Overt and covert object-based attention

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To examine the role of perceptual object representations in the control of eye movements and attention, a pair of experiments adapted the object-cuing paradigm of Egly, Driver, and Rafal (1994) to require eye movements. Displays were pairs of adjacent rectangles, each containing two characters. Observers were asked to make a speeded judgment of a target character's orientation, and a cue was provided prior to target/distractor onset to indicate the target's likely location. Gaze-contingent presentation of target and distractors was used to demand overt scanning of displays. Eye movements during task performance evinced two forms of object-based effects. First, saccades following fixation on an invalidly cued item were more likely to be made within the cued rectangle than between rectangles. Second, saccades within the cued rectangle were preceded by shorter dwell times than saccades between rectangles. Extrafoveal processing of stimuli within the cued rectangle, however, was not facilitated, suggesting that covert attention was not allocated more densely within the cued than within the uncued object.

Visual attention has often been conceived of as primarily a spatially selective mechanism, comparable to a spotlight (Posner, 1980), zoom lens (Eriksen & St. James, 1986), or gradient (LaBerge & Brown, 1989). This understanding holds that attentional mechanisms produce selective processing within a restricted, contiguous region of the visual field, and that, while the size and coarse shape of the selected area may be somewhat malleable, processing within the attended region is independent of that region's contents. Such space-based theories, however, have recently given way in part to object-based notions of visual attention (e.g., Duncan, 1984). These propose that attentional selection operates upon the output of the parsing and grouping mechanisms responsible for perceptual organization (Wertheimer, 1958), and that the units selected for attention are therefore not simply locations, but perceptual representations of objects or groups. The implication of this distinction is that the perceptual organization of a scene should constrain allocation of attention, allowing attention to spread or shift more readily within perceived objects than between them.

Evidence that the control of attention is in fact mediated by perceptual organization has come in part from the demonstration that observers can more easily attend to a sin-

gle object than to multiple objects (e.g., Duncan, 1984; Kramer, Weber, & Watson, 1997; Vecera & Farah, 1994), and in part from the finding that when attention is drawn to a location within an object, processing of another location within the same object is facilitated relative to processing of an equidistant location within a different object. Egly, Driver, and Rafal (1994), who were first to demonstrate this effect, presented observers with displays of two adjacent rectangles and then cued these observers' attention to a location in one of them. The observers' task was to make a speeded response to a luminance probe appearing at the cued location, at an uncued location in the cued rectangle, or at an equidistant uncued location in the alternative rectangle. As expected, reaction times (RTs) were shortest for probes at the cued location. More importantly, RTs for invalidly cued trials were shorter when probes appeared within the cued object than when they appeared within the uncued object, despite the fact that the target was equally likely to appear at either location and that both uncued locations were the same distance from the cued location. Performance was thus constrained not simply by the distance of the probes from the cued location, but by the perceived organization of the displays. Numerous additional experiments have since confirmed and extended this finding (see, e.g., Abrams & Law, 2000; Moore, Yantis, & Vaughan, 1998; Vecera, 1994).

Notably, however, studies of object-based attention have generally examined only the covert deployment of attention (i.e., the deployment of attention absent eye movements), by employing stimuli too brief to allow eye movements (e.g., Duncan, 1984; Vecera & Farah, 1994), by requiring observers to hold gaze steady during stimulus presentation (e.g., Abrams & Law, 2000; Egly et al., 1994), by presenting stimuli at fixation so that no eye movements were demanded of observers (e.g., Kramer & Jacobson, 1991), or by employing experimental tasks for which object- and

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space-based mechanisms would not be expected to produce differential patterns of eye movements (see, e.g., Yantis, 1992). It is reasonable to speculate, though, that object-based mechanisms might guide eye movements much as they guide allocation of covert attention. Evidence indicates that the deployment of covert attention and the control of saccades are intimately linked, with covert attention being obligatorily shifted to the location of a saccade target in advance of the eye movement itself (Deubel & Schneider, 1996; Hoffman & Subramaniam, 1995; Kowler, Anderson, Doshier, & Blaser, 1995). Accordingly, recent studies have converged on the conclusion that covert and overt attention often behave similarly, both being susceptible to "capture" by the abrupt appearance of new objects (Theeuwes, Kramer, Hahn, & Irwin, 1998; Yantis & Jonides, 1984), for example, and both being primed by repeated deployment to the same target during visual search (Maljkovic & Nakayama, 1994; McPeck, Maljkovic, & Nakayama, 1999).

The aim of the present research was to determine whether and how eye movements, like covert shifts of attention, are influenced by the representation of perceptual groups and objects. Toward this end we adapted the object-cuing paradigm of Egly et al. (1994) to incorporate gaze-contingent control of displays, forcing observers to employ saccadic eye movements in order to perform their task. Frequencies and latencies of gaze shifts within and between objects were examined for evidence of object-based effects. In addition, RT data were examined for insight into the mechanisms by which object-based saccadic effects were produced.

EXPERIMENT 1

Method

Observers. The observers were 19 paid volunteers, ages 19 through 28 years, recruited from the community of the University of Illinois at Urbana-Champaign. All observers had normal or corrected-to-normal visual acuity and were naive as to the purpose of the experiment.

Apparatus. Stimuli were presented on a 21-in. ViewSonic P817 monitor with a resolution of 800×600 pixels and a refresh rate of 85 Hz. Eye movements were recorded with an Eyelink eye tracker (SR Research Ltd.) with a temporal resolution of 250 Hz and a spatial resolution of 0.2° . An eye movement was classified as a saccade when either its distance exceeded 0.2° and its velocity reached $30^\circ/\text{sec}$, or its length exceeded 0.2° and its acceleration reached $9,500^\circ/\text{sec}^2$. Observers viewed displays from a distance of 91 cm, with viewing distance controlled by a chinrest.

Stimuli. Figure 1 illustrates the stimuli and sequence of events for a typical trial. Displays comprised a pair of adjacent red rectangles, each containing a pair of gray characters. Rectangles were $2.4^\circ \times 7.2^\circ$ in size, oriented either vertically or horizontally, and were centered 2.4° to either side of or above and below a gray $0.6^\circ \times 0.6^\circ$ fixation cross. Gray characters, $0.6^\circ \times 0.6^\circ$, appeared at the corners of an imaginary square $4.8^\circ \times 4.8^\circ$ in size and centered on the fixation cross. The four characters within each display included three Ls randomly rotated either 0° , 90° , 180° , or 270° from vertical, and one T rotated 90° left or right of vertical.

Procedure. The observers' task was to search for the T-shaped target character among the L-shaped distractors, and to indicate the target's orientation with a manual response. Empty rectangles appeared approximately 500 msec following termination of each trial

Figure 1. Illustration of the stimuli and sequence of events within a typical trial of Experiment 1. Observers were required to gaze at the central fixation cross until cue onset. Target and distractor characters became visible when the observers' gaze encroached upon any one of the four potential target/distractor locations. The dashed circle indicates the location of the observers' gaze, and was not visible in actual stimulus displays. The trial depicted is from the cue-invalid same-object condition.

and remained visible through the remainder of the intertrial interval and the duration of the succeeding trial. The observers initiated a new trial by gazing at the fixation cross and pressing the space bar. After a 525-msec delay, the three line segments 2.4° in length forming one end of one rectangle changed from red to white for a duration of 59 msec, to cue observers' attention to the upcoming target's likely location. The observers were told that they should gaze at the fixation cross until the cue appeared, and that they should then move their eyes freely to search for the target. Following cue offset, no changes occurred within the display until the observer's eye movements began. The target and all three distractors were revealed simultaneously as the observer's gaze passed the boundary delineating an imaginary circle of 1.8° radius centered on any of the four potential target/distractor locations within the display. Thereafter, gaze was considered as being on an item when a saccade landed within an imaginary circle of radius 1.8° centered on that item's location. Sixty percent of all trials were cue valid, with the target ap-

pearing at the cued location. Of the remaining trials, half were cue-invalid *same-object* trials, on which the target was the uncued item within the cued rectangle (the same-object item), and half were cue-invalid *different-object* trials, on which the target was the item at the end of the uncued rectangle nearest the cued location (the near different-object item). The target was never presented as the item within the uncued rectangle farthest from the cued location. The observers were informed that the target was most likely to appear at the cued location, and that they should therefore begin search for the target there. Observers were asked to press the "F" key to indicate a left-pointing target and the "J" key to indicate a right-pointing target, and they were told that they should make their responses as quickly as possible while maintaining high accuracy. Trials were terminated and a warning message was provided if the observer's gaze deviated farther than 1.5° from the center of the fixation cross prior to cue onset. A feedback message was also provided following an incorrect response. An experimental session comprised 40 randomly chosen practice trials and 500 data collection trials. All conditions were divided into equal numbers of trials with vertically and horizontally oriented rectangles. Trial order was randomized.

Results and Discussion

RTs and eye movement data for incorrect responses were excluded from analysis, as were all data from practice trials, trials on which the observers' gaze deviated from the fixation cross before or during presentation of the attentional cue, trials on which the latency of the initial saccade away from the fixation cross was greater than 500 msec, trials on which the item at the cued location was not the first item fixated (i.e., trials on which observers did not appear to utilize the attentional cue), trials on which a

blink occurred, and trials for which manual RT was greater than 5,000 msec. The mean percentage of trials on which the cued location was fixated before any other was 91% with a range of 53% to 100%, and the mean number of trials per subject remaining for analysis was 366. Mean latency of the initial saccade away from the fixation cross was 181 msec.

Mean error rates were uniformly low (3% or less) and showed no evidence of speed-accuracy tradeoffs, and so are not discussed further. As expected, the mean RT for validly cued trials ($M = 834$ msec, $SE = 29$) was shorter than that for either cue-invalid same-object trials [$M = 1,035$ msec, $SE = 46$, $t(18) = 8.01$, $p < .001$] or cue-invalid different-object trials [$M = 1,071$ msec, $SE = 45$, $t(18) = 10.04$, $p < .001$]. Furthermore, mean RT for cue-invalid same-object trials was shorter than that for cue-invalid different-object trials [$t(18) = 3.59$, $p = .002$]. Thus, manual RT data demonstrate the same pattern of effects that has been taken to indicate object-based control of attention in variants of the present task that tested only covert attention. Eye movement data were analyzed to determine the basis of these effects in the present results.

Initial saccades from the fixation cross to the cued location tended to land roughly the same distance from same-object items ($M = 4.43^\circ$) as from near different-object items [$M = 4.48^\circ$, $t(18) = 1.17$, $p = .256$]. Thus, initial saccades to cued items were not biased in the direction of either the uncued same-object or the near different-object item, and such bias cannot have contributed to object-

Figure 2. Mean proportions of invalidly cued trials in Experiment 1 on which the first item fixated after inspection of the cued distractor was the same-object item or the near different-object item, as a function of the target's actual location. Although observers generally tended to shift gaze in the direction of the target rather than in the direction of the equidistant nontarget, the overall proportion of gaze shifts made within the cued rectangle was greater than that made between rectangles.

based effects in manual RT data. Following fixation on an invalidly cued item, observers fixated one or more additional items before responding on 96% of invalid same-object trials and on 99% of invalid different-object trials (these values were not significantly different [$t(18) = 1.205$, $p = .244$]), despite the fact that the target was visible in the periphery during inspection of an invalidly cued item. That is, observers rarely responded while still fixating the cued distractor. Figure 2 presents the proportion of invalidly cued trials on which gaze shifted to the same-object or the near different-object item immediately following fixation of the cued item, as a function of the target item's location. As can be seen, observers shifted their gaze directly from the cued item to the target item on a majority of invalidly cued trials. Nonetheless, saccades from the invalidly cued item to the same-object item were more frequent than those to the near different-object item. A target was significantly more likely to be the second item fixated when it was at the same-object location ($M = 82\%$ of invalidly cued same-object trials, $SE = 3$) than when it was at the near different-object location [$M = 71\%$ of invalidly cued different-object trials, $SE = 3$; $t(18) = 3.42$, $p = .003$]. Likewise, a distractor was significantly more likely to be the target of an erroneous second saccade when it was at the same-object location ($M = 20\%$ of invalidly cued different-object trials, $SE = 2$) than when it was at the near different-object location [$M = 9\%$ of invalidly cued same-object trials, $SE = 1$; $t(18) = 4.708$, $p < .001$] (values sum to less than 100% because observers occasionally shifted gaze from the cued distractor to the far character in the uncued object, which was never the target). Thus, observers demonstrated an object-based bias in selecting saccade targets, preferring to shift gaze within an object instead of between objects after first fixating an invalidly cued item. Saccades within objects were also executed after shorter latencies than saccades between objects. Mean gaze duration on an invalidly cued item was reliably shorter preceding a saccade to a same-object item ($M = 305$ msec, $SE = 12$) than preceding a saccade to a near different-object item [$M = 319$ msec, $SE = 14$; $t(18) = 3.547$, $p = .002$]. This difference did not result from a tradeoff of speed for saccadic accuracy, because within-object and between-objects movements landed roughly the same mean distance from the center of the saccade target [$M = 0.89^\circ$, $SE = 0.02$ for within-object shifts; $M = 0.91^\circ$, $SE = 0.03$ for between-object shifts; $t(18) = 0.975$, $p = .342$].

Object-based mechanisms, thus, influenced both the choice of saccade targets, biasing selection toward same-object items, and the speed at which saccades were executed, facilitating saccades within an object. How might these effects have been produced? One possible account is that covert attention was allocated differentially between and within objects prior to initiation of the saccade away from a cued distractor. More specifically, it is possible that during the time that gaze dwelt on an invalidly cued distractor, extrafoveal covert attention was allocated more densely within the cued than within the uncued rectangle.

Given that a shift of covert attention is prerequisite for a saccadic eye movement, such differential allocation of covert attention would presumably have encouraged and facilitated within-object gaze shifts.

The speculation that attention was preferentially allocated within the cued object can be tested by examining RTs to same-object and different-object targets. Research on eye movements and object recognition (e.g., Pollatsek, Rayner, & Collins, 1984; Pollatsek, Rayner, & Henderson, 1990) has shown that an object that is visible in the periphery immediately before it is foveated enjoys a preview benefit, so that once fixated it is identified more quickly than if no preview had been allowed. Extrafoveal information acquired during one fixation can thus facilitate identification of an item foveated with the subsequent fixation. Here, the hypothesis that attention was allocated more densely within the cued than within the uncued rectangle while the observer foveated a cued distractor suggests that during that time, more information would have accumulated about the identity of the same-object character than about that of the near different-object character. Preview benefits enjoyed by same-object targets should therefore have been greater than those enjoyed by the different-object targets, with same-object targets being identified more quickly once fixated. To test this prediction, invalidly cued trials on which gaze went directly from the cued distractor to the target were culled from the data, and observers' RTs for identifying the target after it had been fixated were analyzed. The results gave no evidence that covert attention was differentially allocated across the two rectangles. Postfixation RTs were nearly identical for same-object ($M = 408$ msec, $SE = 37$) and for different-object [$M = 409$ msec, $SE = 34$; $t(18) = 0.016$, $p = .988$] targets, suggesting that same-object targets were generally not processed more deeply than different-object targets before they were fixated, and that covert attention was not preferentially allocated to the uncued same-object location prior to fixation of the character there.¹

A possible objection to this analysis and conclusion is that dwell times preceding a within-object saccade, as noted above, were longer than those preceding a saccade between objects. A difference in the *rate* at which information accrued from the uncued same- and different-object locations might therefore have been masked by a difference in the *amount of time* for which information accrued. To test this possibility, regression analysis was used to examine the relationship between the dwell time preceding an eye movement from a cued distractor to a target item and the subsequent postfixation RT for discriminating the target's orientation. More specifically, linear regression analysis was performed on individual subjects' data using dwell time on a cued distractor as the predictor variable and subsequent postfixation RT as the criterion variable. Had information from within the cued object accrued more rapidly than information from within the uncued object during the time when gaze dwelt on an invalidly cued distractor, slopes of the equations predicting

postfixation RTs from dwell time on the cued distractor should have been steeper for same-object targets than for different-object targets. In fact, the mean slopes of these equations were not reliably different from one another [$M = .16$, $SE = .11$ for same-object targets; $M = .03$, $SE = .10$ for different-object targets, $t(18) = 1.12$, $p = .278$], and neither differed reliably from zero [$t(18) = 1.53$, $p = .143$ for same-object targets; $t(18) = 0.30$, $p = .768$ for different-object targets]. Thus, dwell time on the cued distractor had little apparent effect on subsequent postfixation RTs, suggesting that comparison of postfixation RTs for same-object and different-object targets was not compromised by differences in latency of within-object and between-objects saccades. In total, the data give no evidence that extrafoveal processing of same-object characters was privileged relative to that of different-object characters during foveation of a cued item.

EXPERIMENT 2

The results of Experiment 1 indicate that observers were faster and more likely to execute saccades within than between objects. Such effects are consistent with the possibility of an object-based effect on saccade target selection and saccade execution. The structure of the stimulus displays used in Experiment 1, however, also allows for a different and potentially simpler explanation. In Experiment 1, the cued item and the different-object item were by definition located within separate rectangles. As a consequence of this fact, they were also separated by the contours forming the edges of the two rectangles. The cued item and the same-object character, conversely, were separated by no contours. This makes it possible that the apparent same-object benefits observed in Experiment 1 reflect an effect of contours in and of themselves, rather than of the objects or regions formed by those contours. Same-object benefits, in other words, might have arisen because between-object saccades entailed movement across contours whereas within-object saccades did not.²

Experiment 2 was conducted to test this possibility. The stimuli and procedure were the same as those of Experiment 1, except that a pair of additional contours was present within each rectangle (see Figure 3) to ensure that both within- and between-object saccades entailed an eye movement across two contours. Were the same-object benefits observed in the first experiment an artifact of the contours separating cued from same-object locations, no similar effects should be observed here.

Method

Observers. The observers were seven paid volunteers, ages 18 through 38 years, recruited from the community of the University of Illinois at Urbana-Champaign. All observers had normal or corrected-to-normal visual acuity and were naive as to the purpose of the experiment.

Apparatus and Stimuli. The apparatus was identical to that of the first experiment. The stimuli were identical to those of the first experiment, except that a pair of contours, 1.8° in length, was centered within each rectangle, 1.2° to either side of or above and below

Figure 3. Illustration of stimuli from a typical trial of Experiment 2. Line segments were placed within each rectangle, perpendicular to the rectangle's major axis, to equate the number of contours that gaze was required to traverse during within- and between-objects eye movements.

the rectangle's center and perpendicular to the rectangle's major axis. Both within-object and between-objects saccades, therefore, required a shift of gaze across two contours. Furthermore, the contours to be traversed by an eye movement of either sort were identically spaced.

Procedure. The procedure was identical to that of the first experiment.

Results and Discussion

Data analysis was identical to that of the first experiment. The mean percentage of trials on which the cued location was fixated before any other was 91%, with a range of 66% to 100%, and the mean number of trials per subject usable for analysis was 391. Mean error rates varied, were 6% or less in all conditions, and showed no evidence of speed-accuracy tradeoffs, and so they are not discussed further.

In contrast to those of the first experiment, manual RT data of Experiment 2 showed no same-object benefit. Although RTs for validly cued trials ($M = 749$ msec, $SE = 45$) were significantly shorter than those for both invalidly cued same-object trials [$M = 963$ msec, $SE = 47$; $t(6) = 27.557$, $p < .001$] and invalidly cued different-object trials [$M = 965$ msec, $SE = 45$; $t(6) = 20.185$, $p < .001$], RTs for invalidly cued same- and different-object trials were not statistically distinguishable [$t(6) = 0.169$, $p = .871$]. Nonetheless, the eye movement data evinced object-based effects similar to those observed in Experiment 1.³ Figure 4 presents the proportion of invalid trials on which gaze shifted to the same-object or to the near different-object item immediately following fixation of the cued item, as a function of the target item's location. Once more, gaze was significantly more likely to shift from the cued item to an uncued same-object item than to the equidistant different-object item; a target was significantly more likely to be the second item fixated when it was located within the cued rectangle ($M = 79\%$ of invalidly cued

same-object trials, $SE = 3$) than when it was located within the uncued rectangle [$M = 70\%$ of invalidly cued different-object trial, $SE = 5$; $t(6) = 2.682, p = .036$], and a distractor was significantly more likely to be the target of an erroneous second saccade when it was at the near same-object location ($M = 19\%$ of invalidly cued different-object trials, $SE = 4$) than when it was at the different-object location [$M = 9\%$ of invalidly cued same-object trials, $SE = 2$; $t(6) = 3.002, p = .024$]. Gaze shifts from an invalidly cued item to a same-object item were also initiated after shorter dwells ($M = 313, SE = 19$) than were shifts to an equidistant different-object item [$M = 328, SE = 17$; $t(6) = 2.568, p = .042$]. Data from the second experiment thus evince same-object benefits in saccade target selection and saccade latency similar to those of the first experiment, discounting the suggestion that the effects obtained in Experiment 1 were produced simply by the presence of contours separating invalidly cued distractors from same-object items. This result accords with the conclusions of similar studies examining the function of strictly covert attention (e.g., Iani, Nicoletti, Rubichi, & Umiltà, 2001).

The data from Experiment 2 also corroborate those of the first experiment in giving no evidence of an object-based extrafoveal preview benefit. Preview effects were analyzed as in Experiment 1. RTs for discriminating target orientation after fixation on the target were again roughly equal for invalidly cued same-object ($M = 351$ msec, $SE = 22$) and invalidly cued different-object [$M = 349, SE = 31$; $t(6) = 0.142, p = .891$] trials. Moreover, there was again little evidence that these RTs differed for same-object and

different-object targets as a function of the dwell time preceding the eye movement from a cued distractor to the target. The mean slopes of the linear regression equations predicting postfixation RTs from dwell times of the gaze preceding fixation on the target were statistically identical for same-object ($M = -.06, SE = .13$) and different-object [$M = -.200, SE = .17$; $t(6) = 0.649, p = .540$] targets, and in both cases were statistically indistinguishable from zero [$t(6) = -0.474, p = .652$ for same-object targets; $t(6) = -1.176, p = .284$ for different object targets]. The results again suggest that object-based effects observed in saccadic behavior were not produced by a differential allocation of covert attention within and between objects during inspection of a cued distractor.

DISCUSSION

To assess the influence of object-based attentional mechanisms on the control of saccades and covert attention during free viewing, the present experiments modified the object-cuing paradigm of Egly et al. (1994) to demand eye movements. Object-based effects were manifest in two ways. First, shifts of gaze were more likely within an object than between objects; following initial fixation on an invalidly cued item, observers moved their gaze directly to the same-object item more frequently than to the near different-object item. Second, shifts of gaze were faster within than between objects; gaze durations on an invalidly cued item were shorter preceding a within-object shift than preceding a between-objects shift. The results indi-

Figure 4. Mean proportions of invalidly cued trials in Experiment 2 on which the first item fixated after inspection of the cued distractor was the same-object item or the near different-object item, as a function of the target's actual location. The overall proportion of gaze shifts made within the cued rectangle was again greater than that made between rectangles.

cate that control of saccades, like control of covert attention when the eyes are fixed, is sensitive to the perceptual organization of a display. Paradoxically, though, the data give no evidence of object-based control of covert attention during free viewing. Same-object targets were identified no more quickly after they were fixated than were different-object targets, indicating that extrafoveal processing within the cued object was not facilitated relative to that within the alternative object during the time when gaze remained fixed on an invalidly cued item, and suggesting that object-based effects on saccade target selection and latency were not produced by a differential spread of covert attention between and within objects.

This final conclusion parallels that drawn from several studies of strictly covert attention, the results of which have shown that the same-object benefit obtained when gaze is held fixed does not result from an asymmetric spread of covert resources within and between objects, or from enhanced perceptual processing of same-object characters (Lamy & Egeth, 2002; Shomstein & Yantis, 2002). However, if effects of object representations on eye movements in the present experiments were not produced by a differential allocation of covert attention, how should they be explained? One possibility is that they are the result of biased competition (Desimone & Duncan, 1995) between same-object and different-object items as saccade targets. Computational models have begun to explain saccade target selection and initiation as a process of parallel competitive interaction between neural representations of multiple potential targets (Findlay & Walker, 1999; Trappenberg, Dorris, Munoz, & Klein, 2001), where bottom-up and top-down factors, through facilitation of the advantaged neural representation and inhibition of competing representations, can bias competition in favor of a particular item. Saccade initiation is presumed to occur after spatial competition has been resolved in favor of a given target location. Within-object saccades could be initiated more frequently and after shorter latencies than between-object saccades, then, as a result of a bias in neural competition that encouraged resolution of competition in favor of same-object targets. Alternatively, observers may adopt a lower criterion for initiation of within-object eye movements, such that a saccade toward the same-object location can be produced by a smaller amount of activity than a saccade toward the different-object location. Such accounts would accord with behavioral findings suggesting that the same-object benefits observed when the eyes do not move might also be produced by a bias in the order in which same- and different-object locations are attended (Shomstein & Yantis, 2002). They might also produce evidence of object-based saccadic effects, as observed here, absent an asymmetry in the spread of covert attention.

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NOTES

1. As noted by a reviewer, the mean difference between same-object and different-object RTs (36 msec) was somewhat greater than the mean difference between saccade latencies preceding within-object and between-object eye movements (13 msec). Given that there was almost no difference in the time necessary to identify and respond to same-object and different-object targets once they had been fixated, how should this discrepancy be explained? First, overall manual RTs incorporated saccade durations, as well as latencies for initial saccades away from the fixation cross. Variability in these times contributed to the discrepancy between the same-object benefits observed in RTs and in latencies for saccades away from a cued distractor. Second, observers on invalidly cued trials occasionally shifted their gaze from the cued item to a second and sometimes to a third distractor before finally fixating the

target item, and the times necessary for these additional saccades and fixations were incorporated within overall manual RTs, but not within saccade latencies or postfixation RTs.

2. We thank Jay Pratt for pointing out this possibility.

3. Discrepancies between the object-based effects measured in manual RTs and the object-based effects measured in saccade latencies and postfixation RTs were again produced by variability in initial saccade latencies and saccade durations, and by the fact that manual-RT data included effects of trials on which a gaze shifted from the cued item to one or two additional distractors before reaching the target (see note 1 above).

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