spatial cue was highly valid and targets now appeared in the cued, different-object location on 80% of the trials. Under these conditions, could participants resist the default tendency to allocate attention to the entire grouped cue object? A two-way target position (cued–different group vs. uncued–same group) × cue–target SOA ANOVA on the response latencies again yielded a significant main effect of target position, $F(1, 19) = 9.0$, $MSE = 1122$, $p < .001$. Here, however, the cued, different-group targets were identified faster (521 ms) than the uncued, same-group targets (537 ms). Again, there was no interaction between target position and cue–target SOA ($F < 1$), although we should note that as expected, the latency advantage at the cued (different-group) location reached statistical significance only at

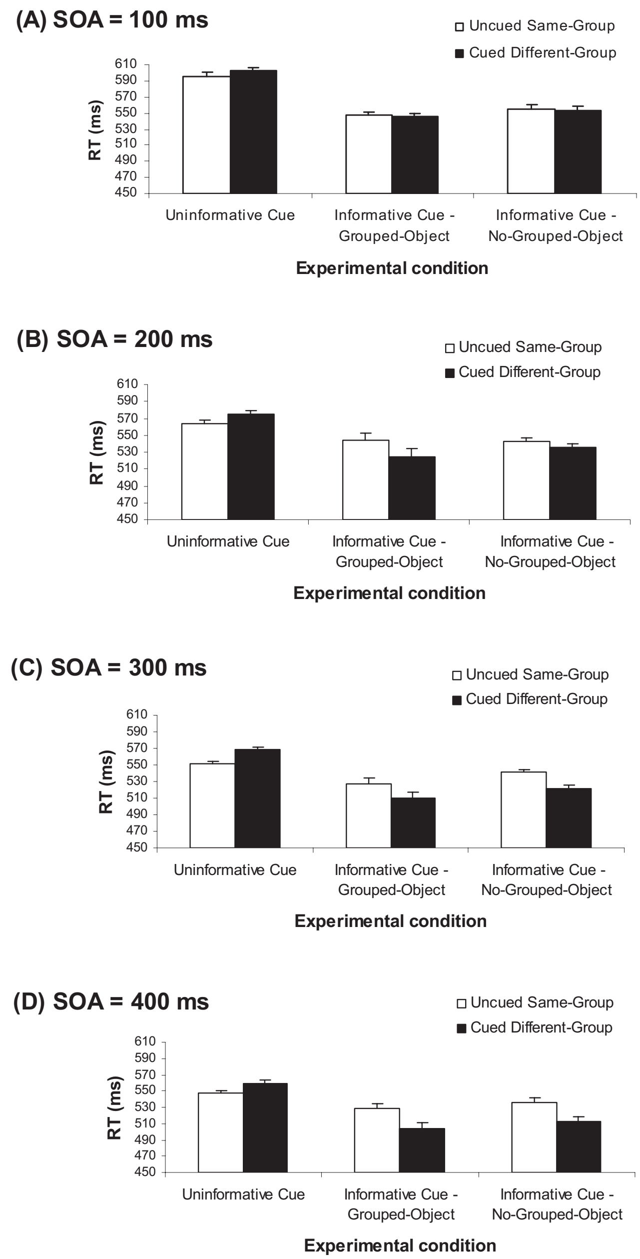

Figure 2. Results from Experiment 1. Mean correct response latency as a function of cue–target stimulus onset asynchrony (SOA), target position (uncued same group or cued different group), and experimental condition (Experiment 1A, uninformative cue with grouped object; Experiment 1B, informative cue with grouped object; and Experiment 1B, informative cue with no grouped object). Note that the target position labels *same-group* and *different-group* pertain to the two grouped-object conditions only. Error bars represent 1 standard error of the mean within participant, target-position difference, uncued same group versus cued different group (see Cousineau, 2005; Loftus & Masson, 1994). RT = response time.

SOAs of 300 ms, $t(19) = 1.8$, $p < .05$ (one-tailed), and 400 ms, $t(19) = 2.6$, $p < .05$. Most important, there was no indication of a same-group advantage at any SOA.

To directly compare the pattern of results observed with an informative cue in Experiment 1B with the one observed earlier

Table 1
Mean Error Rates (in Percentages) of Study 1 Experimental Conditions

	SOA = 100 ms		SOA = 200 ms		SOA = 300 ms		SOA = 400 ms	
Cue	Same group	Different group	Same group	Different group	Same group	Different group	Same group	Different group
Uninformative	2.8	4.3	2.6	4.0	3.4	3.9	3.1	3.0
Informative								
Connected object	3.9	3.6	5.1	3.5	7.6	3.6	7.2	4.2
No connected object	3.4	3.9	3.9	2.9	5.8	4.3	5.8	4.0

Note. SOA = stimulus onset asynchrony.

with an uninformative cue in Experiment 1A, we added cue informativeness (experiment) to the analysis as a between-participants variable. As expected, the interaction between cue informativeness and target position was highly significant, $F(1, 38) = 20.2$, $MSE = 739$, $p < .001$: Whereas under the uninformative cuing in Experiment 1A, uncued same-group targets were identified faster than cued different-group targets, the reverse was true under the informative cuing in Experiment 1B. Again, although the triple interaction with cue–target SOA was not significant, $F(3, 114) = 1.3$, $MSE = 550$, *ns*, the different pattern between the two experiments, reflected in the two-way Cue Informativeness × Target Position interaction, was significant at SOAs of 200 ms, 300 ms, and 400 ms, but not at an SOA of 100 ms; for the latter interaction, $F(1, 38) = 1.1$ $MSE = 452$, *ns*. Note that a marginally significant main effect of cue informativeness was observed, $F(1, 38) = 2.5$, $MSE = 54{,}903$, $p = .12$, suggesting a trend toward faster responding in the informative-cue condition (479 ms) than in the uninformative-cue condition (521 ms). Aside from possible sampling error, the reason for this trend is not completely clear, but we speculate that orienting attention on the basis of an informative cue may cause participants to be more alert, which is then expressed in generally faster responding.

To reinforce the latency results and ensure that these were not the result of a speed–accuracy trade-off, we conducted a similar three-way mixed ANOVA on the error rates. In line with the latency results, this analysis also yielded a highly significant interaction between cue informativeness (experiment) and target position, $F(1, 38) = 17.5$, $MSE = 1.0$, $p < .001$: Whereas under uninformative cuing in Experiment 1A, as reported earlier, fewer errors were made in identifying uncued same-group targets than in identifying cued different-group targets, the reverse was true under the informative cuing in Experiment 1B, where more errors were made in identifying uncued same-group targets (6%) than in identifying cued different-group targets (3.8%), $F(1, 19) = 12.5$, $MSE = 2.0$, $p < .01$. The triple interaction between cue informativeness, target position, and cue–target SOA was not significant ($F < 1$). In fact, the different pattern of error rates, reflected in the two-way Cue Informativeness × Target Position interaction, was statistically significant at SOAs of 200 ms, 300 ms, and 400 ms and approached significance at an SOA of 100 ms, $F(1, 38) = 2.6$, $MSE = 1.6$, $p = .12$ ($p = .06$ by a one-tailed t test on the same–different group difference).

Experiment 1B: Informative cue, no-grouped-object condition. So far, the results comparing performance in Experiments 1A and 1B on grouped-object displays indicate that when valid information about the position of upcoming targets in Experiment 1B made it strategically expedient to avoid object-based attention, the participants were able to do so. To uncover any residual cost of avoiding object-based attention in the grouped-object condition of Experiment 1B, we compared performance in that condition to performance in the no-grouped-object condition. A three-way repeated measures display type (grouped object vs. no grouped object) × target position (cued location–different group vs. uncued location–same group)[2] × cue–target SOA ANOVA on response latencies revealed no differences in performance between the grouped-object and no-grouped-object conditions, with both the main effect of display type and all interactions involving this variable nonsignificant (all Fs < 1). In particular, we note that validly cued targets were responded to equally as fast in the grouped-object (537 ms) and no-grouped-object (544 ms) displays ($F < 1$), even though in the former condition there was an opposing perceptual group that might have attracted attention. Similarly, response latencies at the uncued location, which might have benefitted from object-based attention in the grouped-object condition, were nevertheless equivalent in that condition (521 ms) and in the no-grouped-object condition (531 ms; $F < 1$).

A similar three-way ANOVA on the error rates also yielded a nonsignificant main effect of display type ($F < 1$). There was a significant interaction between display type and target position, $F(1, 19) = 5.5$, $MSE = 0.7$, $p < .05$, reflecting a smaller difference in error rates (0.9%) between the cued and uncued locations in the no-grouped-object condition (3.8% vs. 4.7%, respectively) than that reported earlier in the grouped-object condition (2.2%). Thus, if anything, the effect of the spatial cue on performance was actually somewhat more pronounced in the grouped-object condition (in which the spatial cuing effect was opposed by the potential effect of perceptual grouping) than in the no-grouped-object condition. The Display Type × Cue–Target SOA interaction and the triple interaction were both nonsignificant ($F < 1$).

In sum, the results of this experiment support the two general hypotheses outlined in the introduction: Object-based attention is a default mode of attentional allocation, which occurs when certain boundary conditions are met and when there is no strategic reason to avoid its use. When made strategically disadvantageous, this

[2] The cued location corresponded to the different-group location and the uncued location corresponded to the same-group location in the grouped-object condition only. In the no-grouped-object condition, neither location was grouped with the central cue element; hence, only the cuing effect is relevant to this condition.

default tendency can be completely overridden (a) at both short and long SOAs and (b) without any residual cost in performance.

Experiment 2

The results of Experiment 1 indicate that when it is strategically expedient to do so, observers can attend to a component element of a perceptually grouped object without attention spreading to the other grouped elements. We designed Experiment 2 to extend these findings to uniformly connected objects (Palmer & Rock, 1994; Watson & Kramer, 1999). Given similar strategic incentives, can observers restrict their attention to a spatial cue that is part of a larger uniformly connected object without attention spreading to the entire object? Aside from providing a needed replication of the preceding experiment with different stimuli, this experiment also entailed a more stringent test of the idea that object-based attention can be eliminated by strategic control. One could argue that in Experiment 1B, the strategic change in allocation mode observed with the highly informative cue did not reflect the elimination of object-based attention but rather the use of a more constrained mode of object-based or "part-based" attention to the central arrow element per se (Barenholtz & Feldman, 2003; Vecera, Behrmann, & Filapek, 2001; Vecera, Behrmann, & McGoldrick, 2000). That is, given the physical separation between the component elements in Experiment 1 and their hierarchical relation to the more global diamondlike object, attention could conceivably be confined to the central arrow element in that experiment by attending to that element in an object-based manner at a more local level of object structure (cf. Kimchi, 1992; Navon, 1977). The use of uniformly connected, single-part objects in Experiment 2 disallows such a strategy.

In Experiment 2, we used the same basic design and procedure as in Experiment 1 but with different stimuli and a different number of cue–target SOAs and potential target locations. Four filled rectangles, each in a different color, acted as peripheral target location markers (see Figure 1C). In addition, a central arrow cue was added as a extension of one of the peripheral location markers (in the same color), such that a uniformly connected, elongated arrow object was formed (➡), lacking any gap or point of negative (concave) curvature in contour that might be used to parse the object into separate component parts (Barenholtz & Feldman, 2003; Hoffman & Richards, 1984). Thus, on each trial one of the potential target locations, situated at the peripheral end of the elongated arrow cue object, constituted the uncued, same-object (as the cue) location, whereas the peripheral location pointed to by the arrow cue constituted the cued, different-object location. Two other peripheral locations, positioned perpendicular to the arrow cue, constituted uncued, different-object locations. Again, cue–target SOA was manipulated: A target letter (*L* or *T*) was presented inside one of the four peripheral location markers 100, 200, or 300 ms after the initial display. The participants' task was to identify the target as quickly and as accurately as possible.

Again, the critical manipulation involved the informativeness of the central cue and the relative likelihood of same-object and different-object targets: In Experiment 2A (uninformative cue), targets were equally as likely (25%) to appear in all four potential locations regardless of the direction of the cue, and in Experiment 2B (informative cue), 75% of the targets appeared at the cued different-object location, with the remaining targets distributed equally among the other three locations. As in Experiment 1, to ensure that participants would focus attention on the central arrow cue, regardless of whether it was informative, a no-go cue, instantiated as a small notch in the outer edge of the central arrow (see Figure 1C), appeared on 20% of the trials, in which case the participants were instructed not to respond.

The predictions and methods of analysis were essentially the same as in Experiment 1, although the inclusion of uncued (neutral) different-object targets in this experiment allowed for additional analyses comparing performance on same-object versus different-object targets, both of which were uncued. As in Experiment 1, Experiment 2B included a no-connected-object comparison condition in which none of the peripheral elements was connected to the central cue, which was also presented in a unique color (black; see Figure 1D).

Method

Participants. Thirty-one undergraduate students at the University of Haifa, 15 in the uninformative-cue condition (Experiment 2A) and 16 in the informative-cue condition (Experiment 2B), participated for payment. All participants had normal or corrected-to-normal vision and normal color vision.

Apparatus and stimuli. Participants viewed the monitor from a distance of 80 cm. Four filled rectangles, each subtending 1.3° × 1.9° and each colored red, blue, green, or purple (with luminance approximately equated), were presented on a white background. Two of the rectangles were oriented horizontally at opposite sides of the central horizontal axis of the display, and two were oriented vertically at opposite sides of the central vertical axis, with endpoints 3.65° from the display center. The target stimulus, a white capital letter *L* or *T*, subtending 0.3° × 0.4°, was presented at the peripheral end of one of the rectangles, 3.2° from the display center. A filled isosceles triangle, subtending 1.3° along the base and 1.3° in height, served as a central spatial cue. The color of the cue depended on display type (connected object vs. no connected object), as described in the next paragraphs. On no-go trials, a small rectangular notch, subtending 0.15° × 0.20°, appeared at the midpoint of one of the two longer sides of the central cue triangle. Two types of displays were used, connected object and no connected object.

Experiments 2A and 2B, connected-object condition. In these displays, the shorter side of the central-cue triangle was connected to one of the peripheral rectangles (same-object location marker) by a rectangular bridge segment, subtending 1.3° × 1.1°. The cue triangle, bridge segment, and peripheral location marker shared the same color, with no gaps between them, so that together they formed an elongated, uniformly colored and connected, arrow-shaped object (see Figure 1C). Each of the other peripheral rectangles (different-object location markers) was distinctly colored in one of the three other colors specified earlier.

Experiment 2B, no-connected-object condition. In these displays, none of the rectangles were connected (or grouped) with the central cue triangle. This was accomplished by omitting the rectangular bridge segment and presenting the central cue triangle in a distinct black color (see Figure 1D).

Procedure. Participants were run individually. The procedure was essentially the same as in Experiment 1, except for the number of levels of cue–target SOA (three; 100 ms, 200 ms, and 300 ms) and the number of target locations (four), leading to changes in the number and distribution of trials.

Experiment 2A: Uninformative cue. In this experiment, the target letter was equally as likely to appear within any of the four peripheral location markers, regardless of the direction of the cue. All of the displays were connected-object displays. Of the trials, 20% were no-go trials in which the participants were instructed to refrain from responding. One practice block of 60 trials was followed by two blocks of 240 trials. These were performed in a single session of about 45 min.

Experiment 2B: Informative cue. Experiment 2B differed from Experiment 2A in two essential respects: First, the direction of the central arrow cue was highly informative regarding the upcoming target location, with targets appearing in the cued peripheral location 75% of the time vs. 8.33% of the time in each of the three uncued locations. Again, 20% of the trials were no-go trials. Second, the type of display, connected object versus no connected object, was manipulated within participants, in two blocked sessions in counterbalanced order, separated by about 1 week. Each 45-min session consisted of one practice block of 60 trials followed by four blocks of 225 trials.

Results and Discussion

We calculated trimmed mean correct response latencies and error rates on go trials only for each participant at each of the three cue–target SOAs; for same-object and different-object targets (mean of three positions) in Experiment 2A; and for cued different-object, uncued different-object (mean of two positions), and uncued same-object targets in Experiment 2B. In Experiment 2B, we performed these calculations separately for the connected-object and no-connected-object conditions. Latency means were trimmed by omitting any observation more than 2.5 standard deviations above or below the mean for a particular cell (3.1% for Experiment 2A and 2.6% for Experiment 2B). We also calculated the rate of no-go errors (i.e., the rate of responding on no-go trials) for each participant. Overall, the no-go error rate averaged only 2.6% ($SD = 2.9$), indicating that the participants were in fact focusing their attention initially on the central cue element to detect the no-go cue.

The trimmed mean latencies for all conditions in both experiments are presented in Figure 3. The error results are presented in Table 2. Statistically significant main effects of cue–target SOA on response latencies indicated a general decrease in response time with increasing SOA, across all other conditions. As in Experiment 1, this effect of SOA is not of current interest and is not reported further.

Experiment 2A: Uninformative cue. As before, to establish that object-based attention took place under the baseline conditions of uninformative cuing in Experiment 2A, we conducted a two-way repeated measures target position (same object vs. different object) × cue–target SOA ANOVA, with the different-object condition including all three different-object locations, on the response latencies. The results revealed that, indeed, same-object targets were identified faster (490 ms) than different-object targets (510 ms), $F(1, 14) = 35.1$, $MSE = 270$, $p < .001$. There was no interaction between target position and cue–target SOA ($F < 1$), and in fact, the same-object advantage was statistically significant at each of the three individual cue–target SOAs.

A similar analysis of response accuracy indicated that the mean error rate for same-object targets (2.3%) was also lower than that for different-object targets (3.2%), $F(1, 14) = 5.6$, $MSE = 0.3$, $p < .05$. Here, too, the interaction with cue–target SOA was not significant, $F(1, 14) = 1.5$, $MSE = 0.1$, *ns*. Taken together, the finding of faster response times and lower error rates for same-object targets compared with different-object targets in this experiment again indicates a default tendency to allocate attention to the central arrow cue in an object-based manner, under conditions in which there is no strategic reason to do so (or not to do so).[3]

Experiment 2B: Informative cue, connected-object condition. To examine whether the default tendency for object-based attention can be avoided, we turn to the results under informative cuing in the connected-object condition. We conducted a two-way target position (cued different object, uncued different object, or uncued same object) × cue–target SOA ANOVA, in which the uncued different-object condition included the two uncued different-object locations, on the response latencies. Here, too, there was a significant main effect of target position, $F(2, 32) = 6.0$, $MSE = 770$, $p < .01$. However, unlike in Experiment 2A, here this effect derived from shorter latencies for cued different-object targets (485 ms) than for uncued different-object targets (502 ms) and same-object targets (497 ms). A marginally significant interaction between target position and cue–target SOA, $F(4, 64) = 1.7$, $MSE = 527$, $p = .14$, reflected the fact that the cued-location advantage reached significance only at an SOA of 300 ms. Planned comparisons between the uncued, same-object location and the two types of different-object locations indicated that not only were responses to same-object targets actually slower than responses to cued different-object targets, $F(1, 15) = 6.5$, $MSE = 581$, $p < .05$ (this difference significant only at an SOA of 300 ms), they were also no faster than responses to the uncued different-object targets ($F < 1$). There was no interaction with cue–target SOA in the latter comparison ($F < 1$).

To evaluate the statistical significance of the observed differences in the pattern of results between Experiments 2A and 2B when comparing performance at the same-object location with performance at the two different-object locations, we included cue informativeness (Experiment 2A uninformative vs. Experiment 2B informative) in the analyses as a between-participants variable. As expected, the two-way interaction between cue informativeness and target position was significant in comparing mean response

[3] It is important to rule out an alternative explanation for these results, as reflecting the capture of attention by the relatively large and salient arrow-cue object ("pop-out") rather than ensuing specifically from inability to attend to the central arrow shape without attention spreading to the entire cue object. In fact, one might question whether the need to detect the small no-go cue, when present, is at all effective in forcing participants to attend to the central arrow shape. To verify that the observed object-based effect does in fact stem from the need to focus attention on the central arrow shape to detect the no-go cue (when present), we ran a control experiment ($N = 14$ participants) that was identical to Experiment 2A except that the no-go task was omitted (all trials were go trials). Under these conditions, in which there was no reason for participants to try to focus their attention on the central arrow shape, we observed no same-object advantage (i.e., there were no significant effects or interactions involving target position on either latency or accuracy; all Fs < 1). Thus, we can conclude that the large connected arrow-cue object per se was not capturing attention in a purely bottom-up manner and that the no-go task was apparently effective in requiring the participants to focus their attention on the relevant portion of the cue object, with attention then spreading throughout the entire connected object.

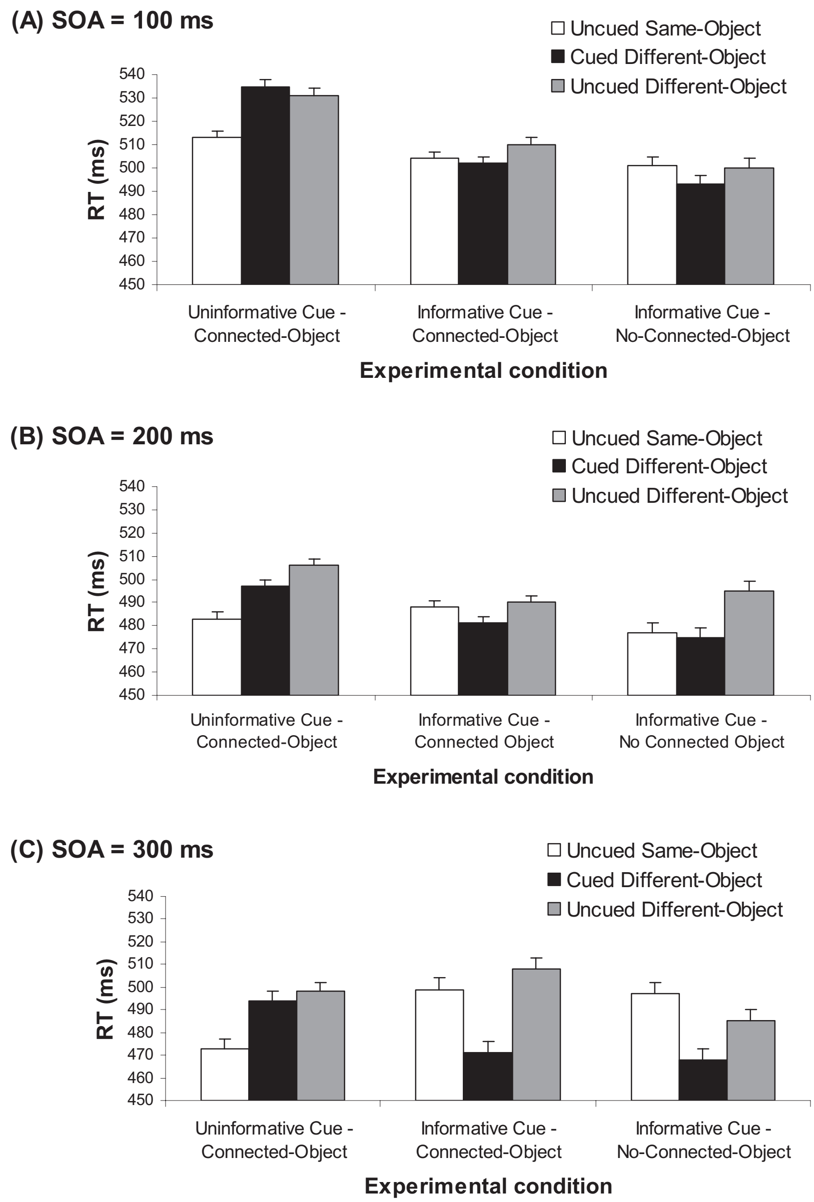

Figure 3. Results from Experiment 2. Mean correct response latency as a function of cue–target stimulus onset asynchrony (SOA), target position (uncued same object, uncued different object, or cued different object), and experimental condition (Experiment 2A, uninformative cue with connected object; Experiment 2B, informative cue with connected object; and Experiment 2B, informative cue with no connected object). Note that the target position labels *same-object* and *different-object* pertain to the two connected-object conditions only. Error bars represent 1 standard error of the within-participant target-position effect (see Cousineau, 2005; Loftus & Masson, 1994). RT = response time.

time at the uncued, same-object location with (a) mean response time at the cued different-object location, $F(1, 29) = 19.3$, $MSE = 646$, $p < .001$; (b) mean response time at the two uncued different-object locations, $F(1, 29) = 5.5$, $MSE = 589$, $p < .05$; and (c) mean response time at all three different-object locations (both cued and uncued), $F(1, 29) = 16.6$, $MSE = 406$, $p < .001$. The comparison involving the cued different-object location was qualified by a triple interaction with cue–target SOA, indicating that the complete reversal of the direction of the object effect as a result of informative cuing was significant only at SOA of 300 ms.

We performed the same set of analyses on the error rates to verify that the preceding pattern was not the result of a speed–accuracy tradeoff. In all cases, the relevant effects and interactions were either significant in the same direction as the latency data or nonsignificant. Thus, there was no evidence of a speed–accuracy trade-off.

Experiment 2B: Informative cue, no-connected-object condition. As in Experiment 1, to examine whether there might be a residual cost of resisting object-based attention in the connected-object condition of Experiment 2B, we compared performance in that condition with performance in the no-connected-object con-

Table 2
Mean Error Rates (in Percentages) of Study 2 Experimental Conditions

Cue	SOA = 100 ms			SOA = 200 ms			SOA = 300 ms		
	Uncued same object	Cued different object	Uncued different object	Uncued same object	Cued different object	Uncued different object	Uncued same object	Cued different object	Uncued different object
Uninformative	1.9	4.0	3.3	2.0	2.0	5.6	3.1	1.7	2.9
Informative									
Connected object	4.7	1.4	2.8	2.3	1.6	1.7	2.5	2.2	2.2
No connected object	1.4	3.9	2.4	0.4	3.1	2.6	3.0	1.8	1.7

Note. SOA = stimulus onset asynchrony.

dition. A three-way repeated measures display type (connected object vs. no connected object) × target position (cued different object, uncued different object, and uncued same object)[4] × cue–target SOA ANOVA on response latencies revealed no differences in mean response time between the connected-object and no-connected-object conditions, with both the main effect of display type and all interactions involving this variable nonsignificant (all Fs < 1) except for the triple interaction, $F(4, 60) = 1.4$, $MSE = 578$, *ns*. Similarly, we found no effects or interactions involving display type in comparing mean response time at the uncued same-object location with mean response time at the cued different-object location (all Fs < 1) or with mean response time at the uncued different-object locations (all Fs < 1) except for the triple interaction, $F(2, 30) = 1.7$, $MSE = 812$, *ns*.

A similar three-way ANOVA on the error rates yielded no significant main effects or interactions involving display type, except for a significant triple interaction between display type, target position, and cue–target SOA, $F(2, 30) = 3.9$, $MSE = 6.3$, $p < .01$. This interaction was difficult to interpret, apparently reflecting a somewhat lower error rate observed at the uncued same-object location compared with the two other target locations in the no-connected-object condition only, at particular levels of SOA (fewer errors compared with the cued different-object location at an SOA of 200 ms and compared with the uncued different-object locations at SOAs of 100 ms and 200 ms).[5] In any case, these differences do not suggest the existence of any residual cost of resisting object-based attention in the connected-object condition.

In sum, the results of Experiment 2 essentially replicate those of Experiment 1, generalizing the findings to the case of uniformly connected objects: Although participants tended to allocate attention to the entire uniformly connected cue object under default–baseline conditions, they were able to restrict attention to a particular region of that object (i.e., the arrow head) when this was made strategically expedient (a) at both short and long SOAs and (b) without any residual performance cost.

General Discussion

These findings indicate that at least under some conditions, object-based attention can be strategically avoided. In two experiments, we found that when beneficial to do so, attention could be allocated selectively either to a particular element of a perceptually grouped object (Experiment 1B) or to an unparsed spatial region of a uniformly connected object (Experiment 2B) without attention spreading to other parts or regions of the same perceptual object, that is, without any benefit to same-object targets. Yet, under the same basic stimulus and task conditions, when there was no reason

[4] These position labels actually apply to the connected-object condition only. In the no-connected-object condition, all locations were different-object (from the cue) locations. Nevertheless, for the sake of comparison, we treated the two uncued locations perpendicular to the cue as uncued different-object locations and the uncued location opposite the cued location as the uncued same-object location.

[5] We remind the reader that the arrow-cue object was not connected to any other location or object in the no-connected-object condition. Hence, these differences cannot be the result of "objectness" or object-based attention.

to avoid attending to the entire object, a same-object advantage was observed (Experiments 1A and 2A). Hence, contrary to the classic object-based view (e.g., Kahneman & Henik, 1981), by which the attentional selection of entire objects is mandatory, these results support the idea that object-based attention is a default mode of allocation that is invoked whenever certain boundary conditions are met, but only as long as there is no strong strategic reason to avoid doing so.

Our discussion of the implications of these results is organized around three interrelated issues: (a) possible boundary conditions for the strategic avoidance of object-based attention, (b) possible mechanisms for the strategic avoidance of object-based attention, and (c) the claim that object-based attention is a "default" mode of selection. The first two issues concern when and how object-based attention might be avoided, whereas the latter issue concerns what object-based attention is and why it might be that objects tend to be selected rather than unparsed regions of space.

When Can Object-Based Attention Be Avoided?

Although these experiments have shown that object-based attention can be completely avoided through strategic control, this need not be so in all situations and under all conditions. Indeed, as we have already discussed, two previous studies on this topic failed to find such a complete elimination of object or grouping effects on attention. What, then, might be the boundary conditions for the strategic avoidance of object-based attention?

One potential factor, considered earlier in the introduction, is the strength of the strategic incentive to avoid object-based attention. As noted earlier, in these experiments we combined two potent incentives: (a) highly imbalanced target probabilities favoring the different-object location over the same-object location and (b) a highly valid spatial arrow cue pointing to the different-object location on all trials. We assumed that the addition of the arrow cue would provide a more explicit basis for orienting attention than the imbalanced object-based probabilities alone and would prevent the need to orient attention to the different-object location by first noticing (attending to) the location of the cue object.[6] Future research, however, might be directed toward isolating the relative contribution of each of these aspects to the negation of the object-based effect. Of course, the specific levels of cue validity or degree of object-based probability imbalance may also contribute to (or detract from) the strength of the strategic incentive to resist object-based attention (e.g., Beck & Palmer, 2002).

A second factor, which presumably opposes the incentive to avoid object-based attention, is the strength of the object-based effect that one is attempting to avoid. Perceptual groups and objects may differ in the extent to which they spontaneously guide or capture attention, which in turn may reflect the organizational quality or strength of the underlying perceptual object representation (e.g., Avrahami, 1999; Kramer & Watson, 1996; Vecera & Behrmann, 2001; Watson & Kramer, 1999). Hence, the difficulty of resisting object-based attention when strategic incentives are introduced may depend on the strength or cohesiveness of the object representations, which may in turn depend on stimulus-related, task-related, and top-down variables, such as the presence or absence of natural parsing points (Singh & Hoffman, 2001; Watson & Kramer, 1999), object salience (Goldsmith, Yeari, Fyodorov, & Friedman, 2006), object exposure duration (Chen & Cave, 2008; Law & Abrams, 2002; Shomstein & Behrmann, 2008), spatial uncertainty (Alvarez & Scholl, 2005; Scholl, Pylyshyn, & Feldman, 2001; Shomstein & Yantis, 2002), the initial focus or spread of attention (Goldsmith & Yeari, 2003), and the specific manner in which the stimulus is interpreted (Baylis & Driver, 1993; Chen, 1998; Chen & Cave, 2006a; Watson & Kramer, 1999).

Recent results by Shomstein and Behrmann (2008) pointed to the importance of object representation in moderating the negation of object-based effects: Object-based effects at short SOAs that were not negated by a highly imbalanced spatial probability of target location on invalid-cue trials in Shomstein and Yantis's (2004) study, described earlier, were negated in the Shomstein and Behrmann (2008) study when the preexposure duration of the rectangle objects was reduced from 1,000 ms to 200 ms, presumably weakening the perceptual object representation. At the same time, the object-based effects reappeared (i.e., were not avoided) even under the 200-ms exposure time, when the objects were made more salient and distinct by coloring them two different solid colors.

Interestingly, in both Experiment 1 and Experiment 2 of this research, participants were able to avoid attending to the entire cue object despite the use of a highly salient and distinct object coloring scheme. Thus, it would seem that one cannot determine whether object-based effects will be negated on the basis of any one factor. Rather, one might need to consider an entire constellation of factors contributing to overall object quality (strength) on the one hand and the strength of the strategic incentive to avoid object-based attention on the other.

How Can Object-Based Attention Be Avoided?

Granted that under the conditions of these experiments, the participants were able to completely resist attending to the entire cue object in an object-based manner, what might be the nature of the mechanism or operations by which they did so? Certainly the most direct mechanism that can be conceived of is to assume that under conditions in which object-based attention is strategically disadvantageous, observers can simply switch to an alternative, space-based mode—a mode in which the perceptual organization of the display in general, and object boundaries and groupings in particular, no longer influence the allocation of attention. Such an idea seems to be implied in some discussions of how object-based and space-based selection effects might coexist (e.g., Atchley & Kramer, 2001; Vecera & Behrmann, 2001).

This type of control mechanism could perhaps help explain findings of mandatory object-based attention in situations in which

[6] Although this issue is not critical for the overall interpretation of our results, there are several reasons to believe that the participants in these experiments were in fact using the arrow cue to orient their attention: (a) They had to attend to the arrow cue anyway to detect the no-go cue (see footnote 3 regarding the substantial effect that this requirement had on the pattern of results); (b) the cue validity effects observed in the grouped- or connected-object conditions of Experiments 1B and 2B were the same as those observed in the corresponding no-group and no-connected-object conditions, in which participants had no choice but to use the central arrow cue to orient attention; and (c) some studies have suggested that arrows can be processed in an automatic fashion (e.g., Hommel, Pratt, Colzato, & Godjin, 2001; Tipples, 2002).

the adoption of a purely space-based mode is precluded by the nature of the task. For example, in a study by Scholl et al. (2001; see also Alvarez & Scholl, 2005), participants were required to track multiple moving targets, each of which could be connected in various ways to a moving distractor to form a single perceptual object. Scholl et al. (2001) found that tracking performance was impaired to different degrees, depending on the type of target–distractor connection, which was taken to reflect the quality of the merged object representation. More important, object-based attention to the higher quality versions of these moving perceptual objects was not avoided even though it was clearly harming performance, and thus appears to be mandatory. Part of this mandatory object-based effect, however, might stem from the dynamic nature of the tracking task and stimuli, which as noted by several authors (e.g., Alvarez & Scholl, 2005; Kahneman, Treisman, & Gibbs, 1992; Pylyshyn, 2001) essentially demand the use of an object-based attention mode: Because the spatial coordinates of the targets and distractors are constantly changing, and in the case of multiobject tracking are generally overlapping, it is simply not possible to track the targets over time on the basis of spatial selection alone. Thus, it is conceivable that whereas one might be able to attend to just one end of a static connected object, by attending to that region in a space-based manner, one would be unable to do so when the object is moving because the space-based mode of attention is now precluded.

Despite its simplicity and appeal, the idea that there are two distinct modes of attending that can be turned on or off as required skirts the issue of how the choice between object-based and space-based modes might be implemented and does not address why the ability to avoid using the object-based mode should depend on the degree of strategic incentive (Beck & Palmer, 2002) or object quality (Scholl et al., 2001; Shomstein & Behrmann, 2008).

A second, more sophisticated type of mechanism that avoids these shortcomings is an interactive mechanism involving top-down modulation of perceptual organization. Such a mechanism might be used to prevent potentially interfering perceptual object representations from forming in the first place or to weaken them after they have formed so that they no longer influence the allocation of attention (see, e.g., Vecera's [2000] "biased-competition" account of object-based attention and Beck & Palmer's [2002] explanation of their results). The feasibility of such a mechanism is suggested by studies in the literature demonstrating top-down control over the quality of the relevant perceptual object representations, which in turn determines whether and how object-based attention is expressed.

Watson and Kramer (1999), for example, showed that when bottom-up stimulus factors, such as color or shape discontinuities, caused participants to parse the stimuli into separate regions, no same-object advantage was observed. Yet, changing the task context to induce a perceptual representation of these same stimuli as whole, meaningful ("wrench") objects reinstated the same-object advantage (see also Chen & Cave, 2006a). In this example, top-down bias of perceptual organization induced the creation of whole-object representations that would not have existed otherwise (see also Baylis & Driver, 1993; Chen, 1998).

Conversely, under conditions in which bottom-up factors spontaneously yield object-based attention, top-down bias of perceptual organization might be used to prevent or weaken it. In the informative-cue condition of our Experiment 2, for example, participants may have attempted to avoid the spread of attention throughout the cue object by subjectively parsing it into two parts: arrow head and rectangle, thereby reducing the perceptual integrality of the object. Note, however, that the curvature of the juncture in this case is convex rather than concave, which does not present a natural parsing point (Hoffman & Richards, 1984; Singh & Hoffman, 2001). Hence, such a subjective segmentation should be relatively difficult because the arrow head and connected rectangle do not constitute separate perceptual "parts" (Gibson, 1994; Vecera et al., 2000; Watson & Kramer, 1999).

The strength and quality of object representations can conceivably also be modulated indirectly, however, through top-down control over the focus of attention. Goldsmith and Yeari (2003) showed that all else equal, object-based effects are observed when attention is initially spread widely across the relevant objects, but not when attention is initially focused elsewhere. Spreading attention over the objects presumably strengthens their perceptual representation, whereas focusing attention elsewhere essentially creates a state of "inattentional blindness" (Mack & Rock, 1998) in which the object representations recede into the background. Thus, if one were motivated to avoid object-based attention, focusing one's attention narrowly enough and long enough for the object representation to recede might be an effective strategy. In these experiments, we tried to minimize the possibility of spontaneous (nonstrategic) differences in attentional focusing between the baseline and informative-cue conditions by requiring participants to focus attention centrally in both conditions to detect the presence of the no-go cue.[7] Thus, if a narrower focus of attention did contribute to the elimination of object-based effects in the informative-cue conditions of these experiments, the reason for the difference is likely to be strategic.

A final potential mechanism by which object-based effects could be modulated might involve inhibition of the irrelevant or interfering object (e.g., Tipper, 1985), yielding a relative advantage at different-object locations. This type of mechanism has found support in selective-attention tasks, in which the object contains interfering information that needs to be filtered out (e.g., Luna, Villarino, Elosua, Merino, & Moreno, 2006; Tipper, 1985; Wühr & Frings, 2008; see also Tipper, Driver, & Weaver, 1991; Watson & Humphreys, 1997). In the present paradigm, however, one would have to make the precarious assumption that the par-

[7] In light of Goldsmith and Yeari's (2003) results, and our use of a central no-go cue in the present paradigm, one might wonder why an object-based effect was observed in the baseline, uninformative-cue conditions. One difference between the two studies is that unlike in Goldsmith and Yeari's (2003) research, in the present paradigm the narrow initial focus is on part of the object itself rather than on a different object or in open space (cf. Chen & Cave, 2006a; Kramer & Jacobson, 1991; Shomstein & Yantis, 2002). A second difference concerns the timing of the focusing: In Goldsmith and Yeari's (2003) experiments, attention was focused for about 1 full second (1,000 ms) after the rectangle objects appeared and before attention was oriented to the rectangle-object location, leaving ample time for the rectangle-object representation to recede into the background of the perceptual organization. By contrast, the object-based effects in this study were examined between 100 and 400 ms after presentation of the cue object (and other location markers), leaving relatively little time for the display to reorganize.

ticipants could inhibit all of the object except for the relevant informative region—the arrow head—which had to be processed effectively to detect the presence or absence of the no-go cue. Thus, the idea that object-specific inhibition might allow observers to attend to one region of an object without attending to the entire object essentially substitutes a new, analogous question for the original one: Can observers inhibit one region of an object without inhibiting the entire object? This too may be an interesting topic for future research.

Object-Based Attention as (Ecologically Adaptive) "Default" Mode

As explained in the introduction to this article, object-based attention was originally conceived as both mandatory and universal (Duncan, 1984; Kahneman & Henik, 1981). Since that time, a number of studies have shown that object-based attention is not universal and is instead subject to various boundary conditions (e.g., Chen & Cave, 2008; Goldsmith & Yeari, 2003; Lamy & Egeth, 2002; Scholl et al., 2001; Watson & Kramer, 1999). Here we have shown that neither is it mandatory, with strategic-probabilistic factors causing participants to avoid object-based attention under conditions in which it would otherwise be observed (see also Shomstein & Behrmann, 2008).

These findings call for a fundamental change in the way in which object-based attention is conceived—as a default rather than a fully automatic mode of attention. In computer science, a default setting is "a particular setting or value for a variable that is assigned automatically by an operating system and remains in effect unless canceled or overridden by the operator" (*American Heritage Dictionary of the English Language*, 2000). By analogy, object-based attention can be conceived of as a bias or tendency to select perceptual objects rather than unparsed regions of space, as long as (a) the boundary conditions for object-based selection are met (e.g., sufficient exposure time) and (b) there is no clear and strong strategic reason to override this tendency. At present, we leave open the issue of whether an explicit instruction or conscious intent might be needed to override the object-based default setting (cf. Lambert, Spencer, & Mohindra, 1987).

A similar proposal of object-based attention as a default tendency was put forward by Shomstein and Yantis (2004) within their attentional prioritization framework:

> Regions within an attended object will, by default, be assigned higher priority for visual exploration than other objects. However, if the behavioral context indicates that some objects or locations should be accorded higher priority than others, then this may dominate the configural bias within a few hundred milliseconds of a cue. (p. 253)

Although we clearly agree with the treatment of object-based attention as a default tendency, we do not believe that this tendency should be conceived solely, or even primarily, in terms of biased scanning priority (see also Alvarez & Scholl, 2005; Chen & Cave, 2006a, 2008; Richard, Lee, & Vecera, 2008).[8] Also, unlike in Shomstein and Yantis's study, our results suggest that there is no minimal amount of time needed to override this default tendency and that it can be accomplished from the first moment an object is presented.

Interestingly, in their recent article, Shomstein and Behrmann (2008) appeared to reject the notion of an object-based default setting. On the basis of their results, they concluded that

> attentional guidance is a dynamic process in which no single mechanism constitutes a frank default setting. Rather, attentional guidance is computed on the basis of relative strengths of object representations, as well as the local contingencies of the environment at hand, and task difficulty. (p. 142)

We, however, see nothing in their findings that warrants abandonment of the object-based default conception. Perhaps the frank default setting that they are referring to (and rejecting) is one that is discrete, in the sense that it can only be turned on or off, rather than one that can perhaps be modulated in a more graded manner and that is subject to various boundary conditions, as suggested earlier.

There are evolutionary arguments that can be made in favor of the object-based default conception as well. Yantis and colleagues (Rauschenberger & Yantis, 2001; Shomstein & Yantis, 2002; Yantis & Hillstrom, 1994; Yantis & Jonides, 1996) have suggested that from an evolutionary perspective, there is an enduring advantage in directing attention to organized objects rather to unorganized sets of visual elements in space. In particular, they argued that it is adaptive to give high priority to perceptual objects in guiding behavior and that the visual system has therefore evolved "hard-wired" mechanisms for efficiently detecting and attending to these objects. Taking an example from the animal kingdom, Yantis and Hillstrom (1994) used the phenomenon of camouflage to illustrate the strategic advantage of attending to meaningful organized objects as opposed to arbitrary sets of local elements: Several dark splotches among the shrubbery might be a harmless collection of disparate shadows or they might belong to a well-camouflaged predator or prey. The ability to quickly perceive and attend to the entire grouped animal stimulus will clearly be generally beneficial for animal survival.

[8] According to Shomstein and Yantis (2002, 2004), *object-based attentional prioritizing* refers specifically to prioritizing the order in which different regions of the scene are scanned when target location is uncertain rather than to a more general attentional benefit, such as sensory enhancement (see also Shomstein & Behrmann, 2008). Perhaps it is not coincidental, then, that both the Shomstein and Yantis (2004) study and the later follow-up study by Shomstein and Behrmann (2008) used what is essentially a visual search task to examine object-based effects: In their version of Egly et al.'s (1994) double-rectangle cuing task, a single target (*T* or *L*) and three distractors (*F*) appeared simultaneously at various orientations at all four potential target locations, presumably requiring a serial search for the (conjunctive) target among the uncued locations on invalid-cue trials. In contrast, in the original Egly et al. (1994) task, and in our studies, the abrupt onset of the target at an uncued location on invalid-cue trials is likely to draw attention to the target location directly and automatically. In this case, object-based effects on invalid-cue trials are likely to reflect a differential allocation of attention (within vs. between objects) before target onset rather than reflecting a differential search priority that is expressed only after the target fails to appear at the cued location. This fundamental difference in the source of object-based effects is suggested by Experiment 5 of Shomstein and Behrmann's (2008) study, the only experiment that did not involve visual search, in which a very different pattern of results was observed: The response time advantage of targets appearing in the highly probable location decreased dramatically, and the same-object advantage was no longer eliminated under short object exposure time. Perhaps, then, it was indeed object-based scanning order rather than object-based attention to the cued location that was being modulated in their other (visual-search) experiments.

This evolutionary perspective, combined with the notion that object-based attention is a default rather than mandatory process, suggests a way of reconciling the conflict between object-based and space-based attention within a common information-oriented conception, encapsulated in the following parsimonious principle: Attention tends to be allocated to the most relevant informative unit of space, taking into account both enduring and transitory strategic considerations. From an evolutionary perspective, it is generally most expedient to allocate attention to perceptually organized objects because of their enduring strategic advantage over unorganized stimuli falling in arbitrary spatial regions. However, this default tendency can be overridden so that attention is allocated in a manner that disregards object and group boundaries, if this is called for strongly enough by transitory strategic considerations in the task at hand.

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