EXPLORING THE EFFECTS OF SIZE AND SPACE ON THE OBJECT ADVANTAGE

by

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(Under the Direction of James M. Brown)

ABSTRACT

In visual attention, there is a distinction between space-based and object-based attention. This study explores object-based attention with a pre-cuing paradigm. Object-based attention has been demonstrated with facilitation to reaction times when the target is in the same object as the cue, as compared to reaction times when the target is equidistant, but in a different object. Experiment 1 tested three different within-object distances to determine whether the object advantage is reduced by a larger within-object distance. Experiment 2 was designed to determine whether attention shifting within the fovea is affected by the object advantage. Results demonstrated that the object advantage is not reduced by greater within-object distances, nor by foveal presentation of the stimuli.

INDEX WORDS: Attention, Spatial cuing, Visual perception, Spatial Perception, Selective attention, Object recognition, Cues

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B.A., The University of Georgia, 1997

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment

of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2004

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May 2004

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INTRODUCTION

Theories of visual attention are divided into two types, space-based and object-based theories. Space-based attention is the allocation of resources to an area of the visual field, irrespective of what is in that area. Object-based attention is the allocation of resources to a specific object. These two conceptualizations of attention are by no means mutually exclusive. It is most likely these two different systems of attention operate in concert. Space-based attention is likely to control distance effects, while objects in the field of view may affect other aspects of attention, e.g., disengaging, focus (e.g., detailed or general), or the order in which the visual field is scanned (Lamy & Egeth, 2002; Posner & Cohen, 1984; Shomstein & Yantis, 2002). The study of attention has traditionally been space-based in theoretical perspective, as shown by a predominance of spatial metaphors in the literature, for example the spotlight metaphor (Posner & Cohen), the zoom lens metaphor (Eriksen & St James, 1986, Eriksen & Yeh, 1985) and spatial gradients (Downing & Pinker, 1985).

More recent experimental evidence (Avrahami, 1999, Duncan, 1984, Egly, Driver, & Rafal, 1994, Lavie & Driver, 1996, Law & Abrams, 2002) showing that an object's presence in the field of view affects allocation of attention has led to the genesis of the object-based view. Attention directed toward an object influences reaction times (RTs) to both shifts of attention and decisions with divided attention. RTs are shorter when attention must either shift or be divided between areas inside one object than areas that are parts of different objects. (Avrahami, 1999; Egly, et al., 1994; Lavie & Driver, 1996;

Law & Abrams, 2002). This effect of an object's presence in the attentional field is typically called an object advantage (or object effect). The purpose of this study is to explore possible mechanisms for the object advantage by addressing two questions. First, can the within-object distance be made so great that there is no longer an object advantage and, second, will an object advantage still be evident when the stimulus array is so small that it fits entirely into the fovea?

Many researchers have used various tasks in different contexts in which the object advantage has been found, indicating that this phenomenon is robust and not specific to a particular task. The tasks that have been used to investigate the object advantage involve such things as divided attention (Duncan, 1984; Lavie & Driver, 1996; Law & Abrams, 2002), spatial cuing (Egly, et al., 1994; Lamy & Egeth, 2002; Tipper, Jordan & Weaver, 1999; Vecera, 1994), temporal order judgments, (Abrams & Law, 2000), distractor paradigms (Lamy & Egeth, 2002), and distance estimation (Avrahami, 1999).

Duncan (1984) used a box and superimposed line as his stimuli, asking participants to judge two different aspects of the stimuli. Participants judged the tilt of the line and whether the line was dashed or dotted, or they judged the size of the box and the placement of a gap in the box, or they judged one aspect of each object. Accuracy was poorer for those judgments that involved two objects than for those that involved one. Therefore, two judgments about the same object can be made without a loss of accuracy.

Lavie and Driver (1996) used a divided attention task in which participants judged discontinuities in dashed lines. Participants observed two intersecting dashed lines, which contained two discontinuities. A discontinuity could be either a dot or a gap in a dashed line. Both discontinuities were contained in either the same line or different lines.

The task was to determine whether both discontinuities were the same (both dots or both gaps) or different (one dot and one gap). RTs were faster when the targeted discontinuities were both on the same line than when they were on different lines, indicating an object advantage.

Abrams and Law (2000) used a temporal order judgment task in a cuing study. Participants were asked to judge the order of onset of multiple coincident targets, appearing after a cue. This can be used as a measure of attention, because the target perceived to appear first does so because its processing is facilitated by attention. Targets at the cued location were judged to appear first; uncued targets within the same object next, and uncued targets in another object last. Their results implied that the presence of an object in the field of view affects the ease of moving the attentional spotlight. The difference in judgments of the order of appearance at the two uncued locations is another example of an object advantage.

Egly et al. (1994) used a cuing task to explore the object advantage using comparisons of RTs to a target under three different cue conditions. Participants were presented with a pair of bars, in which a cue and target appeared. The target was in either the same place as the cue (validly cued) or in one of two other places (invalidly cued) equal in distance from the cue (see Figure 1). Two types of invalidly cued trials were used: within-object invalid and between-objects invalid. Within-object invalid trials occurred when the target was at the other end of the same bar as the cue. Between-objects invalid trials occurred when the target was at the closest end of the other bar. RTs to the target were measured. It must be noted that because the target was at the same distance from the cue in both invalid conditions, a theory of visual attention that is purely space-based would predict that the RTs would be the same for both invalid conditions. Egly et al. found consistently faster RTs for the invalidly cued within-object condition than for the invalidly cued between-objects condition. The increase in reaction time required to shift attention between objects rather than within an object is further evidence for the object advantage.

The object advantage, which is amply demonstrated in the literature, can be reduced and eliminated (in RT experiments) if we manipulate task and stimuli variables (Lamy & Egeth, 2002; Vecera, 1994). Manipulation of the configuration of stimuli is one means of exploring possible interactions between space-based and object-based attention. Specific stimuli may be configured so as to inform us about this interaction. Configural factors such as the shape of an object, the size, directionality, the internal distance, and gestalt factors like good continuation and closure can affect both the allocation of, and shifts of, attention. Since object-based and space-based attention are likely to be controlled by different attentional systems, they may interact in unexpected ways. Testing the two bases for attention in ways that the two views conflict can elucidate how attention works.

Vecera (1994) adapted a now-standard cuing task (Egly et al., 1994) comparing shifts of attention within one object or between two objects using bar stimuli. He placed the bars close together, to make the between-object distance less than the within-object distance. Space-based attention would predict that the (closer) between-objects shift of attention would be faster than the (farther) within-object shift. The results showed that attention was shifted within the same object faster. The object advantage was still present, indicating that the invalid cue condition (i.e., same or different object) affects the rate of attention shifts in addition to spatial distance. Therefore, object-based attention had a greater effect on the RTs than space-based attention.

Avrahami (1999) explored configural factors in a cuing study, using horizontal lines in place of true objects, with cue and target positioned along the same line or between different lines. She found a same-line effect; with RTs faster if the cue and target were along the same line than if they were across different lines. These results suggest that closure and proximity are not crucial for the "object effect" to occur.

Brown, Breitmeyer, Leighty, and Denney (2002) explored configural factors affecting the object advantage to determine effects of stimulus configuration on the object advantage. They used bar stimuli as well as bracket and arc stimuli to determine if internal distance, separate parts (e.g., the separate arms of the brackets) or gestalt factors such as good continuation affect the object advantage in a precuing study. In the within-object invalid condition (when the cue and target were on the opposite ends of the same object), the internal distance from cue to target of the brackets and arcs was three times the internal distance from cue to target within the bars. Brown, et al. found that the object advantage was reduced, but not eliminated under these conditions. There were longer RTs for brackets and arcs than for bars, indicating that within-object distance modulates the object advantage. These results suggest attention does not always have to take the shortest path between the cue and target locations. The fact that the object advantage is still apparent even when the path of the attentional shift for the within-object invalid condition is three times the distance of the between-objects path is important because it has pitted the spatial aspects of attention against the object-based aspects and the object-based aspects again had more of an effect. When brackets were compared to arcs, no difference appeared, indicating that corners (implicated by Jolicoeur & Ingleton 1991, see also Jolicoeur, Ullman, & Mackay, 1991) did not affect the rate of attention shifts.

There have been several proposals brought forward discussing various mental mechanisms through which the object advantage might operate. Boundary crossing was once thought to be involved (Iani, Nicoletti, Rubichi & Umiltà, 2001). Alternatively, attention, once focused on one point within an object, could gradually spread through the whole object (Davis, Driver, Pavani, & Shepherd, 2000). Third, attention might trace or follow the object while shifting internally (Avrahami, 1999). Finally, it is possible that attention is harder to disengage from an object and move to another object than disengaging from one area and moving to another area within an object.

Iani et al. (2001) found that boundary crossing was not the controlling factor of the object effect, by putting boundaries inside an object. In a cuing task with three different sets of object stimuli, they compared RTs when they used a single object that had two internal borders between the cue and target, to an identical object without internal borders, and to a similar pair of separate objects. They compared RTs to within-object invalid and between-objects invalid cuing when the cue and target were in one of these three objects. RTs were faster when the cue and target were in the same object, regardless of whether there were internal borders to cross between the cue and target. Putting boundaries in an object had no effect on RTs, indicating that the object advantage is not a result of crossing borders (see also Brown, et al. 2002, Marrara & Moore, 2003).

Object tracing and spreading attention theories state that attention shifts take time, and the farther attention must shift, the longer it takes. Object tracing involves the route that attention takes. When a cue is detected, there is an orienting response, and attention reorients again, following a within-object path, when the target is detected (Avrahami,1999, Shomstein & Yantis 2002). This view is related to the work of Jolicoeur

(Jolicoeur and Ingleton, 1991; Jolicoeur, Ullman, et al., 1991), who used a line-tracing task. They determined that different amounts of curvature take different amounts of time to trace, and that sharper curves (e.g., corners) take even longer. Similarly, spreading attention theories (Davis et al., 2000) involve the route attention takes. The object advantage occurs because after reorienting, attention gradually spreads through the object. The spreading process reduces the time needed to reorient and the object's contours limit the spread of attention. The simplest conceptualization of these theories is that through object tracing or spreading attention, attention remains within the object and travels the complete pathway from cue to target.

Davis et al. (2000) provided evidence for the potential mechanism that Egly et al. (1994) proposed, attention spreading through objects. They showed that in cuing and divided attention studies, spreading attention predicted the outcomes typically reported. They utilized a divided attention task involving judgment of attributes of one or two objects. RTs to two small objects were compared with RTs to one large object that was nearly equivalent in size and complexity to the two-object display. They found that RTs were slower when the area of the object was larger (e.g., with one large object). To distinguish spreading attention from object tracing theories, attention is proposed to spread when attention first orients, and tracing does not occur until attention must reorient. The tracing hypothesis also explains the data in Brown, et al.'s (2002) experiment. Within-object shifts took longer in their longer brackets and arcs conditions than in their shorter bars condition, suggesting that attention traces the whole internal path between the cue and target.

Avrahami (1999) also found evidence supporting a tracing mechanism using objects she called ribbons, which were curved versions of the bars used by others (e.g., Egly et al., 1994). The task involved distance estimation comparing the distance of two targets from a third comparison stimulus. The targets and the comparison stimulus were presented simultaneously; one target was in the same ribbon as the comparison stimulus, and the other in a second ribbon. The distance was varied between the two ribbons, so the distance between the comparison and same ribbon target could be either the same, closer, or farther than the distance between it and the target in the other ribbon. However, because of the curved ribbons and the various distances between the ribbons tested, the same-ribbon target was frequently erroneously judged to be closer to the comparison target. Avrahami interpreted this result as evidence of an object effect and of a tracing mechanism underlying the object advantage.

Neither spreading attention nor object tracing can explain Duncan's (1984) data that simultaneous judgments about the same object can be made without loss of accuracy. Lamy & Egeth (2002) also found evidence that attention does not spread through or trace objects, in a cuing study. They used a size judgment task, judging the size or relative size of targets in two bars. They manipulated the stimulus onset asynchrony (SOA) to see if the object effect was reduced when there was less time for attention to spread between the cue and the target. At the shortest SOA (100 ms), there was not sufficient time for attention to focus on the cue well enough for the effect of valid cuing to be at its peak. However, the object advantage was apparent at each SOA. This is evidence that attention, which takes time to focus on an area, does not spread through an object during the time between the cue and target.

Another mechanism to be considered as an account for the object advantage involves disengaging attention. Disengaging attention is one of Posner and Cohen's (1984) basic functions of attention, along with engaging and shifting. Disengaging may be the most parsimonious theory, stating that the object effect is simply the delay associated with disengaging attention in preparation for a shift of attention. The process underlying the object effect is that it is more difficult to disengage attention from one object and shift to another than from one part of an object to a different part. Attention is engaged with an object as well as with a location. There has been evidence in inhibition of return studies with moving objects that attention engages with and disengages from locations and objects separately (Tipper, et al., 1999). If this is true given a stationary object as well, the observer would have to disengage separately from both the location and the object in order to shift their attention from the object to another object. But it is only necessary for the observer to disengage from a location to shift within an object. This work indicates that the object advantage may be more aptly seen as a disadvantage for shifting attention between objects (Lamy & Egeth, 2002). From this perspective, the object advantage is actually a cost for attention shifts between objects, because RTs for between-objects compared to within-object shifts are longer, even though the physical distance is the same. For this reason it is proposed that attention may be required to disengage separately from the location and the object. Abrams and Law's (2000) results fit the disengaging theory; they implied that the presence of an object in the field of view affects the ease of moving the attentional spotlight.

Lamy and Egeth (2002) explored the hypothesis that a shift of attention is crucial to the object advantage. In one experiment, they presented one target, then after a variable interstimulus interval (ISI), a second target in either the same object or a different object. The participants judged whether the targets were the same or a different size. RTs were faster when the targets were in the same object. They found the object effect in this study when attention was directed initially to the first target, then had to shift to the second target.

In another experiment designed to test the object advantage when there was no shift of attention, participants judged the size of a single validly cued target (Lamy & Egeth 2002). On two-thirds of the trials, a distractor appeared simultaneously in the same or another object. The presence of a distractor lengthened RTs, but RTs were the same, no matter which object the distractor was in. In this experiment, when the task was performed better without a shift of attention, the object effect was not found. The finding that the object advantage occurred only when attention shifted is strong evidence for the disengaging hypothesis. This hypothesis also explains Duncan's (1948) data, because the observers had to disengage from one object in order to engage on the other, despite the fact that attention did not need to shift spatially in his task.

Our attempts to understand the nature of the object advantage are further complicated by the fact that both of the major models could be true. Results supporting the disengaging hypothesis preclude object tracing/spreading of attention. However, if both models are parts of the object advantage, results would appear to support object tracing/spreading attention. This is unimportant, because to foreshadow our results, only the disengaging model was supported.

The results of Avrahami (1999), of Brown et al. (2002), and those of Davis et al. (2000) suggested object tracing or spreading attention occurs. Duncan's (1984), Law and

Abrams's (2000), and Lamy and Egeth's (2002) results all fit into a general schema that supports disengaging attention. Experiment 1 seeks to follow-up on these results by determining whether object tracing or spreading of attention is necessary to find the object advantage. The present experiment (Experiment 1) was designed to determine whether attention shifts by way of an object-internal path (by spreading or tracing), and to parametrically explore this distinction by measuring RTs for different within-object distances.

EXPERIMENT 1

The first experiment tested the hypothesis that increasing the within-object distance would decrease, and possibly eliminate, the object advantage. It was also designed so that the two potential mechanisms, spreading attention/object tracing and disengaging, would predict opposing results. Experiment 1 explored the object advantage by attempting to determine a within-object to between-objects distance ratio at which an object advantage was no longer evident. It was a cuing study utilizing validly and invalidly cued targets inside objects of different sizes. The objects were brackets for which the retinal distance between the cue and target was held constant on invalid trials, whether they required a within-object or a between-objects shift of attention. The differently sized brackets were used to manipulate the within-object distance to see if the object advantage could be eliminated with increasing within-object distance.

The cost for shifting attention in invalid conditions was calculated by subtracting each participant's valid RT from both invalid conditions for each bracket size. In this study, the object advantage was defined as a smaller cost for within-object shifts than between-objects shifts. We were primarily seeking a within-object distance for which the object advantage would no longer be found. A main effect of cue validity was expected, with the RT to validly cued targets being shorter than RTs to invalidly cued targets (i.e., the standard cuing effect). A main effect for cost was expected, reflecting the object advantage. The results were also expected to provide evidence to help distinguish among the various mechanisms proposed to underlie the object advantage.

If either object tracing or spread of attention within an object is the mechanism underlying the object advantage, then we should find a particular constellation of results. Costs for within-object shifts should increase with increasing within-object distances. If this occurs, either a main effect for bracket size or, more likely, an interaction between bracket size and invalid condition would be found. In other words, if costs for within-object shifts increased with increasing bracket size, and costs for between-objects shifts remained the same, it would mean that spread of attention/object tracing is obligatory. It was expected that the object advantage might disappear at some point, because the time it takes attention to shift from the cue to the target should increase as within-object distance increases. At that point costs for within-object shifts would no longer differ from the costs for between-objects invalid condition. If disengaging is the mechanism, then we would expect a different constellation of results. The disengaging hypothesis predicts that costs for within object shifts would be unaffected by bracket size. If attention does not trace the object, there would be no difference in within object costs across the various sizes of brackets. However, costs for between-objects shifts should always be greater than for within-object shifts because attention would have to disengage from one object to shift to the other.

Methods

Participants

Thirty-one male and 24 female undergraduates participated in the experiment for course credit. Six males and two females were excluded from analysis because they had too many errors, resulting in 25 males and 22 females. They were in the research participant pool at the University of Georgia, and gave consent before they participated in the experiment. Only right-handed participants with normal or corrected-to-normal vision were utilized.

Stimuli & Apparatus

Superlab Tm software was used for stimulus presentation and data collection. A Dell Optiplex GXa computer with a Pentium II processor with Windows 95 was used. The Annett Handedness Scale was used to determine handedness. The viewing distance was held constant by using a chinrest at 60 cm. Responses were collected by a Cedrus RB-610 response box that interfaces with the computer.

The stimuli consisted of three different pairs of brackets designed so that the (variable) within-object distance was in a certain proportion to the (constant) direct cue-to-target distance (see Figure 2). The first bracket was in a 2:1 ratio, the second 4:1 and the last 6:1. These distances were chosen because Brown et al. (2002) used brackets with an internal distance three times as far as the cue-to-target distance and within-object invalid reaction times were still faster than between-objects invalid RTs. In their study, they found that the object advantage was reduced from 22 ms at a one-to-one ratio to 11 ms at a three-to-one ratio. The 2:1 ratio was chosen because it should result in a clear object advantage, and 6:1 because it was expected that the threshold at which the object advantage disappeared might be surpassed and any further effect would be clear with such a great within-object distance.

The brackets appeared as white upon black and were oriented with the openings inward with a fixation point between them (see Figure 2). The stimuli were presented in both horizontal and vertical orientations. The 2:1 bracket subtended 2.67^{o} of visual angle, the 4:1, 8^{o} and the 6:1, 13.33^{o}. The distance between the ends of a bracket (5.33^{o}) was the same as the distance to the contralateral ends of the other bracket. A cue (0.53^{o}) was composed of a brightening (4.39 cd/m^2) and expansion of the end of a bracket. The target (0.53^{o} x 0.53^{o}) was composed of a small square filling in the end of a bracket. The target was the same white as the outline of the bracket (1.23 cd/m^2). While internal distance was different, the retinal distances between cue and target were always the same for both within-object invalid and between-objects invalid conditions and across bracket sizes. The background was black (0cd/m^2).

Procedure

The experiment was run in a darkened room. Participants were instructed to keep their gaze on the fixation point throughout each trial, and to press the response key as quickly as possible when a target appeared. Accuracy and reaction times were measured. Bracket sizes were randomly presented, with brackets in vertical and horizontal orientations and with cues in all four possible bracket ends in all conditions to control for direction of shift.

Participants had 10 practice trials, and 10 more when they did not perform the first set properly. There were three runs of 640 trials, each run on a separate day, for a total of 1920 trials, with each size bracket appearing on one third of the trials. The target was in the same location as the cue on 70% of the trials (valid trials), and a nearby location on 20% of the trials (invalid trials). Ten percent of the invalid trials were within-object invalid. The other 10% were between-objects invalid trials. The remaining 10% of the trials were catch trials, in which no target appeared. If a response was made during a catch trial, a warning appeared instructing participants to respond only when a target is present. Trials were randomly presented.

The initial stimulus screen (depicting the brackets with the fixation cross) was presented for 1000 ms, then the cue appeared for 50 ms to signal the onset of the target. The stimulus screen was presented for another 150 ms, then the target appeared until the observer responded or 1500 ms had elapsed (See Figure 1 as an example of timing events only). Reaction times were measured from onset of the target until the response. If the reaction time was less than 150 ms, it was coded as an anticipatory response and a warning screen appeared instructing the participant not to respond until the target appeared.

Results

Accuracy

The participants with more than 10% false alarms and those with more than 5% errors overall were excluded from the analysis, resulting in a total mean accuracy of 98.3%. Average false alarms were 4.2%. Responses less than 150 ms and greater than 1000 ms were excluded from analysis because they reflect anticipation errors and inattention. Based on RTs, 2.1% of trials were excluded from analysis.

Reaction Times

Data analysis examined both simple reaction time and the cost to reaction time of invalid conditions. Raw RTs were used to compare the valid cue condition to the collapsed invalid cue conditions. To compare within-object attention shifts to between-objects shifts, within-object cost (invalid within RT – valid RT) and between-objects cost (invalid between RT – valid RT) were calculated.

By using each participant's valid score is used as their baseline, we can compare differences between within-object and between-objects shifts of attention and compare the three bracket sizes to each other for within-object shifts of attention. This is valuable, because it removes any effect of stimulus complexity from the cost analysis.

Initial analysis was done with bracket orientation as a factor, but since it had no significant effect, the results reported were analyzed collapsed across bracket orientation. A 2x3 ANOVA was performed on RTs, with validity and bracket size as within-subjects factors. A main effect was obtained for validity, $F(1,45)= 86.8$, $p< .001$. RTs were faster for the valid than the invalid trials (377 ms and 429 ms, respectively. See Figure 3a). There was a main effect for bracket size, $F(2,90)=3.74$, $p<.05$. The means were 401 ms for 2:1, 404 ms for 4:1, and 405 ms for 6:1 brackets. The interaction was not significant.

The RTs for the three bracket sizes increased slightly as the brackets got bigger. However, the pattern of results for the bracket size variable was complicated by divergent results of different statistics, due to certain assumptions of ANOVAs. The results were significant, with $F(2,90)=3.74$, $p < .05$. However, RTs ranged from 401-405 ms, with standard errors of 8 ms. So, while the F and p-values indicate that the results are statistically significant, each standard error is twice the size of the effect. ANOVAs try to determine what proportion of the variance in the data is due to each independent variable. In this case, so much of the variance was attributable to validity that very little is left in need of an explanation. This can artificially inflate the p-value, as happened with the bracket size variable. A four millisecond difference with standard errors of twice the effect size is therefore a meaningless difference. Despite these peculiarities, they are irrelevant to the hypotheses, because these pseudo-significant results are not a modulation of a within-object difference.

A 2 x 3 ANOVA was performed on cost data, with cost and bracket size as within-subjects factors. A main effect was obtained for cost, $F(1,45) = 65.9$, $p < .001$. Costs were less for the within-object than the between-objects invalid conditions (43 ms and 60 ms, respectively. See Figure 3b) indicating an object advantage. The interaction between cost and bracket size was nonsignificant.

Discussion

It was hypothesized that increasing object size might minimize, and even eliminate the object advantage. This did not occur. The expected within-to-between distance ratio at which the object effect might disappear was not found. We conclude that there is no limit to the object advantage based on greater within-object distances, at least for the stimuli and task used here. Since there was no effect of within-object distance at all, the object effect appears to be based on disengaging, not spreading of attention or object tracing.

RTs and costs did not increase with bracket size. They also did not interact with bracket size. This was a surprising finding in a cuing study, where one would expect a distance effect, because a shift of attention was necessary to the task. This finding highlights the importance of object-based selection and suggests that it may not be obligatory for attention to remain within the object during a shift. Finding that the size and within-object distance had no effect on the object advantage provides a strong argument against spreading attention or object tracing as the mechanism.

In Experiment 1, the increased within-object distance did not decrease the object advantage, so in Experiment 2 we attempted to determine if smaller spatial distances (i.e., smaller stimulus sizes) might eliminate the object advantage. Experiment 2 examined whether the object advantage is still found when the stimuli are entirely in the fovea.

EXPERIMENT 2

Our second study evaluated how object-based and space-based attention operate within the fovea. The second experiment was conducted to explore the effect of foveal presentation on the object advantage by reducing the visual angle of the display to 1.75^{o}. Since foveal vision is privileged in the human visual system (i.e., cortical magnification: Sereno, Dale, Reppas, Kwong, et al. 1995), attention may affect participants' reaction times differently in the fovea than in the parafovea and the periphery.

The literature on shifts of attention indicates that there is a metric of space across which attention moves. Attention shifts at a constant rate and in a continuous (not discrete) fashion (Müller and Rabbitt, 1989; Remington & Pierce, 1984). Within the fovea, the distances are so small that they may be trivial. Thus (1) the small distances attention would need to shift might have little or no effect on RTs in the fovea, and (2) attention may not need to shift at all, to perceive something that is entirely in the fovea. If attention does not need to shift, there may be no object effect.

Eriksen and Hoffman (1972) cued a letter to be named with four distractors at varying distances around it. The distractors were 0.53^{o}, 1.0^{o}, or 1.4^{o} away from the target letter. The distractors slowed reaction times more to the target when they were at the nearest position, than when they were at the other two positions. This has been taken as evidence that attention fully processes all within a radius of one degree of visual angle.

With simple detection tasks, however, that require less cognitive processing, the area which attention treats as equivalent may differ. Spatial area can also affect RTs with more focused or diffuse attention. It has been shown that the attentional spotlight can be set to different sizes when the observer expects different stimulus placement (LaBerge & Brown 1986).

Attention has been shown to modulate RTs in a cuing study that involved discriminating letters in a field of distractor letters (i.e., Xs) (Juola, Bouwhis, Cooper, & Warner, 1991). One of three concentric regions of different distance from fixation was verbally cued, each of which subsequently had four letters presented in them. Valid, invalid, and neutral cues were used, with the neutral cue simply prompting the observers to get ready. Participants determined whether the target letter (the only non-X) was an L or an R. The distance from fixation to the center of the letters was approximately 0.35^{o}, 1.25^{o}, or 2.85^{o} of visual angle. Relative to the neutral cue condition, they found benefits and costs for valid and invalid cuing respectively. The Juola, et al. and Eriksen and Hoffman (1972) experiments differ from the present study in two important ways; the task involves more cognitive processing than simple detection, and the cue was not at the exact location of the target in either experiment.

If attention does not have to shift in the fovea, RTs may not be affected by valid or invalid cuing, and by extension to the present study, they may not be affected by the object advantage either. If attention differentially influences different parts of (and is relevant in) the fovea, objects may still be predominant to our visual system and there would still be a cost. This is especially important in light of the support for the disengaging theory from the results of Experiment 1.

In Experiment 2, a main effect was expected to show that reaction times in foveal (1.75^o) vision are faster for within-object invalid than between-objects invalid cuing. The hypothesis was that the object advantage would be evident.

Methods

Participants

Twenty-two male and 21 female undergraduates participated in the experiment for course credit. One male and four females were excluded from analysis due to poor accuracy, resulting in 21 males and 17 females. Only right-handed participants with normal or corrected-to-normal vision were utilized.

Stimuli & Apparatus

The stimuli were pairs of bars (see Figure 1). The cues and targets were presented in the same way as in Experiment 1. The chinrest was at a distance of 225.0 cm. The experiment was carried out on a Dell Dimension XPS R400 computer with a Pentium II, running Windows 98. Responses were collected on a Cedrus RB-610 response box that interfaced with the computer. All other apparatus was the same as in Experiment 1.

The bars appeared as white upon black and were oriented both vertically and horizontally with a fixation point between them. This stimulus display subtended 1.75^o of visual angle, horizontally and vertically. The bars were 1.75^{o} long and .229^{o} wide. The outline of the bar was 0.51^{o} wide. A cue (0.178^{o} x 0.255^{o}) was composed of a brightening (126.5 cd/m^2) and expansion of the end of a bracket. The target (0.178^{o} x 0.229^{o}) was composed of a small square filling in the end of a bracket. The target was the same white as the outline of the bar (77.3 cd/m^2). The background was black (2.7 cd/m^2).

Procedures

There were 640 trials run in two blocks in one visit. All other procedures were the same as in Experiment 1.

Results

Accuracy

The participants with more than 10% false alarms and those with more than 5% errors overall were excluded from the analysis, resulting in a total mean accuracy of 97.5%. Average false alarms were 4.4%. Responses less than 150 ms and greater than 1000 ms were excluded from analysis because they reflected anticipation errors and inattention, respectively. Two percent of the trials were excluded from analysis for these reasons.

Reaction Times

Data analysis considered both simple reaction time and the cost to reaction time of invalid conditions. Each was calculated in the same way as in Experiment 1. A paired samples t-test was performed on RT data. There was a significant difference between valid and invalid trials, $t(37)=7.01$, $p<.001$. RTs were faster for the valid trials than the invalid trials (338 ms and 387 ms, respectively, See Figure 4a). A paired samples t-test was performed on cost data. There was a significant difference between the within-object invalid and between-object invalid conditions, $t(37)=5.40$, $p<.001$. Within-object shifts of attention were faster than between-objects shifts (36 ms and 61 ms, respectively, See Figure 4b).

Discussion

The valid cuing effect found shows that attention does need to shift in the fovea. The hypothesis that the cost for a within-object shift would be less than the cost for a between-objects shift was supported. The effect of cost shows that, although there may be little need for attention to shift in the fovea (Sereno, Dale, Reppas, et al., 1995), there is still a cost of invalid cuing on reaction time when the stimuli are exclusively in the fovea. A shift of attention occurs, despite the tiny distance. This result suggests that the object advantage has a greater function in addition to simple utility.

A possible objection to these findings is that the stimuli may not be small enough. Using a letter recognition task, Eriksen and Hoffman (1972) proposed that with small stimuli ($<1^{o}$), there may be no possibility of detecting a spatial effect. So the object advantage may disappear if the display is even smaller. Further research is required to determine if smaller stimuli may not show the object advantage.

General Discussion

Neither increasing within-object distance nor decreasing stimulus size eliminated the object advantage. Experiment 1 showed that the object advantage, as shown by RTs in a cuing study, is not reduced or eliminated by increasing the within-object distance to six times the between-objects distance with these stimuli. Experiment 2 showed that the object advantage is not eliminated by shrinking the stimulus display so that it fits into the fovea. This result shows how robust the object advantage is. The results were surprising because increasing spatial distance across the differently sized objects had no effect on

RTs. This is the spatial distance attention would have to travel, assuming that attention is required to remain within the object, for the object effect to work. This assumption has been shown to be false.

Disengaging attention is supported as the crucial aspect of object-based attention affecting attention shifts in these experiments. It is proposed that disengaging attention from an object and disengaging attention from an area in space are separate tasks, and therefore it requires more time to do both. This is the proposed mechanism underlying the object advantage. Experiments 1 and 2 are both consistent with disengaging attention as a mechanism for the object advantage. The results of Experiment 1 allow us to reject spreading attention and object tracing as mechanisms for the object advantage, because it would take longer for attention to either spread or trace farther for the differently sized brackets. However, the disengaging attention hypothesis suggests that the object advantage is not an advantage for a within-object shift, but a disadvantage for a between-objects shift.

The results are consistent with the results of Abrams and Law (2000), Lamy and Egeth (2002), and Vecera (1994), but not Avrahami (1999), or Brown, et al. (2002). Vecera (1994) also looked at differing within-object and between-objects differences. He used Egly, et al.'s (1994) bar task but moved the bars closer together, so, as with our Experiment 1, his within-object distances were greater than the between-objects distances. He still found an object advantage, but it was lessened due to lesser between-objects RTs, indicating that disengaging attention affects RTs as well as spatial distance. Our results relate; we also found that the cue condition distinction is more important than spatial distance. His results, however, found an interaction between distance and the invalid conditions, which means RTs in his study were influenced to some degree by spatial distance. This is consistent with the disengaging theory, because it does not apply to the time it takes to shift, only the time it takes to disengage, in preparation for a shift. Basically, his participants took the same amount of time to disengage for all shifts, and less time to shift when the between-objects distance was less. Our participants only had to disengage from the location, not the object, and they took the same amount of time to shift in each bracket size condition. So, when we combine both results, we see that between-objects distance affects RTs and within-objects distance does not.

The discrepancy between these results and Brown, et al.'s (2002) is harder to determine. Brown, et al. compared 1:1 ratio bars to brackets with a 3:1 within-to-between-objects distance ratio and the results showed a cost difference between the bars and the brackets. In considering the difference in shape between a bracket and a bar, one might think that attention could be aimed by the shape of the stimulus, similar to endogenous cuing with an arrow. This would mean that the orientation of the bars might direct the observer to the within-object invalid target, and point at right angles to the between-objects invalid target. The orientation of the brackets, on the other hand, points to the between-objects invalid targets, and at right angles to the within-object invalid targets. However, if this pointing were actually directing the observer's attention, the between-objects invalid RT for the brackets would be less than for the bars, but it was the same. So this interpretation of Brown, et al.'s data would not explain the differences between their findings and those presented here.

The difference between these results and Brown, et al.'s (2002) could be a set effect related to the complexity/level of detail in their stimuli related to how focused or diffuse participants' attention was. Attention could be more focused with bars than brackets, because the stimulus display was so much bigger for brackets than for bars (LaBerge & Brown, 1986). This would affect both invalid conditions the same; it would show up in the RT data, not only in the cost data. This is unlikely to explain the difference between these studies, however, because the task itself is a counter to that argument. Participants were instructed that the cue is where the target usually appears. Irrespective of how the observer processes the display holistically, the paradigm was designed to get them to focus attention on the cue. Therefore, this argument is unlikely to be the difference between our results and Brown et al.'s.

It could be a practice effect. Brown, et al. (2002) blocked trials and counterbalanced; however, one condition could be better practice than the other. This effect could be stronger because Brown, et al.'s trials were blocked so that the participants saw bars at one visit and brackets at another visit, whereas the current study randomly presented the three bracket sizes.

We have only explored the object advantage in a cuing task that involves shifting attention. The mechanism of the object advantage may be different with different tasks, especially those that do not involve shifts of attention. In analogy to the object superiority effect (Weisstein & Harris, 1974), the object advantage could be a result of a higher order cognitive process (e.g., Avrahami, 1999; Shomstein & Yantis, 2002). Our task was a simple detection task; these findings may apply only to this task with these stimuli.

Shomstein and Yantis (2002) have explored whether the mechanism for the object effect is a bottom-up attentional mechanism or a top-down prioritization mechanism. The bottom-up mechanism is a preattentive segmentation of a stimulus set into objects. The spreading of attention or object tracing would both be examples of mechanisms of this type. The top-down mechanism involves prioritization of the areas in the visual field. Priorities are chosen through an attention mechanism, and affect the order of rescanning areas in the visual field. Note that this theory predicts such results as early facilitation and later inhibition of return, as found in classic cuing studies (e.g., Posner & Cohen, 1984). The task Shomstein & Yantis used to test this distinction involved the identification of a target letter with distractors on either the same or a different object. They found that distractors, irrespective of whether they are in the same or a different object, did not affect the RTs to identify the target, which supported their top-down hypothesis. The current results are consistent with Shomstein and Yantis's (2002) top-down prioritization theory as the mechanism.

Since the disengaging hypothesis is so simple, we need more information to locate it in the information processing stream. Shomstein and Yantis (2002) show support for a top-down mechanism of the object effect; other theories are bottom-up. Disengaging attention may be having its effects in an earlier stage of information processing or a later stage. Therefore, future research needs to explore this distinction.

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FIGURE CAPTIONS

Figure 1. Time course for Experiments 1 and 2, and stimuli for Experiment 2; See text for details. The target appeared in one of three positions. The valid target was in the same position as the cue. The invalid-within target was at the other end of the bar that the cue was presented in. The invalid-between target was in the nearest end of the other bar.

Figure 2. Brackets used with 2:1, 4:1, 6:1 ratios of their internal distance to the distance between their ends.

Figure 3(a). Mean RTs for the valid and collapsed invalid conditions from Experiment 1. *(b)* Mean costs for the invalid-within and invalid-between conditions. Error bars represent standard error.

Figure 4(a). Mean RTs for the valid and collapsed invalid conditions from Experiment 2. *(b)* Mean costs for the invalid-within and invalid-between conditions. Error bars represent standard error.

Figure 1

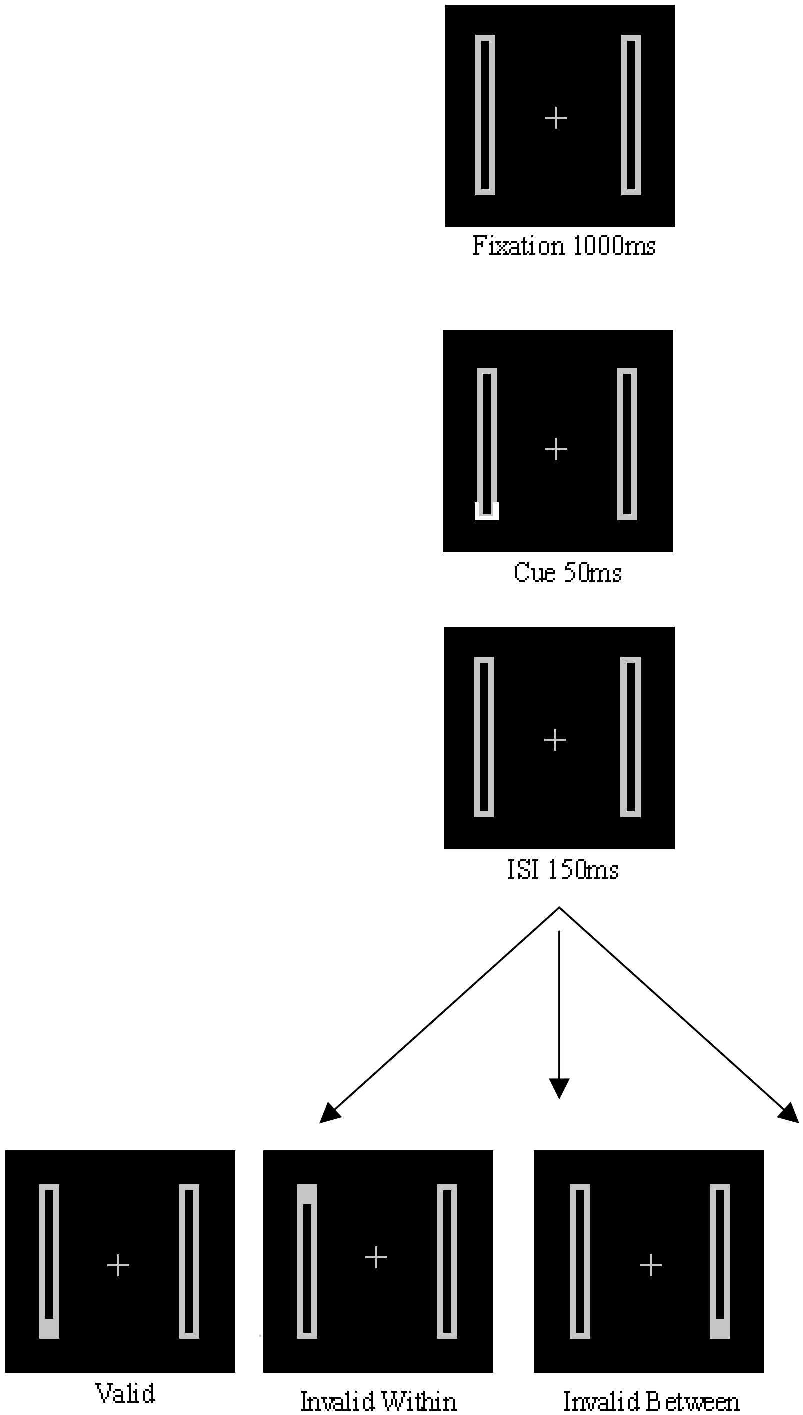
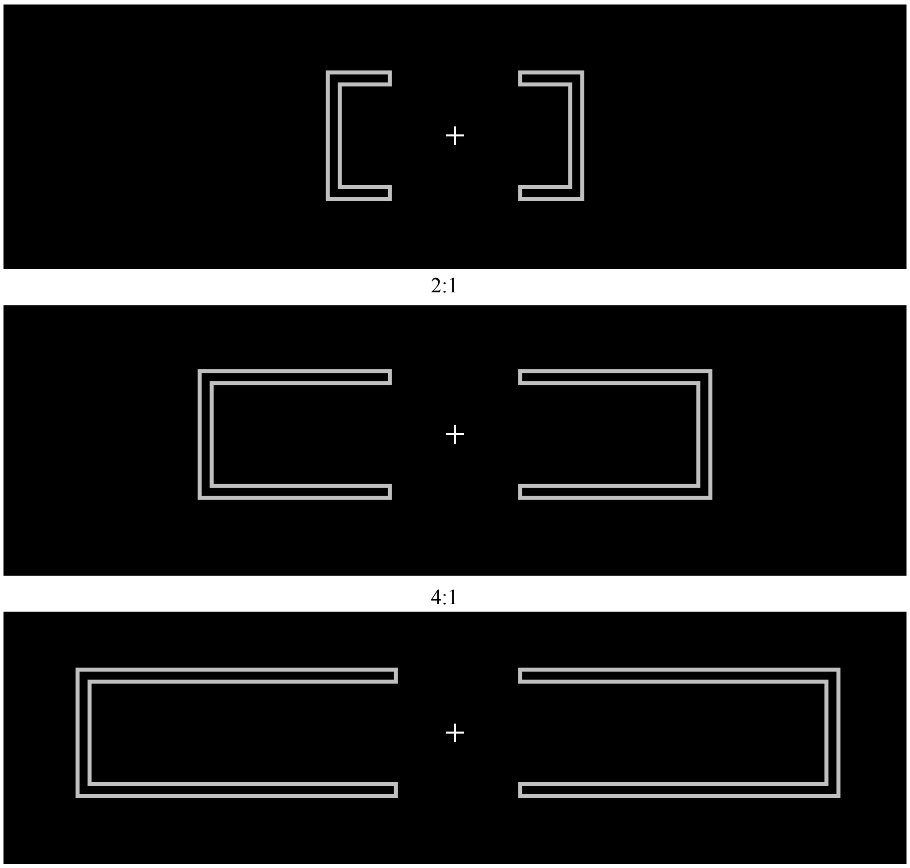

Fixation 1000ms
Cue 50ms
ISI 150ms
Valid
Invalid Within
Invalid Between

Figure 2

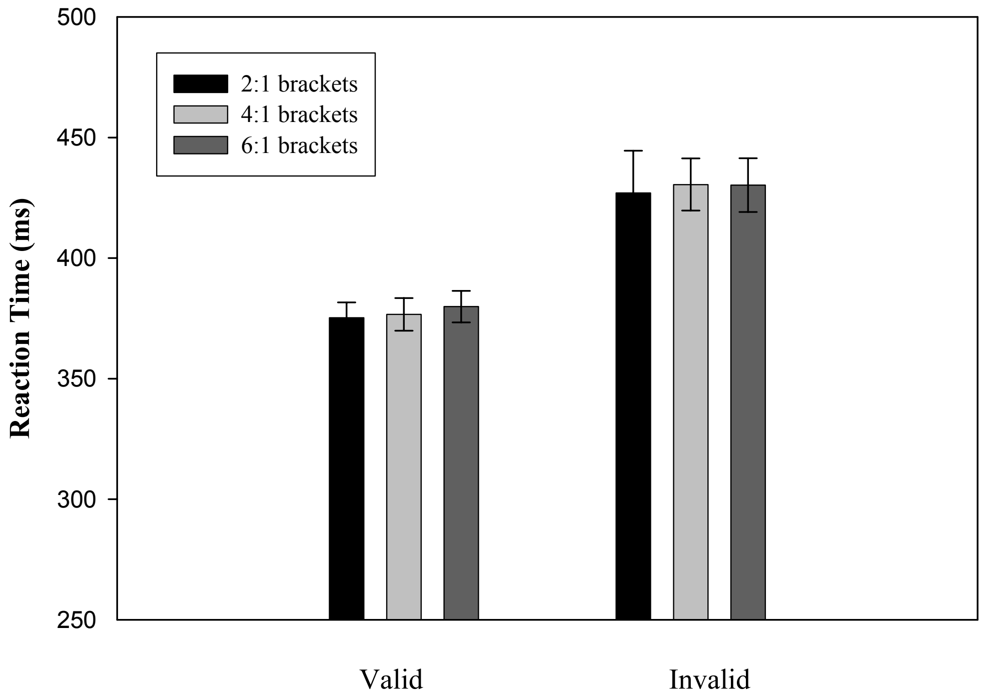


2:1

4:1

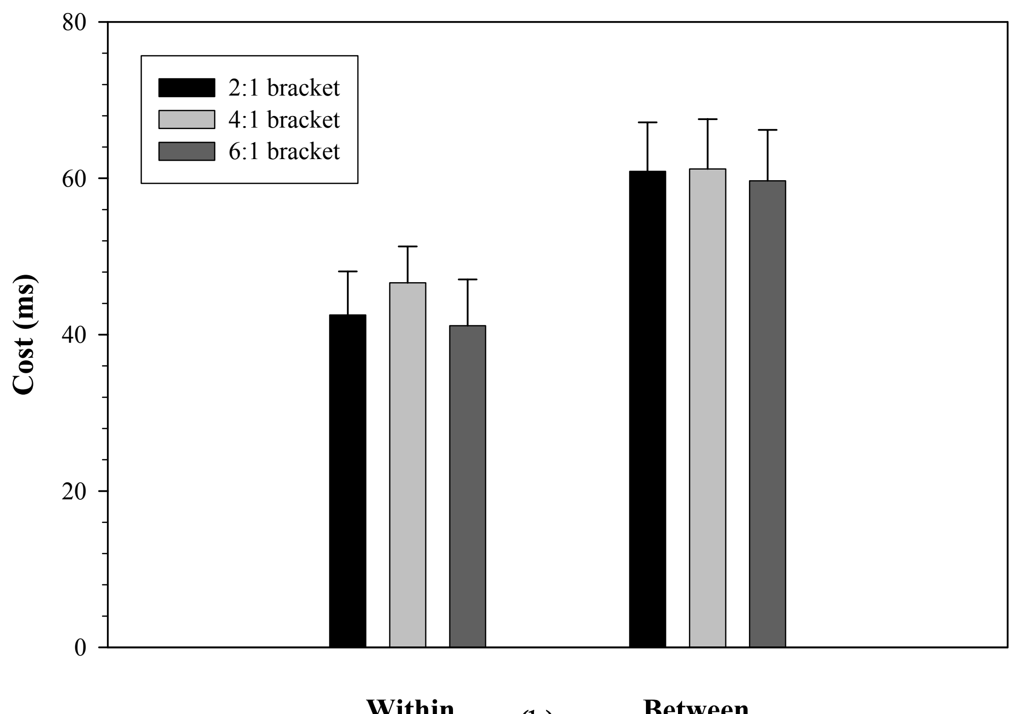
6:1

Figure 3



500
450
400
350
300
250
Reaction Time (ms)
2:1 brackets
4:1 brackets
6:1 brackets
Valid
Invalid

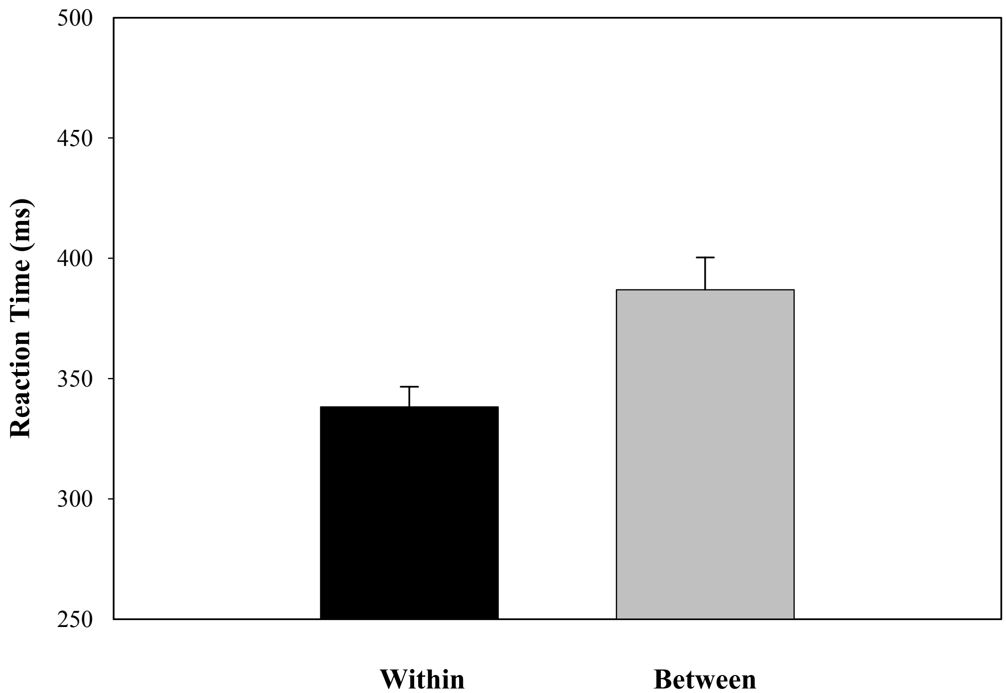
(a)



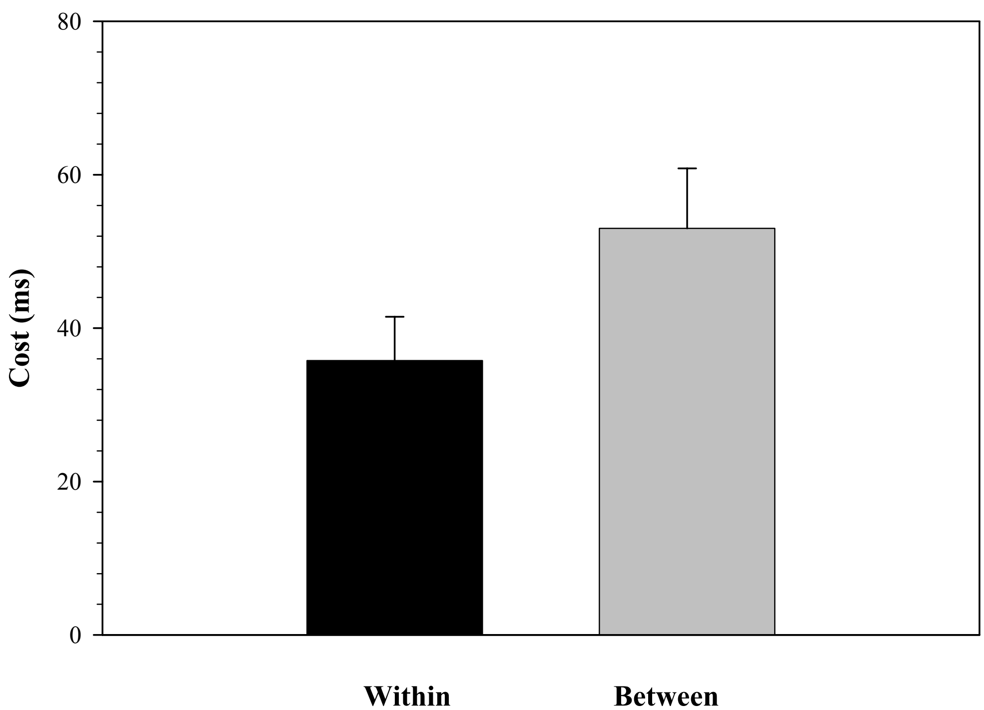
80
60
40
20
0
Cost (ms)
2:1 bracket
4:1 bracket
6:1 bracket
Within
Between

(b)

Figure 4


500
450
400
350
300
250
Reaction Time (ms)
Within
Between

(a)


80
60
40
20
0
Cost (ms)
Within
Between

(b)