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When is Object-Based Attention Not Based on Objects?

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Abstract

Some studies using methods introduced by Egly, Driver, and Rafal (1994) to measure object-based attention have shown surprising effects of object orientation. Rectangles oriented horizontally produce evidence for object-based attention, while vertical rectangles do not. We explore these differences using a two-letter comparison task. Across all the experiments, responses are faster when the targets are arranged horizontally rather than vertically. The horizontal advantage persists when the rectangles are removed, demonstrating its independence from object-based attention. Furthermore, responses are faster for vertically configured targets when they are within the same rectangle. This effect only arises when the rectangle orientation is informative about the target configuration orientation. This same-object advantage would normally be attributed to object-based attention, but the same pattern of data emerged when the rectangles were replaced with a salient orientation cue. The rectangles can apparently serve as a cue, making the cuing effect appear to be an object-based attention effect. However, the cuing effect can also be triggered by a horizontal bar in the center of the display. Thus participants can adopt an attentional set for a horizontal orientation independently of stimulus location. Results from comparison tasks that might have been attributed to object-based attention could instead be due to a combination of a horizontal advantage and an orientation set cost. While these results lead to a diminished role for object-based attention, they also call for a better understanding of how an attentional set can be adopted without selecting either locations or objects.

Public significance statement

Previous research has shown that visual comparison is more efficient for stimuli within the same object than between two different objects, and this same-object advantage, or object effect, is typically explained in terms of object-based attentional guidance that respects object boundaries. This study shows that a similar pattern of data can arise even when target stimuli do not appear within object boundaries, raising the possibility that many previously reported object effects may have little to do with object-based attention.

When is Object-Based Attention Not Based on Objects?

Object-based attention has been a central theme in visual attention research for many years, and claims about attention to objects have been supported with a variety of different experimental paradigms showing that responses are facilitated when stimuli and cues appear within the same object boundaries. The new experiments presented below use two-target comparison tasks with stimuli similar to those in a large number of object-based attention studies. They reveal new aspects of performance in this paradigm, including the fact that some of the outcomes from previous studies arise even when the two rectangles are absent from the display.

Previous Studies

One of the most widely used paradigms for demonstrating object-based attention is built around displays consisting of two long rectangles oriented parallel to one another. A spatial cue directs attention to one end of one rectangle, and the participant responds to a subsequent stimulus that can appear at either end of either rectangle. This display was first introduced by Egly, Driver, and Rafal (1994) as an extension of the Posner cuing task (Posner, 1980). The two rectangles were positioned so that the uncued end of the cued rectangle was the same distance from the cue as one end of the uncued rectangle. When responses to stimuli at these two locations are compared, responses are often faster to stimuli on the cued rectangle, suggesting that the benefits of attention are applying to the entire object, and not just the end with the cue.

This original study triggered a wave of experiments using modifications of Egly *et al.'s* stimuli and task to explore object-based attention (see Chen, 2012, for a review). In some of these experiments, the two rectangles are replaced with ellipses (Al-Janabi & Greenberg, 2016), wrenches (Kramer & Watson, 1996), or other oblong objects. Many of these experiments are like the original in that one location is chosen for the cue, and the same location or another location is chosen for the test stimulus to which the participant responds. Another set of experiments (*i.e.,* Kramer & Watson, 1996; Lamy & Egeth, 2002) uses a modified procedure: there are still two relevant locations, but those locations are filled by two stimuli that must both be processed to determine the correct response. Usually the two stimuli are compared, and the response alternatives are “same” or “different”. If responses are faster when the two items are within the same object, then this is taken as evidence for object-based attention. This comparison procedure requires no cuing, although it has been combined with a spatial cue, and has been done with objects that are not two rectangles oriented parallel to one another, but are instead rectangles arranged to form a cross pattern (Chen & Cave, 2008). This study will focus specifically on this two-target comparison task.

In some recent experiments (Al-Janabi & Greenberg, 2016; Harrison & Feldman, 2009) using this comparison procedure with parallel rectangles or other elongated objects, an unusual pattern has emerged: some conditions produce faster responses when the two items are on the same object rather than on different objects, as predicted.[1] However, other conditions produce no object-based effect or a reversed effect, with slower responses when the two items are on the same object than when they are on different objects. The factor that makes such a big difference in the outcome is the orientation of the two rectangles in the display.

One example of a strong orientation effect comes from Al-Janabi and Greenberg (2016), in which the two objects were ovals rather than rectangles. In their Experiment 1, they combined results across two different comparison tasks, and found the standard same-object advantage if the two objects were oriented horizontally. With vertically oriented objects, the effect reversed; responses were significantly faster when the two targets to be compared were on different objects. Al-Janabi and Greenberg explained this reversal by concluding that it is relatively harder to move attention across the horizontal midline than across the vertical midline, although the pattern could also be explained by assuming that two targets are more easily compared when they are aligned horizontally rather than vertically. Harrison and Feldman (2009) also found a horizontal advantage in a comparison task.

Although these comparison tasks benefit when the two items to be compared are arranged horizontally, there is often not a measurable benefit in cuing tasks when the cue location and the test stimulus location are arranged horizontally rather than vertically. The original object-based cuing study by Egly *et al.* (1994) showed no differences between horizontally and vertically oriented rectangles, and as a result, the data were not reported separately for horizontal and vertical conditions in many of the later cuing studies (e.g., Chen, 1998; Chen & O'Neill, 2001; Goldsmith & Yeari, 2003). Some studies that did include a horizontal-vertical comparison found no difference (e.g., Drummond & Shomstein, 2010; Moore, Yantis, & Vaughan, 1998), raising the possibility that there might be important differences between attention directed to targets via a spatial cue and attention attracted by targets directly. Differences between cued and uncued attention are also suggested by Donovan, Pratt, and Shomstein (2017), who used a temporal order judgement task and found object effects only when there was a spatial bias for a particular location or the targets were preceded by a spatial cue, so that attention could be directed to the relevant object. This led them to propose that object-based attention only occurs when attention is guided by a spatial cue or spatial bias.

There are however, some spatial cuing studies that show significant effects of rectangle orientation. One study by Pilz, Roggeveen, Creighton, Bennett, and Sekuler (2012) is informative because it includes two different cuing conditions. In one condition, subjects simply detected and responded to a test stimulus that appeared with no distractor items present. The effect of object-based attention was significant with horizontal rectangles but not with vertical. In the other condition, participants had to distinguish between two different possible target stimuli (rotated T or L), and each appeared along with three similarly-shaped distractors. In this more difficult discrimination task, horizontal rectangles produced the expected object-based effect, with faster responses when cue and target were on the same rectangle, but vertical rectangles produced the opposite effect, with significantly faster responses when cue and target were on different rectangles.

Hein, Blaschke, and Rolke (2017) used similar targets and distractors, and also found horizontal-vertical differences. Al-Janabi and Greenberg (2016) also used a cuing task and found horizontal-vertical differences. Their participants had to discriminate between two possible targets to determine the correct response, but there were no distractor items in the display. These data demonstrate that the difference between horizontal and vertical objects can arise in tasks other than two-object comparison, and suggest that the effect might be tied to discrimination difficulty. Ten Brink, Nijboer, Van der Stoep, and Van der Stigchel (2014) presented a novel demonstration of a horizontal advantage that did not involve visual similarity. They showed that eye movements to an auditory stimulus location were affected more by visual distractors that were positioned vertically relative to the target location than those positioned horizontally.

The Current Experiments

Taken together, the previous studies show that the orientation of the rectangle plays a crucial role when object-based attention is measured with a two-target comparison task, and that orientation can also exert effects in location cuing tasks, especially when target-distractor discimination is difficult. The new experiments reported here focus on the comparison task. They test how performance in this task varies between horizontal and vertical configurations, and between experiments where the targets are presented on objects and those where the targets are shown without object boundaries surrounding them. These experiments allow us to investigate the nature of the orientation by object asymmetry reported in previous research: whether the asymmetry is caused by the guidance of object-based attention sensitive to the orientation of objects, or whether it can be explained by some other factor, such as the joint effect of a horizontal target configuration benefit and an attentional set induced by the orientation of the objects shown before target onset. If the results are consistent with the latter account, then theories of object-based attention must take into consideration the degree to which an attentional set guides the allocation of attention.

To foreshadow our results, some aspects of these new experiments are similar to those of the experiments described above: they show effects consistent with object-based attention when the two rectangles are oriented horizontally, but when the rectangles are oriented vertically, they show the opposite effect. Other aspects of these results are more surprising: they show that the effects of orientation can occur even when there are no object boundaries surrounding the targets. Thus, what previous research would have interpreted as an object effect can arise without targets appearing on any objects.

These results challenge the interpretation offered by previous studies for this orientation-by-object symmetry: that attention to objects varies depending on the object's orientation. Instead, they raise doubt as to whether object-based attention occurs at all with this type of task and this type of stimuli, and limit the scope of visual phenomena that can be explained by theories of object-based attention. Furthermore, these experiments reveal surprisingly complex aspects of how information about the orientation of an upcoming stimulus configuration is used to shape visual processing. This result suggests that previous experiments with this comparison task are not telling us much about object-based attention, but they are telling us something important about how visual objects are compared, and how foreknowledge about orientation can be used to prepare for those comparisons.

In Experiments 1 to 3, the targets were presented within outlined rectangles, as in previous experiments that were designed to measure object-based attention. There was a general pattern across all these experiments of faster responses for horizontal target configurations than for vertical configurations. This horizontal benefit was accompanied by a second, more complex effect: responses were slow when the rectangles were oriented horizontally but the two targets were configured vertically. This effect only appeared in certain conditions, suggesting that it might be a new type of cuing effect.

In Experiments 4 to 6, no rectangles were used in any displays. Instead, the targets were shown on a gray background following a cue that indicated the likely orientation of the target configuration. The horizontal advantage persisted, demonstrating that it is not caused by object-based attention; instead, the shape comparison required here was performed more quickly when the two shapes were horizontally aligned. Experiments 4 to 6 also demonstrated a cuing effect similar to that found in Experiments 1 to 3: even though participants did not know where the two targets would appear and were unable to allocate spatial attention to facilitate their processing, they did seem to adopt an attentional set when cued for a horizontal configuration, and this slowed their response to a vertical configuration. Experiments 4 to 6 show that this effect is also clearly separate from object-based attention.

These results lead to a series of theoretical conclusions. First, visual comparison is facilitated when the objects being compared are horizontally aligned. Second, the role of object-based attention is more limited than many have thought, and it may not affect visual comparison. Third, our understanding of attentional set needs to expand to include the ability to facilitate configurations of a specific orientation, independently of location. This orientation selection is applied asymmetrically to horizontal and vertical orientations.

EXPERIMENT 1

This experiment was modelled loosely on the two-rectangle paradigm developed by Egly *et al*. (1994). As in Egly *et a*l., stimuli were presented in oriented rectangles, which were equally likely to be horizontal or vertical. Unlike Egly *et al*., there was no cue, and there were two target letters. The task was to judge whether the two letters were the same or different.

To determine the role of spatial selection in the allocation of object-based attention, we manipulated the onset of the targets: they were shown simultaneously in one session, but sequentially in the other session. In the simultaneous session, the two targets would appear at the same time on every trial. As there would be no reason for participants to favor one rectangle over the other before the onset of the targets, spatial attention would not be allocated before the appearance of a target letter. In the sequential session, one target would appear before the other, and the onset of the first target could attract spatial attention to the rectangle where the target appeared. If a spatial cue is required for the deployment of object-based attention, we should find object effects in the sequential session, but not in the simultaneous session.

Experiment 1 also explored whether there would be differences in object effects between horizontal and vertical rectangle trials, and if so, to what degree this pattern of data would reflect an advantage for target pairs arranged horizontally rather than vertically (Barnas & Greenberg, 2016; de-Wit, Kentridge, & Milner, 2009; Hein *et al*., 2017; Sereno & Kosslyn, 1991): i.e., a horizontal configuration benefit. To investigate this, we analysed the data in two different ways. We first organized the data by rectangle orientation, with a horizontal-rectangle condition and a vertical-rectangle condition. The orientation of target configuration was not controlled under this organization. Specifically, on horizontal rectangle trials, the targets were horizontally aligned in the same-object condition, but vertically aligned in the different-object condition. (See Figure 1.) Conversely, on vertical rectangle trials, the targets were vertically aligned in the same-object condition, but horizontally aligned in the different-object condition. Thus, any object effect, regardless of whether it was a same-object advantage or a same-object cost, was confounded with a target configuration effect. We then organized the data by target configuration, which allowed us to assess the effect of object representation within a specific object configuration. The absence of an object effect while target configuration was held constant within a condition would suggest that the asymmetry in the object effects observed in previous research reflects a horizontal configuration benefit rather than object-based deployment of attention on horizontal rectangle trials.

Method

The primary analyses in Experiment 1 were two repeated-measures ANOVA on RTs, one on the data organized by rectangle orientation and the other by target configuration. For the former analysis, we were particularly interested in the interaction between rectangle orientation and object. If a significant same-object effect was found only on the horizontal but not on the vertical rectangle trials, this would replicate the results of previous research (e.g., Al-Janabi & Greenberg, 2016; Hein *et al*., 2017; Pilz *et al*., 2012), which in turn would allow us to examine the nature of the interaction in a subsequent analysis when the orientation of the target configuration was held constant.

For the analysis on the data organized by letter configuration, we were primarily interested in three effects: the main effects of letter configuration and object, and the interaction between target presentation type (simultaneous vs sequential) and object. Faster response latencies on the horizontal configuration compared with vertical configuration trials would indicate a horizontal configuration benefit. Faster RTs on the same object than different object trials would indicate object-based guidance of attention while holding constant the orientation of the target configuration. An interaction between target presentation type and object, with a significant object effect in the sequential but not the simultaneous presentation session, would provide evidence for the importance of spatial selection in the allocation of object-based attention.

Because it was important that we replicated the asymmetry in object effects observed in previous studies, our decision on sample size was based on previous research that showed the asymmetry. Hein *et al*. (2017) reported a large effect size for the interaction between rectangle orientation and object (i.e., η_p^2 =.4 in Experiment 1 and η_p^2 =.39 in Experiments 2A and 2B combined). Assuming a smaller effect of η_p^2 =.3, we conducted a power analysis with G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). For α = .05 and 80% power, the recommended sample size was 11[2]. The sample size we used was 20, which gave us more than 95% of power to detect the interaction if the effect was there. As most of the experiments had the same structure, we used the same number of participants for each. (See note 7 for the one exception: Experiment 3A.)

Ethics statement. The study reported here received approval from the University of Canterbury Human Ethics Committee. All participants gave written informed consent in accordance with the Declaration of Helsinki.

Participants. Twenty undergraduate students (mean age = 19, SD = 1.4; 2 male) from the University of Canterbury took part in the experiment in exchange for course credit.

Apparatus and stimuli. All stimuli were black against a white background on a PC with a 24-inch monitor. E-Prime was used to generate the stimuli and collect responses. Participants were tested individually in two dimly lit rooms. The viewing distance was about 60 cm.

Each trial began with a central fixation, followed by an object display that consisted of two outlined, oriented rectangles, and one or two target displays depending on the experimental session. (See Figure 1.) The fixation was a cross that subtended 0.3°. The object display consisted of the fixation and two identical rectangles that were either horizontally (50%) or vertically (50%) oriented. Each rectangle subtended 13.4° x 2.7°, and the separation between the inner contours of the two rectangles was 8.0°. The entire configuration subtended 13.4° in both length and width. In the simultaneous session, two target letters, which were two Ts (25%), two Ls (25%), or one T and one L (50%), were presented concurrently on either the same rectangle (50%) or different rectangles (50%). In the sequential session, one target letter, which was equally likely to be a T or an L, appeared before the other letter, which was also equally likely to be a T or an L. In both sessions, each letter subtended 0.76° in width and 0.86° in length. The two-letter configuration was equally likely to be oriented horizontally or vertically, and it either matched (50%) or mismatched the orientation of the rectangles (50%). The spatial separation between the two targets was the same regardless of whether the targets appeared in the same rectangle or in different rectangles, and whether the configuration was horizontal or vertical.

Insert Figure 1 about here

Design and procedure. The design of the experiment can be described in one of two ways: with a focus on rectangle orientation, or with a focus on target configuration. When the focus is on rectangle orientation, the three variables are presentation (targets displayed sequentially vs simultaneously), rectangle orientation (rectangles oriented horizontally vs vertically), and object (targets presented in the same rectangle vs in different rectangles). When the focus is on target configuration, the variables are presentation (targets displayed sequentially vs simultaneously), target configuration (targets aligned horizontally vs vertically), and object (targets presented in the same rectangle vs in different rectangles). This choice between organizations reflects a dependency between the orientation of the rectangles, the orientation of the target configuration, and the same-different object manipulation. When the orientation of the rectangles matched the orientation of the target configuration, the targets appeared within the same rectangle (i.e., the same-object condition). Conversely, when the two mismatched, the targets appeared in different rectangles (i.e., the different-object condition). The same dependency has been built into a number of previous object-based attention experiments. Regardless of which description was used, all the variables were manipulated within subjects. While presentation (simultaneous or sequential) was varied between sessions, with the session order counterbalanced across the participants, the other two variables were varied with a block.

Each trial started with the fixation for 1,000 ms, followed by the rectangle display for another 1,000 ms. The rectangles were oriented horizontally on half the trials, and vertically on the other half. In the simultaneous session, two target letters would then appear concurrently for 120 ms before the display was replaced by a blank screen. In the sequential session, one target was shown for 50 ms before it was joined by the second target, and both targets remained on the screen for additional 120 ms. In both sessions, the targets were equally likely to be aligned horizontally or vertically, and they were equally likely to appear within the same rectangle or in different rectangles.

The participants were instructed to make a speeded response by pressing one of two labelled keys on the number pad of the keyboard to indicate whether the targets were the same or different. They used their right forefinger to press the “4” key (labelled “Same” for the same response) if the targets were two Ts or two Ls, and they used their middle finger to press the “5” key (labelled “Diff” for the different response) if the targets were one T and one L. Both speed and accuracy were emphasized. No feedback was given during the experiment. The intertrial interval was 500 ms. Half the participants completed the simultaneous session before the sequential session, and the order was reversed for the other half.

The experiment started with two short blocks of 12 practice trials, with the targets presented sequentially in one block and simultaneously in the other block. Presentation order was the same as that in the main experiment. After the practice, participants completed two sessions, with each session consisting of 256 trials divided into 128 trials per block. Participants were encouraged to take a short break after each block. The entire experiment took approximately 40 minutes to complete.

Results and Discussion

In all the experiments reported here, trials with particularly fast responses (i.e., below two standard deviations) or particularly slow responses (i.e., above two standard deviations) were excluded from both RT and error analyses. In addition, the data from any participant whose mean RT after the data treatment described above exceeded 4 standard deviations above the mean RT for the rest of the participants or whose incorrect responses exceeded one-third of the trials in an experimental condition were also excluded from analyses.

In Experiment 1, one participant’s data were excluded from data analyses due to high error rate. For the remaining 19 participants, the proportion of the data excluded was 2.8% of the total data.[3]

To investigate whether an object by orientation interaction reported in previous studies (e.g., Al-Janabi & Greenberg, 2016; Hein *et al*., 2017; Pilz *et al*., 2012) also appeared in the present experiment, we first examined the data organized by rectangle orientation. The mean RT results are shown in Figures 2A and 2B, and the error rates are shown in Table 1.[4] In all the tables and figures in this article, the error bars show the within-subjects standard error of the mean (Cousineau, 2005). A 2 x 2 x 2 repeated-measures analysis of variance (ANOVA) on the mean RTs with presentation, rectangle orientation, and object as the factors revealed a significant main effect of rectangle orientation, $F(1, 18) = 4.90$, $MS_e = 366$, $p = .04$, $\eta_p^2 = 0.21$, indicating faster responses for vertical rectangle trials (658 ms) than for horizontal ones (665 ms). Importantly, there was also a significant interaction between object and rectangle orientation, $F(1, 18) = 15.57$, $MS_e = 841$, $p < .001$, $\eta_p^2 = 0.46$, indicating a same-object advantage (18 ms) when the rectangles were horizontal but a same-object cost (-20 ms) when the rectangles were vertical. To see whether the same-object advantage and the same-object cost were reliable, we conducted two *t* tests, one for each. In all the experiments reported here, we used Cohen's *d* (i.e., the difference between the means of the two conditions divided by pooled standard deviation) as the measure of effect size when comparing two conditions. The results showed that both the same-object advantage, $t(18) = 2.56$, $p = .02$ (two tails), $d = .59$, and the same-object cost, $t(18) = -3.29$, $p = .004$ (two tails), $d = 0.76$, were significant. No other effects reached significance. Tables 5 to 12 in the appendix provide detailed information on the results of the analyses in all the experiments reported here.

Insert Figures 2A, 2B, and Table 1 about here

A similar ANOVA was conducted on the error rates. The only significant effect was the interaction between object and rectangle orientation, $F(1, 18) = 10.94$, $MS_e = 20$, $p = .004$, $\eta_p^2 = 0.38$. Consistent with the RT results, there was a same-object advantage (2.7% error rate) when the rectangles were horizontal, but a same-object cost (-2.1% error rate) when the rectangles were vertical. Both effects were significant, $t(18) = 3.41$, $p = .003$ (two tails), $d = 0.76$ for horizontal rectangle trials and $t(18) = -2.15$, $p = .045$ (two tails), $d = 0.48$ for vertical rectangle trials. These results replicated the object by orientation interaction observed in prior research (e.g., Al-Janabi & Greenberg, 2016; Pilz *et al*., 2012).

Next, we explored whether the results in Experiment 1 were also consistent with a horizontal configuration benefit account. To do this, we organized the data by the orientation of the target configuration. The RT results are shown in Figures 3A and 3B, and the error rates are shown in Table 1. Two 2 x 2 x 2 ANOVAs, one on the RT data and the other on the error rates, were conducted, and the three variables were presentation, target configuration, and object. A significant main effect of target configuration was found, both in RT, $F(1, 18) = 15.57$, $MS_e = 841$, $p < .001$, $\eta_p^2 = 0.46$, and in error rates, $F(1, 18) = 10.94$, $MS_e = 20$, $p = .004$, $\eta_p^2 = 0.38$, indicating faster and more accurate responses when the target configuration was horizontal (652 ms with an error rate of 6.3%) rather than vertical (671 ms with an error rate of 8.7%). Importantly, there was no main effect of object in either RT or error rates, *F*(1,

18) < 1 in both cases. Although presentation and object interacted in RT, $F(1, 18) = 4.90$, $MS_e = 366$, $p = .04$, $\eta_p^2 = 0.21$, this interaction was driven by a numerical cost in the same object condition (656 ms) compared with the different object condition (648 ms) when the target configuration was horizontal, but a numerical gain in the same object condition (668 ms) compared with the different object condition (674 ms) when the target configuration was vertical. Neither difference was statistically reliable. No other results reached significance, and there was no indication of speed-accuracy trade-off.

Consistent with previous research (Al-Janabi & Greenberg, 2016; Hein *et al*., 2017; Pilz *et al*., 2012), our participants showed an asymmetry in object effects when the data were organized by rectangle orientation. There was a same-object advantage on horizontal trials and a same-object cost on vertical trials. However, as we have noted, when the data were arranged in this way (Figures 2A and 2B), the orientation of the target configuration was not held constant across the same and different object conditions. Specifically, on the horizontal rectangle trials, the targets were aligned horizontally in the same object condition and vertically in the different object condition. In contrast, on the vertical rectangle trials, the targets were aligned vertically in the same object condition and horizontally in the different object condition. This horizontal configuration benefit may be an effect of crossing the horizontal and vertical meridians, given that responses to horizontal stimuli that cross the vertical meridian tend to be faster than responses to vertical stimuli that cross the horizontal meridian (Barnas & Greenberg, 2016; de-Wit *et al*., 2009; Hein *et al*., 2017; Sereno & Kosslyn, 1991). Indeed, when the data were organized by target configuration (Figures 3A and 3B), both the same-object advantage on horizontal rectangle trials and the same-object cost on vertical rectangle trials disappeared. What emerged was a reliable horizontal configuration benefit with no object effects.

Insert Figures 3A and 3B about here

The results of Experiment 1 are thus consistent with previous research showing a horizontal processing advantage (Barnes & Greenberg, 2016; Carrasco, Talgar, & Cameron, 2001; Corbett & Carrasco, 2011; Mackeben, 1999). They are also in line with the suggestion made by several researchers that some object effects reported in prior studies may in fact be target orientation effects (Al-Janabi & Greenberg, 2016; Greenberg, Hayes, Roggeveen *et al*., 2014).

When the orientation of the target configuration was held constant, Experiment 1 found no object effect on either the simultaneous or sequential trials. The absence of an object effect in the simultaneous session was not surprising. It was consistent with Donovan *et al*.'s proposal that object-based attention only occurs when attention is guided by a spatial cue or spatial bias. It was also in line with previous research, which shows that object-based allocation of attention is not an automatic process but is subject to strategic control (Yeari & Goldsmith, 2010). As the targets were equally likely to appear within the same object or between two different objects in Experiment 1, from a participant's perspective, there was no advantage to allocate more attention to locations within an object compared to locations between objects. If attention was equally distributed across all possible target locations, no object effects would be found. Indeed, no object effect was observed.

The absence of an object effect in the sequential session came as a surprise. This result appeared to differ from both Donovan *et al.*'s proposal and the findings of Lamy and Egeth (2002, Experiment 3).[5] In the latter study, participants saw two target squares presented on a pair of outlined rectangles, and the task was to judge whether the squares were of the same size. The squares were shown simultaneously in one experiment (Experiment 1) and sequentially in another experiment (Experiment 3). No object effect was found in the simultaneous experiment. However, in the sequential experiment, object effects were observed when the SOA between the 1st and 2nd target was 100 ms and 200 ms, but not 300 ms. In Experiment 1 of the present study, the SOA between the 1st and 2nd target in the sequential session was 50 ms. It is possible that the shorter SOA in our experiment was too brief for object-based attention to be deployed, and as a result, no object effect was found. Experiment 2 investigated this possibility.

EXPERIMENT 2

Experiment 1 found no object effect in either the sequential or the simultaneous session when the data were organized by target configuration, and we attributed the absence of the object effect in the sequential session to the very short SOA between the 1st and 2nd target. Object effects are typically interpreted as the results of enhanced sensory representation of the selected object (Chen & Cave, 2006; 2008; Roelfsema, Lamme, & Spekreijse, 1998; Wanning, Rodríguex, & Freiwald, 2007), attentional prioritization of the stimuli within the same object (Shomstein & Yantis, 2002), higher cost in between-object than within-object shift of attention (Brown & Denney, 2007; Lamy & Egeth, 2002), or some combination of these depending on the task (see Chen 2012, for a review). Regardless of the underlying mechanisms, some minimum amount of time may be needed for object-based attention to be deployed (Chen & Cave, 2008). In Experiment 2, we increased the SOA between the sequential targets from 50 ms to 100 ms on some trials and to 200 ms on the other trials. The goal was to confirm that the absence of an object effect in Experiment 1 was caused by insufficient time for object-based attention to be deployed rather than by the specific paradigm that we used.

Method

The method was the same as that of Experiment 1 except for the following changes. The targets were presented sequentially on every trial. The first letter was shown for 100 ms on half the trials, and for 200 ms on the rest of the trials. This was then followed by the onset of the 2nd letter, which was shown, together with the 1st letter, for 120 ms. The two types of SOA trials were randomly mixed within a block. We used a within-block instead of a between-block design for the SOA manipulation as previous research has shown that a between-block design is prone to top-down search strategy, which in turn can affect the allocation of attention (Chen & Cave, 2015; 2016; Leber & Egeth, 2006). As in Experiment 1, the targets were equally likely to be in the same rectangle or in different rectangles, and the target configuration was horizontal on half the trials, and vertical on the rest.

The experiment used a 2 x 2 x 2 within-subjects design, with SOA (100 ms vs 200 ms), target configuration (targets aligned horizontally vs vertically), and object (same vs different) as the principal variables. Participants completed 24 practice trials before proceeding to 512 experimental trials divided into 4 equal blocks. Twenty new participants (mean age = 19.3, SD = 3.8; 3 male) took part in the experiment.

Results and Discussion

To examine object-based attention while controlling for target configuration, we organized the data by target configuration. The data from one participant were excluded from analyses due to long RTs. For the remaining participants, their mean RT results are shown in Figures 4A and 4B, and the error rates are shown in Table2. A 2 x 2 x 2 repeated-measures ANOVA on the RT data showed a main effect of SOA, $F(1, 18) = 22.58$, $MS_e = 775$, $p < .001$, $\eta_p^2 = 0.56$, indicating faster responses when the SOA was 200 ms (586 ms) compared with 100 ms (607 ms). This effect was to be expected, for the participants had more time to process the 1st target when the SOA was long relative to when it was short. The main effect of target configuration was also significant, $F(1, 18) = 16.75$, $MS_e = 319$, $p < .001$, $\eta_p^2 = 0.48$, indicating faster responses when the two targets were configured horizontally (591 ms) rather than vertically (602 ms), replicating the horizontal configuration benefit found in Experiment 1. In addition, there was a significant interaction between target configuration and object, $F(1, 18) = 4.68$, $MS_e = 285$, $p = .04$, $\eta_p^2 = 0.21$. Response latencies differed very little between the same (591 ms) and different (590 ms) object conditions on the horizontal configuration trials. In contrast, RT was significantly longer in the different object condition (608 ms) than in the same object condition (597 ms) on the vertical configuration trials, $t(18) = 2.41$, $p = .03$, $d = .55$, demonstrating an object effect that only arises when the targets are vertically configured. No other effects reached significance.

Insert Figures 4A, 4B, and Table 2 about here

A similar ANOVA was conducted on the accuracy data. A marginally significant horizontal configuration benefit was found, $F(1, 18) = 4.39$, $MS_e = 13$, $p = .05$, $\eta_p^2 = 0.20$, indicating higher accuracy when the targets were arranged horizontally (6.1% error rate) rather than vertically (7.3% error rate). The interaction between target configuration and object was also marginally significant, $F(1, 18) = 3.73$, $MS_e = 7$, $p = .07$, $\eta_p^2 = 0.17$. Participants showed a slight same-object cost on the horizontal trials (-0.7% error rate), but a slight same-object benefit on the vertical trials (1% error rate). These results are in the same direction as those found in RT, indicating no speed-accuracy tradeoff. No other results were significant.

Consistent with the findings in Experiment 1, a reliable horizontal configuration benefit was found. Once again, responses were faster when the target configuration was horizontal than vertical. Importantly, unlike the results in Experiment 1, there was a significant object effect in Experiment 2 on vertical configuration trials. Increasing the SOA between the 1st and 2nd target apparently facilitated the deployment of object-based attention. [6] This result is consistent with the prediction of Donovan *et al.* (2017) and the finding of Lamy and Egeth (2002). Lamy and Egeth also found an object effect when the SOA between the targets was 100 ms or 200 ms. Taken together, the results of the present experiments are in line with the finding in spatial cuing experiments that object effects are more robust when the cue-to-target SOA was relatively long (Avrahami, 1999).

As in Experiment 1, responses were faster when the two targets were configured horizontally. In both Experiments 1 and 2, this horizontal advantage appears regardless of whether the targets are on the same object or different objects; thus it seems to be independent of object-based attention.

When the two targets are configured vertically, responses take more time, but some of that extra time can be shaved off if both targets are within the same rectangle. If we assume that the appearance of the 1st target would trigger attention to spread within the boundaries of the attended object, the onset of the 2nd target would require no change in attentional set in the same object condition. In the different object condition, either attention needs to be shifted to select both targets, or the targets need to be compared with the wrong attentional set. Either way, there could be a cost in RT, but the data only show this cost when attention has incorrectly selected a horizontal object.

The pattern of response times in Experiment 2 seems to reflect the interaction of two different processes: a general horizontal advantage, and a separate attentional effect that becomes important with vertical targets. The most straightforward explanation of this interaction is perhaps that responses to horizontal target configurations are so fast that attention does not matter. Another possible explanation is that there is some extra difficulty in adjusting to a vertical configuration after attention has been allocated to a horizontal object. On the vertical target configuration trials, the rectangles were vertical in the same object condition but horizontal in the different object condition. When attention incorrectly selects a horizontal rectangle, it apparently incurs an attentional set cost, as shown by the significant object effect found in the vertical configuration trials. The results suggest that dealing with an incorrect attentional set might slow down the speed of processing only when it has been set for an efficient mode of processing and an inefficient mode is required, but not vice versa.

EXPERIMENTS 3A AND 3B

The results of Experiments 1 and 2 are largely consistent with Donovan *et al*.'s (2017) proposal that spatial selection is required for the deployment of object-based attention. In Experiments 3A and 3B, we tested the generality of this proposal. In Experiment 3A, we manipulated the proportion of the same-object trials so that it was 50% in one session (the equal session) but 75% in the other session (the more session). In Experiment 3B, we replicated the more session with a different group of participants. By increasing the proportion of same-object trials, we hoped to encourage participants to favor locations within an object relative to locations between objects. It is important to note that even though participants knew in advance that the targets in the more session were more likely to appear within an object, this knowledge was not useful in terms of guiding spatial attention to a specific rectangle because the rectangle in which the targets would appear on a given trial was randomly determined, and the targets appeared in the two rectangles with equal probability. Of particular interest was whether object-based attention would be observed above and beyond horizontal configuration benefits without prior spatial selection of an object.

Experiment 3A

Method

The method of Experiment 3A was the same as that of Experiment 1 except for the following differences. There was no sequential session in this experiment; the targets appeared concurrently on all the trials. The experiment consisted of two sessions: one identical to the simultaneous session in Experiment 1 (the equal session), and the other having more same-object trials (75%) than different-object trials (25%). On the same-object trials in both sessions, the rectangle in which the letter targets would appear on a given trial was randomly determined. So, there was equal probability for the targets to appear in either rectangle.

The experiment used a 2 x 2 x 2 within-subjects design, with proportion (equal vs more), target configuration (horizontal vs vertical), and object (same vs different) as the principal variables. While proportion was manipulated between sessions, target configuration and object were varied within a block. Thirty-three new participants (mean age = 19.6, SD = 2.6; 14 male) took part in the experiment.[7] Seventeen completed the equal session before the more session. This order was reversed for the rest.

Results

The data from 2 participants were excluded from analyses due to high error rates. For the rest of the participants, the mean RT results are shown in Figures 5A and 5B, and the error rates are shown in Table 3. To examine object-based attention above and beyond horizontal configuration benefits, we organized the data by target configuration, and conducted two 2 x 2 x 2 repeated-measures ANOVAs, one on the RT and the other on the accuracy data. The results showed a significant target configuration effect in both RTs and error rates, $F(1, 30) = 39.14$, $MS_e = 1046$, $p < .001$, $\eta_p^2 = 0.57$, for RT, and $F(1, 30) = 5.41$, $MS_e = 14$, $p = .03$, $\eta_p^2 = 0.15$, for error rates. Participants were faster and more accurate on the horizontal configuration trials (631 ms with an error rate of 5.5%) than on vertical ones (656 ms with an error rate of 6.7%), indicating a horizontal configuration benefit. In addition, a significant interaction between target configuration and object was found in RT, $F(1, 30) = 7.32$, $MS_e = 684$, $p = .01$, $\eta_p^2 = 0.20$. On vertical trials, there was a significant same-object advantage, with faster responses in the same object condition (650 ms) than in different object condition (663 ms). In contrast, on horizontal trials, there was little difference between the same (633 ms) and different (628 ms) object conditions. No other effects were significant.

Insert Figures 5A to 5C, and Table 3 about here

To determine whether an object effect would be found in the vertical trials of the more session in RT, we conducted two separate ANOVAs, one for the data in the equal session and the other for the data in the more session. For the equal session, the only significant effect was the main effect of configuration, $F(1, 30) = 22.62$, $MS_e = 678$, $p < .001$, $\eta_p^2 = 0.43$, showing a horizontal configuration benefit. For the more session, in addition to a horizontal configuration benefit, $F(1, 30) = 29.93$, $MS_e = 880$, $p < .001$, $\eta_p^2 = 0.50$, there was also a main effect of object, $F(1, 30) = 4.22$, $MS_e = 441$, $p = .049$, $\eta_p^2 = 0.12$, and an object by configuration interaction, $F(1, 30) = 6.80$, $MS_e = 731$, $p = .01$, $\eta_p^2 = 0.18$. Participants were faster when the targets were on the same object (640 ms) compared to different objects (648 ms), but this same-object advantage appeared only on the vertical configuration trials (a same-object advantage of 21 ms), but not on the horizontal configuration trials (a same-object cost of 3 ms). We will discuss these results in the discussion section of Experiment 3B.

Experiment 3B

Method

Experiment 3B was conducted to verify that the object effect found in the more session of Experiment 3A could be observed with a different group of participants. The method was the same as that of Experiment 3A except for the following differences. First, only the more session was included in the experiment. Second, the duration of the rectangle display before the onset decreased from 1000 ms to 500 ms. Third, the total number of trials in the session increased from 256 to 384 divided into 4 blocks, and the number of practice trials was 24 devided into 2 blocks. As before, the targets appeared in the same rectangle on 3/4 of the trials, and in different rectangles on 1/4 of the trials. Twenty new participants (mean age = 19.4, SD = 3.9; 7 male) took part in the experiment.

Results

The data from 3 participants were excluded from analyses, two due to high error rates and one due to high RT. For the remaining 17 participants, the RT results are shown in Figure 5C, and the error rates are shown in Table 3. Once again, we arranged the data by the orientation of the target configuration. Two 2 x 2 repeated-measures ANOVAs were conducted, one on the RT data and the other on the error rates. The analysis on the RTs revealed a significant horizontal configuration benefit, $F(1, 16) = 27.19$, $MS_e = 560$, $p < .001$, $\eta_p^2 = 0.63$, with faster responses on the horizontal (628 ms) than vertical (658 ms) configuration trials. Both the main effect of object, $F(1, 16) = 3.78$, $MS_e = 273$, $p = .07$, $\eta_p^2 = 0.19$, and the configuration by object interaction, $F(1, 16) = 4.07$, $MS_e = 288$, $p = .06$, $\eta_p^2 = 0.20$, were marginally significant. Although the interaction between the configuration and object did not quite reach significance, we still carried out planned comparisons on the vertical and horizontal trials separately because it is important to know whether a same-object advantage could be found on the vertical trials as such a result was observed in Experiment 3A. The results indicated a significant same-object advantage (16 ms) on the vertical configuration trials, $t(16) = 2.63$, $p = .02$, $d = .63$, but not on the horizontal configuration trials, $t(16) = .10$, *ns*. No significant effects were found on the error rates, and there was no evidence of a speed-accuracy tradeoff.

Discussion

The most important result of Experiments 3A and 3B was the finding of an object effect on the vertical configuration trials in the more sessions. In these sessions, the targets were more likely to appear within the same object than between different objects. The expectation of a same-object configuration apparently produced an attentional set. This attentional set could not simply facilitate specific locations as in most cuing experiments, however, because there was no way to predict which rectangle was more likely to contain the targets. Perhaps the attentional set was based on the orientation of the rectangles, so that it could facilitate letter configurations regardless of their location. Such an attentional set would be useful because the orientation of the rectangles was the same as the orientation of the letter configuration on the majority of the trials. As shown in Experiment 2, a horizontal attentional set would incur a cost for vertically configured targets, but a vertical set did not impair the processing of horizontally configured targets. The same pattern of data was found in Experiments 3A and 3B, in which it appears as an object effect on the vertical configuration trials, but not on the horizontal configuration trials.

If we consider the differential reaction times in the two vertical configuration conditions in the more session of Experiment 3A and Experiment 3B as “object effects” (but see Experiments 4 – 6 below), then these results are inconsistent with Donovan *et al.*’s (2017) proposal that object representations can only guide attention in tandem with spatial selection, because there was no spatial selection prior to the onset of the targets in our experiments.

As in Experiments 1 and 2, the participants in Experiments 3A and 3B also showed a horizontal configuration benefit, and this effect was found in both the equal and the more session. The robust horizontal configuration benefit observed in the present study provided converging evidence to the horizontal advantage reported in prior research (Barnas & Greenberg, 2016; de-Wit *et al*., 2009; Hein *et al*., 2017; Sereno & Kosslyn, 1991).

Experiment 4

In Experiments 3A and 3B, an effect was found on the vertical configuration trials in the more session that we attributed to an attentional set cost when there was a horizontal attentional set that did not match the targets. If this orientation set was not associated with object-based attention, then we should find the same pattern of data without targets being presented on any objects so long as a horizontal target set could be established before the onset of vertically configured targets. Experiment 4 tested this hypothesis.

Although several researchers have proposed the idea that some effects in object-based attention experiments may reflect target orientation effects (Al-Janabi & Greenberg, 2016; Greenberg *et al*., 2014), this is the first empirical test of this idea. To exclude object-based attention as a potential explanation for the results in Experiment 4, we eliminated rectangles in the target display, and presented the targets without any background objects. (See Figure 6.) To induce participants to have an attentional set before the onset of the targets, we used a precue to indicate the orientation of the target configuration. The cue was a horizontal or vertical bar, and the orientation of the cue matched the orientation of the target configuration on 75% of the trials. Similar to Experiment 3A and 3B, the cue provided useful information about target configuration, but not the exact locations of the targets, because the targets were equally likely to appear at one of two sets of locations even when the cue was valid. If the pattern of data found in the more sessions of Experiments 3A and 3B was observed in Experiment 4, this would show that the effect found in these previous experiments was likely the result of an attentional set for orientation.

Insert Figure 6 about here

Method

The method was the same as that in Experiment 3B except for the following differences. All stimuli were presented against a gray background, and no rectangles were used in the experiment. The fixation was followed by a 500 ms blank screen, and then a 500 ms cue. The cue was a 13.4° x 0.7° elongated white bar presented at the center of the screen, and it was equally likely to be oriented horizontally or vertically. The orientation of the cue provided information about the orientation of the target configuration without cuing locations, just as the orientation of the two rectangles cued the target configuration orientation in the more sessions of Experiments 3A and 3B. The cue validity was 75%.

The experiment used a 2 x 2 within-subjects design, with the principal factors being target configuration (horizontal vs vertical) and cue-target orientation congruency (congruent vs incongruent). The experiment consisted of 4 blocks of 96 trials, and it took about 30 minutes to complete the experiment. Twenty new participants (mean age = 19.5, SD = 4.0; 4 male) took part in the study.

Results and Discussion

Two participants' data were excluded from analyses, one due to high error rates and the other due to high RTs. For the remaining participants, the mean RT data are shown in Figure 7 and the error rates in Table 4. A 2 x 2 repeated-measures ANOVA on the RT data showed a significant main effect of target configuration, $F(1, 17) = 31.20$, $MS_e = 203$, $p < .001$, $\eta_p^2 = 0.65$. Once again, participants showed a horizontal configuration benefit, with faster RT to respond to the targets when the target configuration was horizontal (566 ms) rather than vertical (585 ms). There was also a configuration by congruency interaction, $F(1, 17) = 16.34$, $MS_e = 201$, $p < .001$, $\eta_p^2 = 0.49$. A congruency effect was found on the vertical trials, but not on the horizontal ones. For vertically configured targets, the participants took significantly longer to respond when the cue was invalid (594 ms) compared with when it was valid (577 ms). However, for horizontally configured targets, reaction time was numerically slower when the cue was congruent (571 ms) than incongruent (561 ms), but this difference did not reach significance. No significant effects were found in the analysis of the error rates.

Insert Figure 7 and Table 4 about here

Although no rectangles were used in Experiment 4, the pattern of data was remarkably similar to the pattern of data found in the more sessions of Experiments 3A and 3B. In all of these experiments, responses were faster when the two letters to be compared were arranged horizontally rather than vertically. This experiment shows that the horizontal advantage is not tied to the rectangles that appeared in Experiments 1-3, and thus it is consistent with the conclusions of Harrison and Feldman (2009). They designed a clever stimulus arrangement that allowed them to manipulate the degree to which two locations were perceived as part of the same object, and found an advantage for horizontally arranged comparison stimuli regardless of the perceived objecthood.

This experiment, like the previous experiments, also showed increased response latencies on vertical target configuration trials when the orientation of the target configuration did not match the orientation of the attentional set. Given that object representations could not have played a role in the results of Experiment 4, it seems reasonable to attribute the cue congruency effect to the cost of employing a horizontal set with vertically configured targets. Although we cannot rule out the possibility that object-based attention contributed to some extent to the observed effects in Experiments 3A and 3B, in light of the findings in Experiment 4, a more parsimonious account would be to explain the results in terms of an orientation set cost, which incurs when there is a horizontal attentional set that does not match the targets.

Experiment 5

In Experiment 4, the cue was an oriented bar having approximately the same span as the spatial separation between the targets. Given its size, information value, and clear orientation, the cue should facilitate the generation of a directional attentional set in accordance with the orientation of the cue before the onset of the targets. The same could be said of Experiments 3A and 3B, in which the pattern display that preceded the targets consisted of a pair of large, oriented rectangles. If having a horizontal attentional set was a critical factor in the manifestation of the attentional set costs found in the vertical target configuration trials, a similar cost may not be found when the cue is not conducive to the generation of a horizontal attentional set. Experiment 5 tested this hypothesis.

Method

The method was the same as that in Experiment 4 except that the cue was a letter instead of an oriented bar and the cue was shown for 1,000 ms. We increased the duration of the cue from 500 ms in Experiment 4 to 1,000 ms in Experiment 5 to give participants sufficient time to interpret the cue. The cue was shown at the center of the screen, and it was equally likely to be an H (for horizontal) or a V (for vertical) written in bold, 40-point Arial font. As before, the cue validity was 75%. Twenty new participants (mean age = 19.5, SD = 2.9; 4 male) took part in the experiment.

Results and Discussion

Figure 8 shows the mean RT data and Table 4 shows the error rates. A 2 x 2 repeated-measures ANOVA on the RT data again revealed a significant horizontal configuration benefit, $F(1, 19) = 8.63$, $MS_e = 525$, $p = .01$, $\eta_p^2 = 0.31$, with faster RT on the horizontal trials (652 ms) than on the vertical trials (667 ms). No other effects were reliable. No significant results were found in the analysis of the accuracy data.

Insert Figure 8 about here

In Experiment 4, we used a direct image cue consisting of an oriented bar, and a cue congruency effect was found on the vertical configuration trials. In Experiment 5, we used a symbolic letter cue, but no congruency effect was found on either the horizontal or vertical trials. Because two groups of participants were used in Experiments 4 and 5, it was possible that the participants in these experiments deployed different response strategies, which in turn affected the effect of the cue as a function of target configuration. To minimize possible effects of response strategies, we mixed the two types of cues within the same block in Experiment 6. The goal was to test whether the participants would show a cue congruency effect in vertical trials only when the cue was an image.

Experiment 6

Method

Experiment 6 was the same as Experiment 5 except for the following differences. The cue was equally likely to be an image (a horizontal or vertical bar) or a letter (the letter H or V). Regardless of the type of cue, the duration of the cue was 1,000 ms, and the number of trials in each cue type was the same. As before, the cue validity was 75%, and the targets were horizontally configured on half of the trials and vertically configured on the rest of the trials. Thus, the experiment used a 2 x 2 x 2 within-subjects design, with cue type (image vs letter), target configuration (horizontal vs vertical), and cue-target orientation congruency (congruent vs incongruent) as the principal variables. All types of the trials were randomly presented within a block. The experiment consisted of 512 trials divided into 4 blocks. Twenty new participants (mean age = 19.0, SD = 1.4; 3 male) took part in the experiment.

Results and Discussion

The mean RT results are shown in Figures 9A and 9B, and the error rates are shown in Table 4. Two 2 x 2 x 2 repeated-measures ANOVAs were conducted. The analysis on the error rates revealed no significant effects. The analysis on the RTs again showed a significant horizontal configuration benefit, $F(1, 19) = 25.75$, $MS_e = 549$, $p < .001$, $\eta_p^2 = 0.58$, with faster responses on horizontal (621 ms) than vertical (640 ms) configuration trials. In addition, there was a main effect of congruency, $F(1, 19) = 4.52$, $MS_e = 265$, $p = .047$, $\eta_p^2 = 0.19$, indicating faster responses when the orientation of the cue matched the orientation of the target configuration (628 ms) compared with when the two did not match (633 ms). Cue type also interacted with target configuration, $F(1, 19) = 13.34$, $MS_e = 195$, $p = .002$, $\eta_p^2 = 0.41$. The horizontal configuration benefit was larger when the cue was an image (27 ms) compared with a letter (11 ms), although both effects were significant. Finally, there was a 3-way interaction of cue type, target configuration, and congruency, $F(1, 19) = 5.51$, $MS_e = 470$, $p = .03$, $\eta_p^2 = 0.22$.

Insert Figures 9A and 9B about here

To clarify the 3-way interaction, we conducted two 2 x 2 repeated-measures ANOVAs on RTs, one on the image cue trials, and the other on the letter cue trials. On the image cue trials, in addition to the main effects of horizontal configuration benefit, $F(1, 19) = 39.07$, $MS_e = 370$, $p < .001$, $\eta_p^2 = 0.67$, and congruency, $F(1, 19) = 8.69$, $MS_e = 224$, $p = .01$, $\eta_p^2 = 0.31$, there was a significant interaction between the two, $F(1, 19) = 6.26$, $MS_e = 404$, $p = .02$, $\eta_p^2 = 0.25$. A significant congruency effect was found on the vertical configuration trials (12 ms), but not on the horizontal configuration trials (-2 ms). These results replicated the findings in Experiment 4.

In contrast to the above results, the analysis on the verbal cue trials revealed only one significant effect, which was the horizontal configuration benefit, $F(1, 19) = 6.14$, $MS_e = 375$, $p = .02$, $\eta_p^2 = 0.24$. These results replicated the findings of Experiment 5.

The results of Experiment 6 were very similar to the results found in Experiments 4 and 5. Because the two types of cue trials were randomly mixed within a block, Experiment 6 ruled out the possibility that the different pattern of results found in Experiments 4 and 5 was caused by different response strategies between the participant groups. Taken together, these experiments show that an attentional set for configuration orientation was more readily induced by stimulus-driven, bottom-up processes than by knowledge-driven, top-down processes.

General Discussion

Two consistent patterns emerge from this series of experiments. First, every experiment demonstrates better performance in comparing two stimuli when they are arranged horizontally rather than vertically. Second, when the two stimuli are arranged vertically, performance is generally worse if an oriented stimulus cued participants to expect a horizontal configuration. Both of these effects appear as a performance cost in comparing vertically arranged stimulus pairs, and both effects might at first appear to be consequences of object-based attention, although Experiments 4-6 show that they are not. Despite the similarities between the two effects, there are important differences, and we will consider them separately.

Horizontal Advantage

Regardless of expectations generated by precues, the two letters were compared more quickly if they were arranged horizontally. Experiments 4-6 show that this horizontal advantage occurs even when the items to be compared do not appear within object boundaries, demonstrating that it is not a consequence of object-based attention. Nonetheless, this horizontal advantage is an important factor to consider in many experiments testing object-based attention, and it can easily be mistaken for an object-based effect in some cases.

Before we discuss the horizontal advantage further, it is worth considering whether this effect might be caused by the specific stimuli used in the present study. In all the 6 experiments, the targets were letters. As English speakers read horizontally, is it possible that the horizontal benefit was exclusive for letter stimuli?[8] Although we cannot exclude this possibility, especially in those experiments in which the targets were presented simultaneously, two pieces of evidence suggest that the possibility is very small.

First, we examined the data from Experiment 2, in which the targets were shown sequentially, and found no evidence that the pattern of data differed between the trials in which the letters were presented from left to right and the trials in which the letters were presented from right to left.[9] The participants showed a marginally significant position effect (p = .056), with faster responses when the letters were presented from left to right (472 ms) rather than from right to left (480 ms), and a significant horizontal benefit (470 ms and 483 ms for horizontal and vertical configured trials, respectively). However, the two factors did not interact ($F < 1$), indicating that the horizontal benefit does not arise from the habit of reading left-to-right.

Second, the horizontal benefit has also been reported in previous studies that used non-letter stimuli as the targets. In several studies reported by Davis and colleagues (Davis, 2001; Davie & Holmes, 2005; Davis, Welch, Holmes, & Shepherd, 2001), participants compared notch-like shapes arranged either horizontally or vertically. Among other findings, the result most relevant here is the finding of the horizontal benefit. In light of these results, it is unlikely that the horizontal benefit is an effect exclusive for letter stimuli.

The horizontal advantage in these experiments might arise from the boundaries that separate different cortical visual areas. In the horizontal arrangements in these experiments, the two stimuli to be compared are on opposite sides of the vertical midline, and thus in the early stages of cortical processing, each will be represented in a separate hemisphere. Sereno and Kosslyn (1991) found faster comparisons of stimuli when they were on opposite sides of the vertical midline, and suggested that the two stimuli might compete more for resources when they were both represented within the same hemisphere. When the representation for each stimulus can be constructed in a separate hemisphere, there may be more neurons available to represent each stimulus, and there will probably be fewer connections between the neural groups activated by the two stimuli, which may make it easier to create two distinct representations without interference between them. Thus, the horizontal advantage may arise from representational issues that are not directly the result of the allocation of attention.

Barnas and Greenberg (2016) offered a somewhat different explanation, attributing the horizontal advantage to a cost in shifting attention across the horizontal midline. They tested their claim with a spatial cuing experiment in which both the cue and the test stimulus were in the same quadrant of the visual field, so that the two locations were not separated by the horizontal or vertical midline. Response times were still numerically faster with a horizontal arrangement than with a vertical arrangement in this experiment, but the horizontal advantage was only statistically significant for one of the two spatial arrangements that they used. Thus, although they concluded that shifts across the horizontal midline were responsible for horizontal advantage, their data suggest that there may still be a horizontal advantage when a midline is not crossed.

A different explanation has been offered by Davis and Holmes (2005) and by Harrison and Feldman (2009), who point out the possibility that the comparison task might be accomplished by symmetry detection. Given that symmetry is more easily detected across the vertical midline, such a comparison strategy would be easier if the two targets to be compared are positioned on corresponding locations on either side of the vertical midline, as they are in the horizontal condition of these experiments and many others. Saiki (2000) demonstrated the importance of symmetry in another comparison task that did not use the parallel rectangles used here. Hein *et al*. (2017) found that same-object advantage in their cuing experiments could be enhanced if the two objects differed from one another in color or shape.

They concluded that these featural differences strengthened the representation of the two forms as separate objects, but it is also conceivable that these differences might affect the perception of horizontal and vertical symmetry. One important area for future research is to determine the role of symmetry detection in comparison tasks such as these.

As noted in the introduction, some of the cuing experiments that have used Egly *et al.*'s (1994) parallel rectangles have also shown a horizontal advantage, while others have not. More work is necessary to understand the horizontal advantage in tasks with a single cued location and a single target location. One possible area of research is to measure whether the horizontal advantage in these tasks is associated with the presence of distractors that are easily confusable with the target. Adding such distractors makes the task more similar to the comparison task used here, and it might help to explain why the horizontal advantage arises in some cuing tasks.

Although the horizontal advantage tends to appear in experiments in which two target objects must be compared, it did not arise in Donovan *et al.'s* (2017) experiments. Responses in these experiments depended on two target objects, but the task was not a shape comparison, but a temporal order judgment. It seems plausible that the symmetry detection that could aid in shape comparison would not facilitate temporal order judgment, and thus the lack of a horizontal advantage in Donovan *et al.'s* experiments is generally consistent with the symmetry account.

Attentional Set Cost when Expecting Horizontal

A second effect also emerges consistently from these results. Responses were slower when subjects were cued to expect a horizontal arrangement of the two stimuli but then viewed a vertical arrangement. As with the horizontal benefit, this set cost appeared whether or not the two stimuli appeared within enclosing rectangles, indicating that it is also not a consequence of object-based attention. This effect occurs in a more limited set of circumstances than the horizontal benefit. It does not arise in *all* instances in which the stimulus configuration differs from the cued configuration; if the two stimuli are arranged horizontally, then the cued orientation doesn't affect the response time. Perhaps the horizontally-arranged stimuli are compared so quickly that the attentional set does not matter. The vertically-arranged stimuli take longer to compare, but part of that extra time can be eliminated by the correct attentional set.

Experiment 6 suggests that subjects are not intentionally interpreting the cue and constructing a corresponding orientation set. Instead, the orientation set arises more automatically when subjects view one or two oriented rectangles before the comparison stimuli appear. Viewing a horizontal rectangle might create an attentional set that makes it more difficult to compare two stimuli oriented vertically. However, if the orientation set is entirely stimulus driven, we might expect to see its effects in the equal condition of Experiment 3A, in which the two oriented rectangles appear, but the two targets are equally likely to be within the same or different objects. The difference between Experiments 3A and 3B suggests that intention may play some role in establishing the orientation set.

One question to consider is whether the effects in Donovan *et al.'s* (2017) experiments could be explained by orientation set rather than by object-based attention. Their effect seems different from the effect shown here, because it arises with both horizontally and vertically oriented target configurations, while the orientation set effect in the current experiment only arises with vertically oriented targets. If the orientation set occurs for both horizontal and vertical cues, but its effects are obscured by the horizontal advantage in the current experiments or are influenced by some other factors such as the extent of attentional zoom (see discussion in the next section), then we might expect to see orientation set effects with both horizontal and vertical target arrangements in Donovan *et al.'s* temporal order judgment task, which produces no horizontal advantage.

Implications for Studies of Object-Based Attention and Visual Comparison

There are two important implications that arise from these results. First, when interpreting results from the many experiments that use stimuli and procedures similar to Egly *et al*.'s (1994), the results from horizontally oriented and vertically oriented rectangles must be considered separately. If the response times from these experiments had simply been averaged across horizontal and vertical orientations, the results would look like object-based attention, but these experiments show that the results are linked to the stimulus configuration and to the orientation set created by viewing rectangles oriented one way or the other. Furthermore, Experiments 4-6 show that these effects are not due to object-based attention, because they arise even when the comparison stimuli do not appear within object boundaries.

The second implication is that there are factors that exert strong and consistent effects on visual comparison that are not well understood. It may be that comparisons are easier when each item to be compared can be processed within a separate hemisphere, or perhaps some comparisons are done by detecting symmetry. The mode of comparison is shaped to some extent by an attentional set triggered automatically by earlier stimuli. These comparison processes need to be understood more fully, and the methods used here could be useful tools in those investigations.

The Possible Role of Attentional Zoom

It is worth noting that although we used Egly *et al*.'s (1994) two-rectangle displays in several of our experiments, the two studies differed in their tasks, and with that, the demand required by the tasks. This raises the question whether the asymmetry in attentional set cost observed in our study appears only in visual-comparison tasks similar to the one that we used in our experiments. If so, what are the features of these tasks that produce the asymmetry? In our study, the orientation cue (i.e., rectangles in Experiments 3A and 3B, and an oriented bar in Experiments 4 and 6) was predictive of the orientation but not the location of the target configuration. As the targets were equally likely to appear at one of two sets of locations, a good strategy would be to adopt a broad attentional zoom with an appropriate attentional set for the specific configuration orientation independently of location.

Two lines of evidence are consistent with the notion that an oriented distribution of attention with a broad zoom may be an important factor in the manifestation of an asymmetry in attentional set cost. In several recent experiments conducted in our lab (Chen, Humphries, & Cave, 2019), we used a precue predictive of both the orientation and location of the target configuration, and the task was to compare whether two target letters were the same. A reliable horizontal benefit was found. In addition, the cue enhanced performance for both horizontal and vertical configuration trials. Thus, when a precue predicts target locations so that attention can be allocated directly to the locations of the targets without an orientation set, there is no asymmetry in the orientation set cost.

A similar explanation can be applied to the studies that use Egly *et al*.'s (1994) spatial cuing paradigm, with stimuli presented either on rectangles (Drummond & Shomstein, 2010; Moore *et al*., 1998) or on boomerang type objects (Barnas & Greenberg, 2016). In these studies, an informative spatial cue preceded the onset of the target, which would then appear at the cued location on the majority of the trials, or at one of two uncued locations on the rest of the trials. As the onset of the cue would attract spatial attention to the cued location, there was no reason to establish an orientation set independently of location, or to use a broad attentional zoom. No asymmetry in the orientation set cost was found in these studies. This result is largely consistent with the notion that the manifestation of an asymmetry in attentional set cost may require a location-independent orientation set with a broad attentional zoom.

Conclusions

These experiments show that it is possible to adopt an attentional set for orientation that is not mediated by either spatial attention or object-based attention. This orientation set is unusual in that its use varies between horizontal and vertical orientation cues. Also, these experiments clearly demonstrate a very consistent horizontal benefit in visual comparison that cannot be produced by object selection.

Together these two effects can explain results from earlier experiments that were previously explained by object-based attention.

There are a couple of theoretical options for explaining the horizontal benefit: symmetry detection may be contributing to object comparison, or it may reflect differences between interhemispheric and intrahemispheric cortical connections. While these results suggest a smaller role for theories of object-based attention, they also suggest a greater role for attentional set: theories of attentional selection need to include a mechanism for selecting a particular orientation of stimulus configuration without selecting a specific location.

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Notes:

1. Davis and colleagues (Davis, 2001; Davie & Holmes, 2005; Davis, Welch, Holmes, & Shepherd, 2001) used a similar comparison procedure with concave-shaped objects.
2. Even though we used a 2 x 2 x 2 repeated-measures design, to be conservative when calculating the power for the interaction between orientation and object, for the number of measurements, we entered the value "4" instead of "8", as our main interest was the interaction between rectangle orientation and object. For α = .05 and 80% power, the recommended sample size was 11 for 4 measurements, 7 for 8 measurements.
3. The proportion of data excluded was 3.5% in Experiment 2, 3.8% in Experiment 3A, 4.0% in Experiment 3B, 3.3% in Experiment 4, 3.8% in Experiment 5, and 3.3% in Experiment 6. The average error rate for each experiment after the application of the data exclusion criteria is 7.5% in Experiment 1, 6.7% in Experiment 2, 6.1% in Experiment 3A, 7.1% in Experiment 3B, 6.7% in Experiment 4, 8.0% in Experiment 5, and 6.7% in Experiment 6.
4. In all the experiments, the RTs shown are from the time when both targets appeared on the screen; i.e., from the onset of the 2nd target if the targets were presented sequentially.
5. It is unclear what role the horizontal configuration benefit played in the observed object effects in the two sequential presentation conditions in Lamy and Egeth (2002) because the data were not broken down into trials of different orientations.

6. The longer SOA between the two targets in Experiment 2 compared with that in Experiment 1 necessarily made the overall target display duration longer in Experiment 2 (220 ms or 320 ms depending on the SOA) than in the sequential condition of Experiment 1 (170 ms). Although we cannot exclude the possibility that the longer display duration played a role in the observed object effect in Experiment 2, it is unlikely that this was the main reason that the object effect was found. In previous research, object effects have been found in many studies that use presentation duration shorter than or up to 120 ms (e.g., Chen, 1998; Chen & Cave, 2008; Duncan, 1984; Harms & Bundesen, 1983; Kramer & Watson, 1996; Macquistan, 1997; Watson & Kramer, 1999), and there was no evidence that relatively short or long target display time affects object-based attention in a qualitative way (Chen, 1998). In light of these previous findings, it seems more plausible that the key factor in the different results between Experiments 1 and 2 in the present study was the difference in the interval duration between the onset of the 1st target before that of the 2nd target rather than the overall target display duration.
7. We had planned to use 40 participants in case the effect of object interacted with the effect of session order (the equal session 1st vs. the more session 1st). Unfortunately, we ended up with fewer participants due to “no-shows” and difficulty in recruiting new participants as the experiment was conducted around the end of a semester. No interactions involving both object and order were found in RTs. In accuracy, there was a 3-way interaction of proportion, object, and order, $F(1, 29) = 4.41$, $MS_e = 9$, $p = .04$, $\eta_p^2 = 0.13$. To clarify the interaction, we conducted two separate analyses, one on the equal-first data, and the other on the more-first data. For the participants in the equal-first

group, no significant effects were found. For the participants in the more-first group, the only significant effect was the interaction between proportion and object, $F(1, 14) = 6.51$, $MS_e = 6$, $p = .02$, $\eta_p^2 = 0.32$. There was a slight reduction in error rates in the different-object condition (4.6%) compared with the same-object condition (5.3%) in the equal session, but a slight increase in error rates in the different-object condition (6.5%) relative to the same-object donation (5.1%) in the more session. However, neither effect was significant, $p > .13$ in both cases.

8. We thank an anonymous reviewer for raising this possibility.
9. To determine whether the pattern of data would differ between the trials in which the letters were presented from left to right and the trials in which the letters were presented from right to left, we conducted a 2 x 2 x 2 repeated-measures ANOVA on the mean RTs. The three factors were position (left-to-right vs right-to-left), target configuration (horizontal vs vertical), and object (same vs different). The two SOAs were collapsed in these analyses as there were no significant interactions involving SOA in the previous analyses. This allowed us to have a decent number of trials per condition. The results on the RTs showed faster responses when the target configuration was horizontal (470 ms) rather than vertical (483 ms), indicating a horizontal benefit, $F(1, 18) = 16.61$, $MS_e = 322$, $p < .001$, $\eta_p^2 = 0.48$. Target configuration interacted with object, $F(1, 18) = 4.79$, $MS_e = 284$, $p = .04$, $\eta_p^2 = 0.21$, indicating a difference in response latencies between the same and different object conditions on the vertical configuration trials (10 ms) compared with the horizontal configuration trials (-1 ms). There was also a marginally significant position effect, $F(1, 18) = 4.19$, $MS_e = 584$, $p = .056$, $\eta_p^2 = 0.19$, indicating faster responses when the

letters were presented from left to right (472 ms) than from right to left (480 ms). Importantly, this position effect did not interact with target configuration, $F(1, 18) < 1$. No other effects reached significance. A similar analysis was performed on the error rates. Two marginally significant effects were found: one was the main effect of target configuration, $F(1, 18) = 4.34$, $MS_e = 13$, $p = .05$, $\eta_p^2 = 0.19$, and the other a two-way interaction between target configuration and object, $F(1, 18) = 3.79$, $MS_e = 7$, $p = .07$, $\eta_p^2 = 0.17$. There was no indication of speed-accuracy tradeoffs.

Table 1

Mean error rates (percent incorrect) as a function of presentation, rectangle or target configuration orientation, and object in Experiment 1. Within-subject standard errors are in the parentheses. Note that when the data are organized by rectangle orientation, the effect of object is confounded with the effect of target configuration.

	Rectangle Orientation			
Presentation	Horizontal		Vertical	
	Same	Different	Same	Different
Simultaneous	6.5 (0.9)	10.1 (1.1)	7.6 (0.9)	6.2 (0.8)
Sequential	6.8 (0.6)	8.6 (0.7)	8.5 (1.1)	5.7 (0.8)
	Orientation of Target Configuration			
Presentation	Horizontal		Vertical	
	Same	Different	Same	Different
Simultaneous	6.5 (0.9)	6.2 (0.8)	7.6 (0.9)	10.1 (1.1)
Sequential	6.8 (0.6)	5.7 (0.8)	8.5 (1.1)	8.6 (0.7)

Table 2

Mean error rates (percent incorrect) as a function of the stimulus-onset-asynchrony (SOA) between the targets, the orientation of the target configuration, and object in Experiment 2. Within-subject Standard errors are in the parentheses.

SOA	Horizontal Configuration		Vertical Configuration	
	Same	Different	Same	Different
100 ms	7.3 (0.8)	6.2 (0.6)	6.8 (0.6)	8.0 (0.5)
200 ms	5.6 (0.5)	5.2 (0.6)	6.8 (0.6)	7.5 (0.7)

Table 3

Mean error rates (percent incorrect) as a function of the proportion of same-object trials, the orientation of the target configuration, and object in Experiments 3A and 3B. Standard errors are in the parentheses.

Presentation	Horizontal Configuration		Vertical Configuration	
	Same	Different	Same	Different
		Experiment 3A		
Equal	5.6 (0.5)	5.5 (0.6)	6.8 (0.5)	6.9 (0.7)
More	5.6 (0.4)	5.5 (0.8)	5.9 (0.5)	7.1 (0.7)
		Experiment 3B		
More	6.4 (0.5)	6.6 (0.5)	7.0 (0.5)	8.4 (0.6)

Table 4

Mean error rates (percent incorrect) as a function of the orientation of the target configuration and the cue-target congruency in Experiments 4 to 6. Standard errors are in the parentheses.

Cue Type	Horizontal Configuration		Vertical Configuration	
	Congruent	Incongruent	Congruent	Incongruent
		Experiment 4		
Image	6.7 (0.7)	5.8 (0.6)	7.5 (0.5)	6.7 (0.8)
		Experiment 5		
Letter	8.1 (0.6)	6.5 (0.6)	8.5 (0.5)	8.9 (0.8)
		Experiment 6		
Image	6.0 (0.4)	5.2 (1.0)	6.2 (0.5)	8.5 (1.1)
Letter	6.2 (0.5)	6.9 (1.1)	7.4 (0.7)	7.0 (1.0)

Figure Captions

Figure 1. Examples of trials from Experiment 1. On each trial, participants saw two horizontal or vertical rectangles followed by two target letters that were either horizontally or vertically aligned. In the same object condition, the targets were within the same rectangle, and the orientation of the target configuration matched that of the rectangles. In the different object condition, the targets were in two different rectangles, and the orientation of the letter configuration differed from that of the rectangles. HRect = horizontal rectangles; VRect = vertical rectangles; HLetter = horizontal letter/target configuration; VLetter = vertical letter/target configuration; Same object = targets in the same object; Different object = targets in different objects.

Figures 2A and 2B. Mean reaction time results from Experiment 1, with the data organized by rectangle orientation. (A) The simultaneous session, in which the targets were presented at the same time. (B) The sequential session, in which one target was shown 50 ms before the onset of the other target. The error bars show the within-subjects standard error of the mean.

Figures 3A and 3B. Mean reaction time results from Experiment 1, with the data organized by the orientation of the target configuration. (A) The simultaneous session. (B) The sequential session. The error bars show the within-subjects standard error of the mean.

Figures 4A and 4B. Mean reaction time results from Experiment 2. (A) The 100 ms SOA condition. (B) The 200 ms SOA condition. The error bars show the within-subjects standard error of the mean.

Figures 5A to 5C. Mean reaction time results from Experiments 3A and 3B. (A) The equal condition in Experiment 3A. (B) The more condition in Experiment 3A. (C) Experiment 3B. The error bars show the within-subjects standard error of the mean.

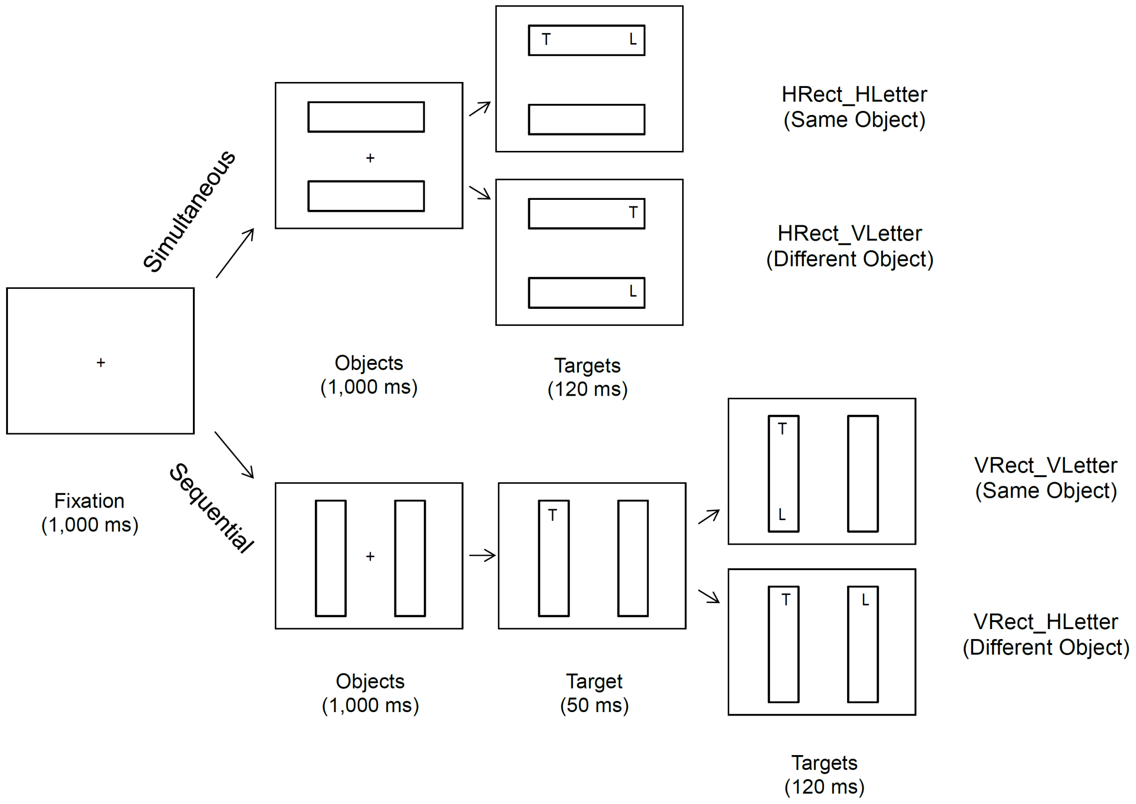
Figure 6. Examples of trials from Experiment 4. On each trial, participants saw a horizontal or vertical cue followed by two target letters that were either horizontally or vertically aligned. In the congruent condition, the orientation of the cue matched the orientation of the target configuration. In the incongruent condition, the two mismatched. Each condition is denoted by two words, with the first word referring to the orientation of the target configuration and the second word referring to the cue-target congruency.

Figure 7. Mean reaction time results from Experiment 4. The error bars show the within-subjects standard error of the mean.

Figure 8. Mean reaction time results from Experiment 5. The error bars show the within-subjects standard error of the mean. The letter above each bar indicates the cue for that condition.

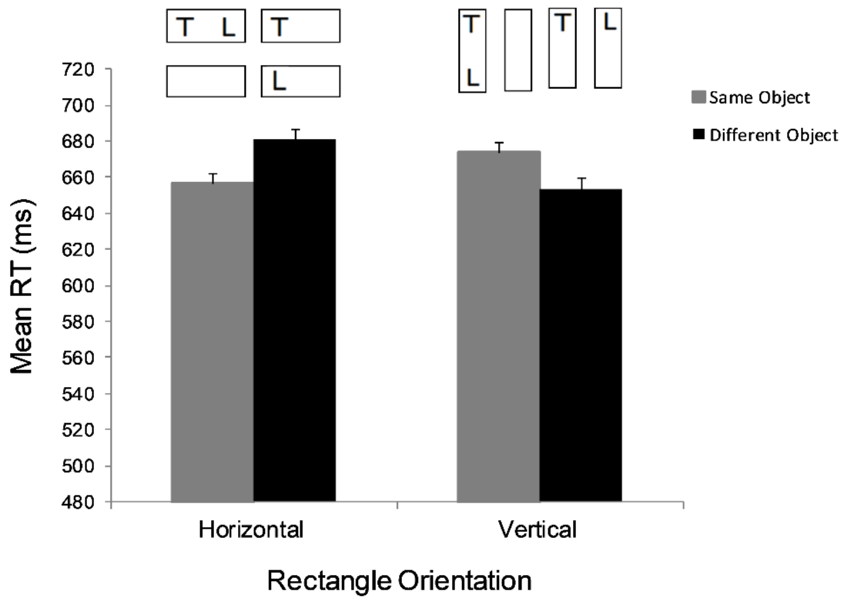
Figure 9. Mean reaction time results from Experiment 6. (A) The image condition. (B) The letter condition. The error bars show the within-subjects standard error of the mean.

Figure 1


HRect_HLetter
(Same Object)
HRect_VLetter
(Different Object)
Simultaneous
Sequential
Fixation
(1,000 ms)
Objects
(1,000 ms)
Targets
(120 ms)
VRect_VLetter
(Same Object)
VRect_HLetter
(Different Object)
Objects
(1,000 ms)
Target
(50 ms)
Targets
(120 ms)

Figures 2A and 2B

(A)



(B)

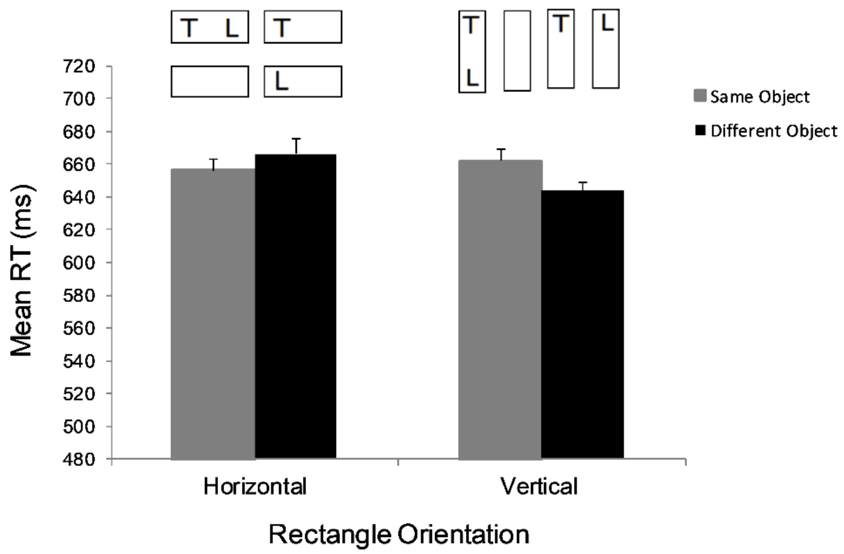
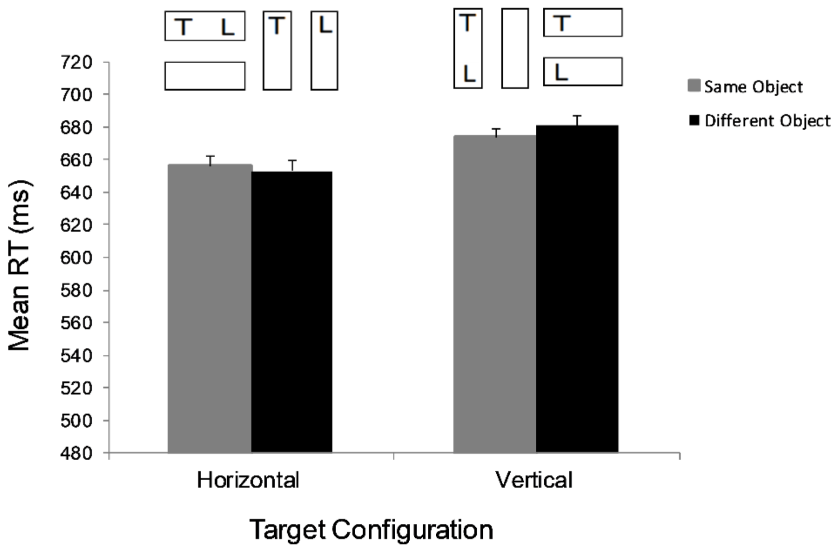
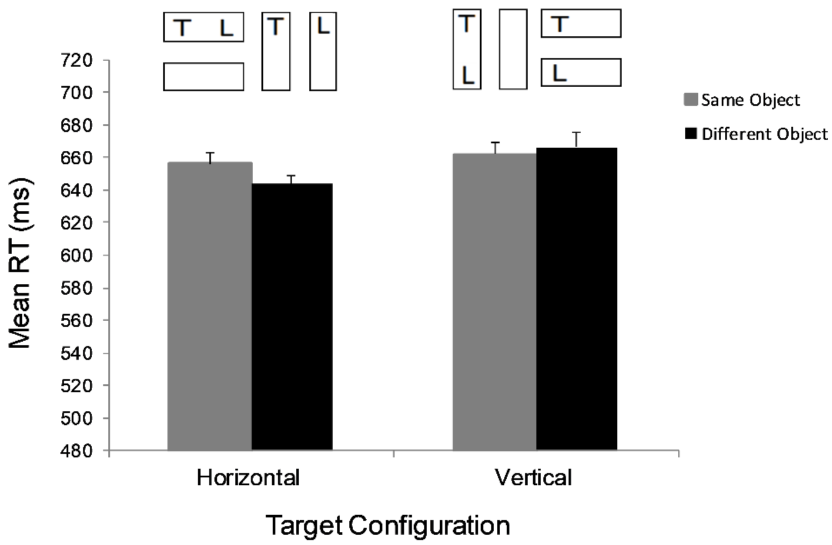


Figure 3A and 3B

(A)

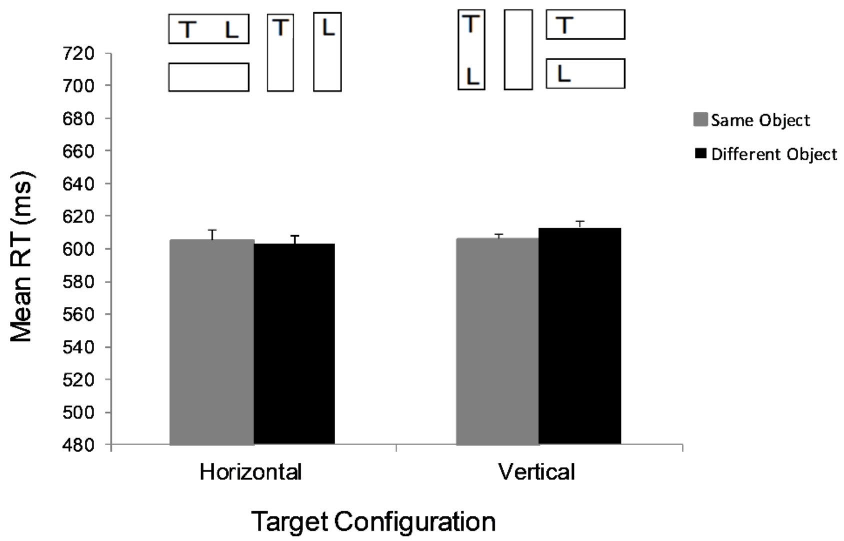


(B)

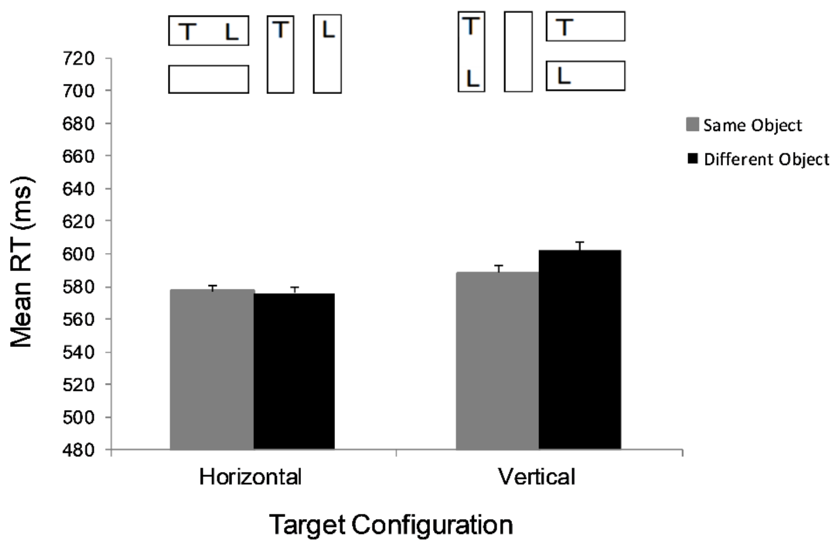


Figures 4A and 4B

(A)

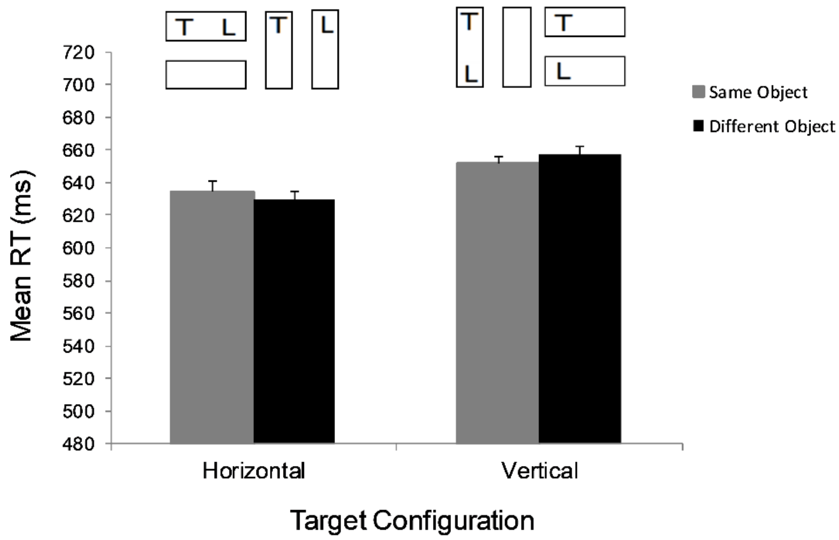


(B)

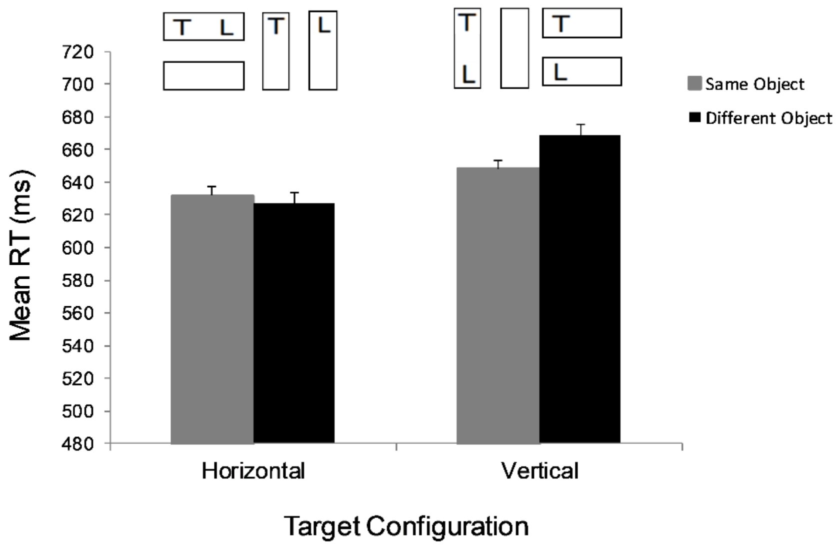


Figures 5A, 5B, and 5C

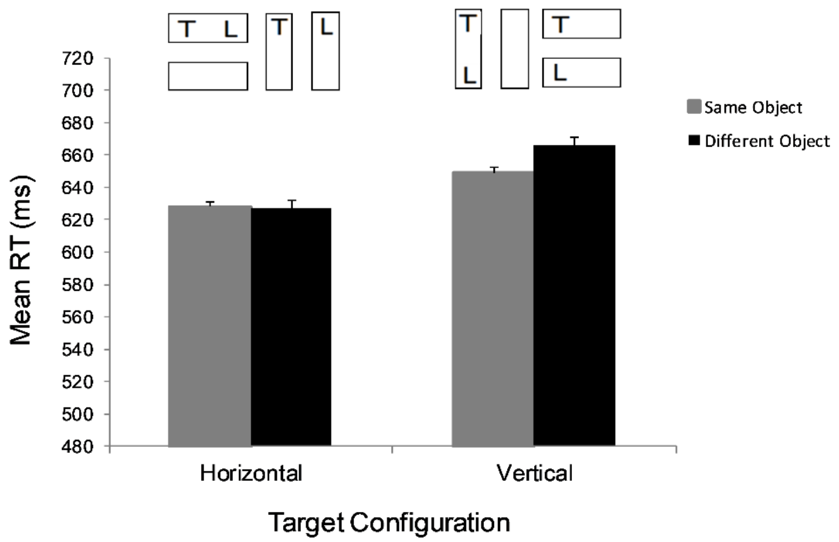
(A)



(B)



(C)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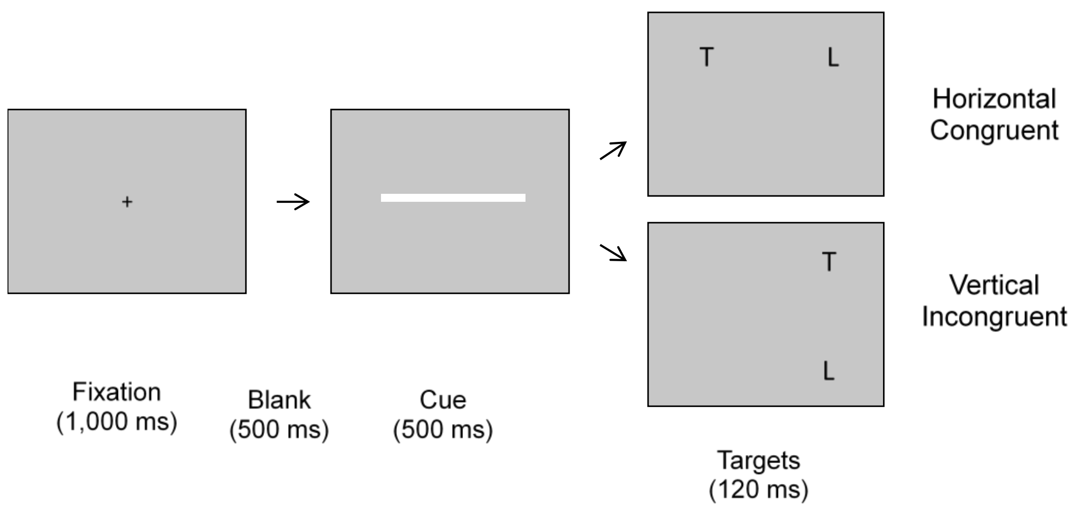
Mean RT (ms)
Same Object
Different Object
Horizontal
Vertical
Target Configuration

Figure 6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Horizontal
Congruent
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L
Vertical
Incongruent
Fixation
(1,000 ms)
Blank
(500 ms)
Cue
(500 ms)
Targets
(120 ms)

Figure 7

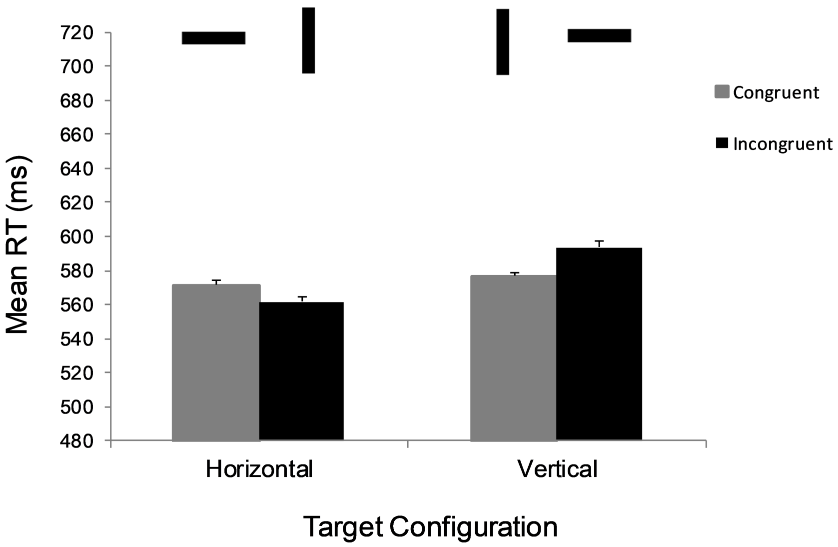
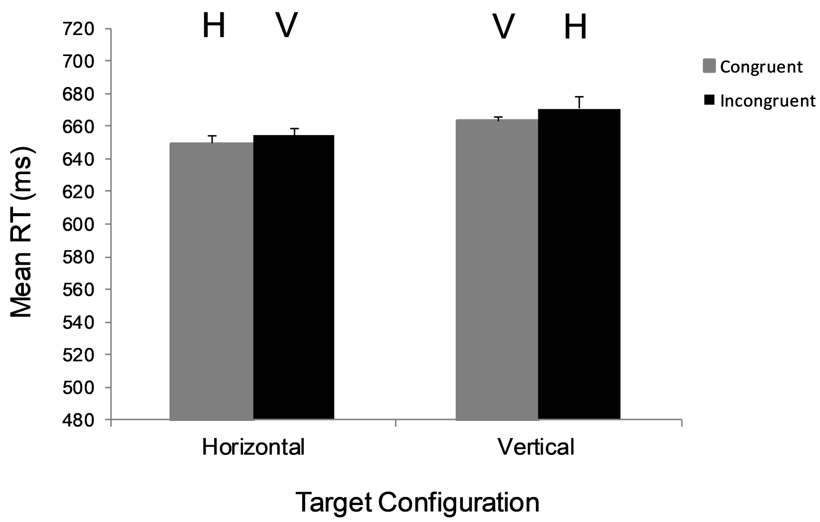
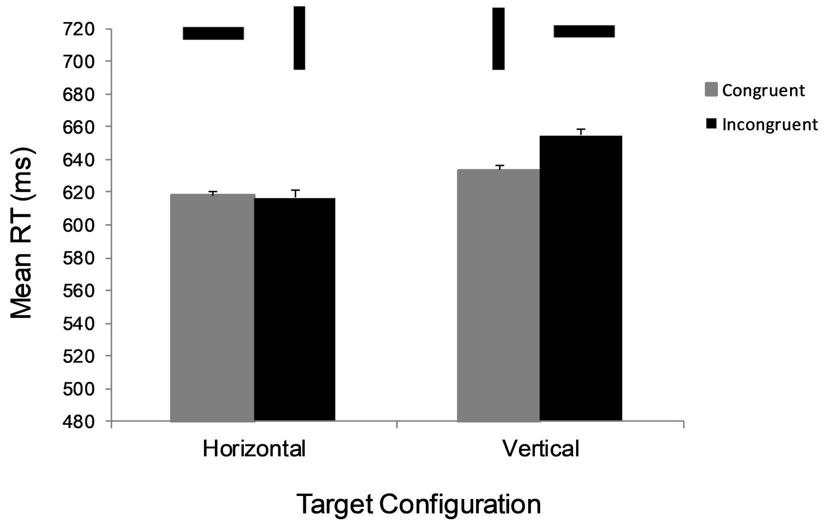


Figure 8

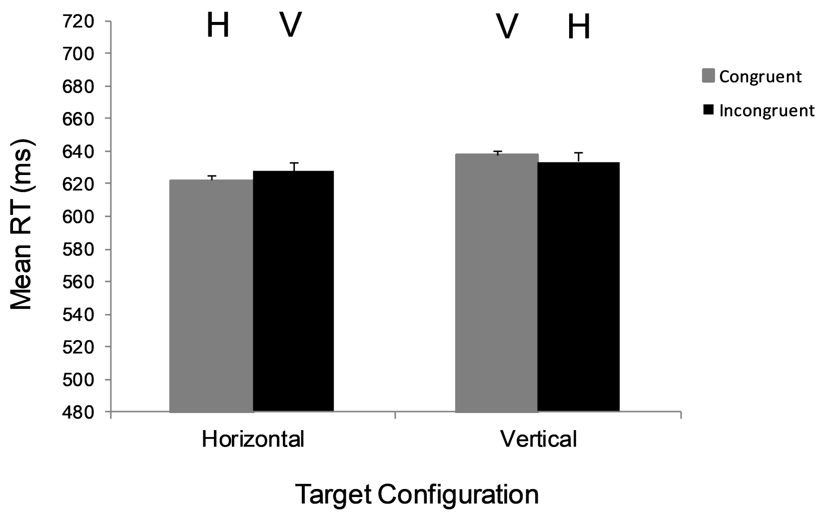


Figures 9A and 9B

(A)



(B)



Appendix

Table 5

Results of ANOVAs on the reaction times and error rates in Experiment 1 as a function of target presentation, rectangle orientation, and object.

	Reaction Times			Error Rates		
	F (1, 18)	p	η_p^2	F (1, 18)	p	η_p^2
Pres	.96	.341	.05	.11	.747	<.01
RectOri	4.90	.040	.21	1.13	.302	.06
Obj	.05	.818	<.01	.32	.578	.02
Pres*RectOri	.16	.692	<.01	.64	.435	.03
Pres*Obj	.58	.456	.03	1.44	.246	.07
RectOri*Obj	15.57	<.001	.46	10.94	.004	.38
Pres*RectOri*Obj	2.18	.157	.11	.03	.861	<.01

Note: Pres = Presentation; RectOri = Rectangle Orientation; Obj = Object

Table 6

Results of ANOVAs on the reaction times and error rates in Experiment 1 as a function of target presentation, target configuration, and object.

	Reaction Times			Error Rates		
	F (1, 18)	*p*	η_p^2	*F* (1, 18)	*p*	η_p^2
Pres	.96	.341	.05	.11	.747	<.01
TarConf	15.57	<.001	.46	10.94	.004	.38
Obj	.05	.818	<.01	.32	.578	.02
Pres*TarConf	2.18	.157	.11	.03	.861	<.01
Pres*Obj	.58	.456	.03	1.44	.246	.07
TarConf*Obj	4.90	.040	.21	1.13	.302	.06
Pres*TarConf*Obj	.16	.692	<.01	.64	.435	.03

Note: Pres = Presentation; TarCong = Target Configuration; Obj = Object

Table 7

Results of ANOVAs on the reaction times and error rates in Experiment 2 as a function of SOA, target configuration, and object.

	Reaction Times			Error Rates		
	F (1, 18)	*p*	η_p^2	*F* (1, 18)	*p*	η_p^2
SOA	22.58	<.001	.56	2.23	.153	.11
TarConf	16.75	<.001	.48	4.39	.050	.20
Obj	2.12	.163	.11	.11	.737	<.01
SOA*TarConf	3.72	.070	.17	2.12	.163	.11
SOA*Obj	.21	.652	.01	.01	.910	<.01
TarConf*Obj	4.68	.044	.21	3.73	.069	.17
SOA*TarConf*Obj	.11	.744	<.01	.35	.560	.02

Note: TarCong = Target Configuration; Obj = Object

Table 8

A. *Results of ANOVAs on the reaction times and error rates in Experiment 3A as a function of the proportion of same-object trials, target configuration, and object.*

	Reaction Times			Error Rates		
	F (1, 30)	*p*	η_p^2	*F* (1, 30)	*p*	η_p^2
Prop	.01	.919	<.01	.17	.681	<.01
TarConf	39.14	<.001	.57	5.41	.027	.15
Obj	2.37	.134	.07	.38	.541	.01
Prop*TarConf	1.44	.239	.05	.26	.613	<.01
Prop*Obj	1.84	.189	.06	.51	.481	.02
TarConf*Obj	7.32	.011	.20	.74	.395	.02
Prop*TarConf*Obj	2.62	.116	.08	.36	.554	.01

Note: Prop = Proportion; TarCong = Target Configuration; Obj = Object

B. *Results of ANOVAs on the reaction times in the equal and more sessions in Experiment 3A as a function of target configuration and object.*

	Equal			More		
	F (1, 30)	*p*	η_p^2	*F* (1, 30)	*p*	η_p^2
TarConf	22.62	<.001	.43	29.93	<.001	.50
Obj	.00	.991	<.01	4.22	.049	.12
TarConf*Obj	3.21	.083	.10	6.80	.014	.18

Note: TarCong = Target Configuration; Obj = Object

Table 9

Results of ANOVAs on the reaction times and error rates in Experiment 3B as a function of target configuration and object.

	Reaction Times			Error Rates		
	F (1, 16)	*p*	η_p^2	*F* (1, 16)	*p*	η_p^2
TarConf	27.19	<.001	.63	2.47	.135	.13
Obj	3.78	.070	.19	2.83	.112	.15
TarConf*Obj	4.07	.061	.20	1.00	.332	.06

Note: TarCong = Target Configuration; Obj = Object

Table 10

Results of ANOVAs on the reaction times and error rates in Experiment 4 as a function of target configuration and cue-target orientation congruency.

	Reaction Times			Error Rates		
	F (1, 17)	p	η_p^2	F (1, 17)	p	η_p^2
TarConf	31.20	<.001	.65	.70	.415	.04
Cong	1.29	.272	.07	1.38	.256	.08
TarConf*Cong	16.34	<.001	.49	.02	.878	<.01

Note: TarCong = Target Configuration; Cong = Congruency

Table 11

Results of ANOVAs on the reaction times and error rates in Experiment 5 as a function of target configuration and cue-target orientation congruency.

	Reaction Times			Error Rates		
	F (1, 19)	p	η_p^2	F (1, 19)	p	η_p^2
TarConf	8.63	.008	.31	2.52	.129	.12
Cong	1.02	.325	.05	1.07	.313	.05
TarConf*Cong	.05	.817	<.01	2.76	.113	.13

Note: TarCong = Target Configuration; Cong = Congruency

Table 12

A. *Results of ANOVAs on the reaction times and error rates in Experiment 6 as a function of cue type, target configuration, and cue-target orientation congruency.*

	Reaction Times			Error Rates		
	F (1, 19)	*p*	η_p^2	*F* (1, 19)	*p*	η_p^2
Cue	.02	.880	<.01	.47	.500	.02
TarConf	25.75	<.001	.58	2.43	.136	.11
Cong	4.52	.047	.19	.86	.367	.04
Cue*TarConf	13.34	.002	.41	.89	.356	.04
Cue*Cong	2.52	.129	.12	.17	.685	<.01
TarConf*Cong	1.10	.308	.05	.47	.503	.02
Cue*TarConf*Cong	5.51	.030	.22	2.97	.101	.14

Note: TarCong = Target Configuration; Cong = Congruency

B. *Results of ANOVAs on the reaction times in the bar and letter cue trials in Experiment 6 as a function of target configuration and cue-target orientation congruency.*

	Image			Letter		
	F (1, 19)	*p*	η_p^2	*F* (1, 19)	*p*	η_p^2
TarConf	39.07	<.001	.67	6.14	.023	.24
Cong	8.68	.008	.31	.07	.797	<.01
TarConf*Cong	6.26	.022	.25	1.08	.312	.05

Note: TarCong = Target Configuration; Cong = Congruency