ATTENTION AND PERCEPTUAL ORGANIZATION:

WHAT THE OBJECT EFFECT REVEALS ABOUT THE REPRESENTATION OF OBJECTS IN THE VISUAL SYSTEM

by

HOPE DENNEY

(Under the direction of James M. Brown)

Abstract

This study explored the representation of objects in the object-based attention system in terms of how the system incorporates cues based on perceptual organization. Uniform connectedness is an organizing principle thought to underlie the segregation of the visual field into figure and ground, and ultimately into separate objects. At what point does object-based attention begin to have an influence as processing progresses from uniformly connected (UC) regions to objects? To address this question, this experiment explored a boundary condition of the object effect in terms of perceptual organization with two different types of UC stimuli: silhouettes of two recognizable objects (Experiments 1 and 2a) and self-splitting figures (Experiment 3a). Object-based attention may process a UC stimulus as a single object, as the bottom-up information indicates, or it may process it as two separate objects, as the silhouettes and splitting figures are perceived. Two different tasks, discrimination (Experiment 1) and detection paradigms (Experiments 2 and 3), were used to achieve convergent validity.

An object effect was found in the cuing experiment that used silhouettes, and not in the discrimination experiment or the cuing experiment with self-splitting figures. The targets that were discriminated were small, and this may have reduced the focus of attention to the point that it did not encompass the silhouette in which the targets appeared. This is a reasonable possibility why there was a lack of an object effect in the discrimination experiment. The self-splitting figures were reversible figures, and the cues and targets appeared in the part of the figure that changed which object it was a part of when the figure reversed. The ambiguity involved in this may explain the lack of an object effect in the self-splitting figure experiment.

INDEX WORDS: Object-based Attention, Perceptual Organization, Uniform Connectedness, Object recognition, Segregation, Selective Attention, Attention, Spatial Cuing, Visual Perception, Spatial Perception

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INTRODUCTION

What is an object? This question seems simplistic, but is very important since many research studies have been completed under the assumption that they are using objects. Merriam Webster defines the term as “something material that may be perceived by the senses.” (Merriam-Webster Online Dictionary, n.d.) Peterson (2001) defines an object as a three dimensional (3D) solid structure that remains in existence and remains intact when it moves. It cannot be a puddle, shadow, hole, part of another object, or an illusion. She also explains how the term is typically used by visual researchers. It can be an animate or inanimate structure, two-dimensional (2D) or 3D. Most object recognition researchers accept illusory objects as true objects (Peterson, 2001). Behrmann, Zemel and Mozer (1998) state that neither a name, nor even the label of “object” is necessary for a visual stimulus to be an object to the visual system. They define an object as “a set of features that has structure or regularity by virtue of being organized into the same configuration over multiple occurrences” (p. 1034). This paper is empirically exploring what an appropriate definition would be, with regard to the representation of an object in the visual system.

This research explored object-based attention, the process in visual attention that is attuned to objects. It also explored what the representation of an object is in object-based attention. In perceptual organization, there is a concept called uniform connectedness. A uniformly connected (UC) region is a connected region of visual space that is uniform in the most basic visual properties. It is considered to be one of the most basic parts of a scene, and to be a prerequisite to grouping and segmentation (Palmer & Rock, 1994b). This research attempts to answer several questions. Is the representation of an object that is used in object-based attention the representation involving uniformly connected regions, or does object-based attention have access to a representation similar to what is consciously perceived? Is the stimulus segmented in the representation used by object-based attention? In the present experiment, different types of segmentation (object recognition, segmentation by concavities) and different tasks (cuing, discrimination) were used to test this question.

The following section will review perceptual organization, with an emphasis on uniform connectedness. Subsequent sections will describe the research on object-based attention, and the phenomenon called the object effect. The next section will review the literature that has explored the relationship between perceptual organization and object-based attention. The next section will describe and explain the motivation for the current research.

Perceptual Organization

The purpose of perceptual organization is to organize the visual world into discrete objects, to determine what stimulus information belongs together and what does not. Perceptual organization involves a number of important processes: figure/ground processing, visual interpolation, segregation and grouping. Figure/ground processing is a term for the designation of one stimulus as a foreground figure (i.e., an object) and the rest of the scene as the background, and the assignment of intervening contours to the figure. Observers perceive the ground as complete behind the figure. This prepares the way for determining whether two things that are occluded by a figure belong together. Visual interpolation is the completion of contours that belong to the same object, but are for some reason interrupted. Segregation involves distinguishing which parts of the visual image do not belong together. Grouping involves distinguishing which parts of the stimuli do belong together. There are many principles that grouping follows, including proximity, similarity, common fate, good continuation, closure, temporal synchrony, common region, closed contour, and homogeneity (Peterson, 2001). The steps of perceptual organization are considered to operate in cascade (Humphreys, Riddoch, & Price, 1997); they must begin in a particular order, but later processes can begin before the previous one is completed. Therefore, a later stage can affect the outcome of an earlier stage (Palmer & Rock, 1994a; Peterson, 2001, 2003; Humphreys, et al., 1997).

Since there must be elements in order for the observer to segment them into subparts, group them, or designate them as a figure, there must be a step prior to the generally accepted ones just described, one that provides the elements on which perceptual organization operates. In other words, there must be some entry-level step in perceptual organization. Palmer and Rock (1994b) have proposed a first basic step in perceptual organization, called uniform connectedness. UC regions are formed by the detection of edges. These regions, once transformed by figure/ground operations, are considered the entry-level unit into perceptual organization. As previously defined, a UC region is a region that is uniform in basic visual properties and is connected. However, this definition is not exhaustive, because Palmer and Rock note that the color and luminance do not have to be entirely uniform; a UC region can be a consistent gradient or a uniform texture (see below for more explanation of this fact). After UC regions are distinguished, figure and ground are organized, and then segmentation and grouping occur. However, UC regions tend to retain their identity after these operations; for instance, despite the segmentation into parts, the whole is still perceived as a whole.

Palmer and Rock (1994b) propose the possibility of separate (possibly parallel) entry-level steps, one for each basic property of the image (luminance, color, texture, etc.). In their theory, there are separate "region maps" for luminance and color. When they provide different information, the color representation predominates over luminance. The ecological reason for this is that it is a common real-world occurrence that an object is uniform in color and is partly differently illuminated. It is possible that there is also a region map based on texture, made up of smaller regions that are UC in their color and luminance. This map would also be compatible with the color and luminance maps, because they can be hierarchically nested within each other. After these processes operate, figure/ground operations would begin, in order to disconnect the mosaic of UC regions. According to Palmer and Rock, only then are the true entry-level units formed.

Uniform connectedness can be more easily understood by considering the three pictures of a stapler and a tape dispenser in Figure 1. In Figure 1a, the stapler is uniformly black and all its parts are connected to each other. Therefore, it is one UC region. However, the stapler and tape dispenser in Figure 1b are also black and connected. Therefore, while they are two objects, they are still one UC region. From a bottom-up perspective it is UC, even though it is perceived as two things. The stapler in Figure 1c, on the other hand, has at least nine different colors and therefore many distinct UC regions, but it is still seen as a single object. This research also tests boundary conditions of the object effect, a phenomenon discussed in more detail in the next section.

Object-based attention

There are two separate processes in visual selective attention, space-based and object-based attention (Duncan, 1984; Egly, Driver, & Rafal, 1994). Space-based attention is the allocation of resources to an area of the visual field, irrespective of what is in that area. Object-based attention is the allocation of resources to a specific object. Object-based attention can be experimentally seen in the facilitation of a task by the task's containment within an object. These two systems of attention work together to allocate resources in the visual field. Space-based attention is demonstrated by distance effects, while objects in the field of view affect other aspects of attention, for example disengaging (Brown & Denney, submitted; Denney, 2004), focusing (e.g., diffuse or narrow; Goldsmith & Yeari, 2003), and the order in which the visual field is scanned (Shomstein & Yantis, 2002).

Empirical data has shown (Avrahami, 1999; Brown & Denney, submitted; Denney, 2004; Duncan, 1984; Egly et al., 1994; Lavie & Driver, 1996; Law & Abrams, 2002) that an object's presence in the field of view affects the allocation of attention. This effect is typically called the object effect. Many researchers have used widely differing tasks to provide evidence of the object effect. The evidence includes divided attention (Duncan, 1984; Lavie & Driver, 1996; Law & Abrams, 2002), spatial cuing (Brown & Denney, submitted; Brown, Breitmeyer, Leighty & Denney, 2006; Denney, 2004; Egly et al., 1994; Lamy & Egeth, 2002; Tipper, Jordan & Weaver, 1999; Vecera, 1994), temporal order judgments, (Abrams & Law, 2000), flanker paradigms (Lamy & Egeth, 2002; Shomstein & Yantis, 2004), and distance estimation (Avrahami, 1999).

Two classic examples of evidence of an object effect are Duncan's (1984) divided attention and Egly et al.'s (1994) cuing studies. Duncan asked participants to judge two different features of a square with a line running across it. Participants judged either two aspects of one stimulus (the square or the line) or one aspect of each. Accuracy was poorer for those judgments that involved two objects than for those that involved one. This demonstrates that two judgments about the same object can be made without a loss of accuracy. The other classic study, by Egly et al. (1994), used a cuing task in a display with two objects. A pair of bars was displayed, a cue appeared in one bar, and then a target. When the target appeared in a different location in the same object as the cue RTs to the target were shorter than when it appeared in a location in the other object, despite these two locations being equidistant from the cue. Many subsequent studies have used variations on this paradigm to explore the object effect (see below for several examples). This brings up the question of how objects are represented in the object-based attention system.

Perceptual Organization and Object-Based Attention

In order to explore the representation of objects in the object-based attention system, the present study explored the interaction between perceptual organization and object-based attention. Several other studies have explored how perceptual organization affects the object effect, but they predominantly tested grouping and feature binding, and this study tested segmentation.

Brown, et al. (2006) tested effects of stimulus configuration on the object effect. They used a cuing task, with cue and target appearing in bars, brackets, and arcs, to determine whether spatial factors and configural factors affect the object effect. They explored whether differences in Gestalt grouping factors could degrade the object effect. They manipulated the ratio of within-object to between-object distance, the number of separate parts (e.g., the separate arms of the brackets, as contrasted to the single-part arc), and Gestalt factors such as good continuation (e.g., the curve of the arc vs. the 90^{o} angles in the brackets). In conditions involving a shift of attention within an object, the within-object distance of the brackets and arcs was three times that of the bars. The magnitude of the object effect was greater with the bars than with the 3:1 ratio stimuli. This means that the object effect is affected by within-object distance (a spatial factor). These results suggest that attention may trace the objects, when shifting within the object. However, the object effect was still apparent, so object-based attention is robust to spatial manipulations of the within-object distance. There was no difference in magnitude of the object effect between arcs and brackets, indicating that the perceptual organization factors, good continuation and separate parts, do not affect object-based attention.

In a paradigm similar to that of Egly, et al. (1994), Avrahami (1999) used horizontal lines that crossed the whole monitor as borders, in place of true objects, with cue and target positioned between the same line or different lines. Her stimuli were not enclosed; therefore, it was not certain whether the object effect would occur. She found an effect similar to the object effect; RTs were less when the cue and target were between the same lines, compared to when they were across different lines. These results suggest that the grouping factor of closure is not necessary for the object effect to occur.

Behrmann et al. (1998) found evidence that occluded objects are represented as one object in object-based attention. In Behrmann et al.'s study, participants viewed two bars arranged in an X, one occluding the other, and made same/different judgments about two ends of the bars. The ends were forked with either two or three prongs. RTs and accuracy in response to targets on the occluded bar were the same as responses to the unoccluded bar, and both were faster than when the forks were on different bars. Results were the same with a different task (determine whether the forks are on the same or a different object) and with different stimuli (the bars were changed into Vs, also occluded at the center - differing from the previous stimuli only by the position of one line, designating the occlusion). The results suggest that the representation of an object is not determined exclusively by physically present edges, because occluded objects are properly interpreted by it.

Once an object representation has been formed, research shows that use of additional Gestalt grouping cues has little effect. Kramer and Jacobson (1991) used five parallel vertical lines as their stimuli. The lines were connected and colored in various ways to make them appear to be different objects. The participants' task was to discriminate whether the center line was dashed or dotted. The two lines surrounding it (the second and fourth lines) were distractors and could be the same or different (i.e., dashed or dotted). They also were connected to and of the same color as the center (target) line in some trials, and in other trials they were connected to and colored like the outermost lines (different colors were not used as a distracting factor- only as a grouping factor). This provided grouping cues, and permitted the target line and the distractors to appear to be parts of the same object or parts of different objects. Kramer and Jacobson tested same-object, different-object, and control trials (with no color or closure cues). They found the object effect, with the control condition intermediate in magnitude to the same object and different object conditions. These results suggested that the object effect is due to facilitation of attention inside objects and to inhibition of attention between objects.

To explore whether different grouping factors affect the object effect differently, and whether their effects are additive, Kramer and Jacobson conducted two more experiments, one with only color cues to designate the objects, and one with only closure. When they compared the three experiments, they found no interactions that suggested different object effect magnitudes between the three experiments. This suggests that the cues of similarity of color and common contour do not differentially affect the object effect, nor are their effects additive.

Chen (1998) has shown that subjective perceptual organization can play a role in what constitutes an object. Chen used stimuli that were large Xs made of two differently colored Vs (i.e., two different UC regions) in a precued discrimination task. (There were also trials with only half an X, i.e., a V, which Chen called filler trials and which are not relevant to the current discussion). Participants discriminated an L or a T in one end of the X, with Os in all the other ends. The correct location was cued in 60% of the trials using Xs. In one experiment, an object effect was found, with RTs to the uncued target being less when it was in the same colored (i.e., UC) V as the cue was in. In another experiment, with special instructions to perceive one large two-toned X, no object effect occurred in the V, compared to when attention had to cross into the other V that made up part of the X. Therefore, when participants had no instructions, UC objects were used as the representation of objects. When observers were instructed to perceive the stimuli as one large object, they grouped the UC regions. This data shows that object-based attention can treat a grouped set of two UC regions as one object. It also shows that conscious choice can affect the representation used by object-based attention.

Watson and Kramer (1999) also found evidence of top-down effects on object-based selection in some situations. They used a display of two wrenches in which either the wrenches were UC or the grip area of each wrench was different from the ends. The wrenches could have a bent end or a straight end, a closed or an open end. One or two of these target properties occurred in one or two wrenches. Participants determined if there were one or two of these properties in the wrenches. The object effect was found only when the properties were on a UC wrench.

In another experiment, however, Watson and Kramer (1999) found the object effect with non-UC wrenches. In that experiment, after some trials the participants were required to tell whether a wrench displayed after the trial had been in the previous display. This extra task was to encourage participants to group the wrenches that were made of multiple UC regions. Since Watson and Kramer found the object effect in this experiment, the data suggests that participants do not naturally use object-based attention when objects are made of multiple UC regions, only when there is one UC region. However, when there is a good reason to use a representation of an object that includes multiple UC regions, they can override the UC region representation.

Consistent with that of Chen, (1998) Watson and Kramer's (1999) research suggests that object-based attention utilizes a representation based on the UC region, but not just that. They found that it was the preferred representation, in conditions that were not biased toward a higher-level representation. The magnitude of the object effect was greater when bottom-up factors were used. The results suggest that there are different representational levels that can be used. To summarize their results, UC is a powerful cue, but not the only one that can be used.

Finally, Woodman and Luck (2003) found that in some cases of masking, the visual system can shift attention to the object that the viewer was instructed to locate, without the participant being able to report its presence (measured by EEG). They used a phenomenon called four-dot masking, which research suggests is a form of masking that allows perceptual information into processing, and masks it during later recurrent processing in the visual system (Enns, 2004). This shows that object recognition can inform attention, even if conscious identification does not take place. This suggests that not only does attention affect object recognition, but the relationship is reciprocal. The implications of Woodman and Luck's findings for the current study is that the representation of the object that object-based attention uses can be informed by object recognition, but it does not have to be exactly like the conscious percept.

The Current Research

The use of UC stimuli is an excellent way to explore how low-level features can be used to define an object. Are UC stimuli that are perceptually segmented into two objects processed as one or two objects? The current study provides convergent validity to the Watson and Kramer (1999) experiment described earlier, using a different organization process. The Watson and Kramer study offers a reason to hypothesize that the UC stimuli used in this study would be processed as one object, not two.

In Experiment 1, a variation on Lamy and Egeth's (2002) two-rectangle discrimination paradigm was used. Two targets appeared, one with delayed onset, in UC silhouettes of two objects. Participants performed a same/different judgment, and RTs and accuracy were measured. In order for an object effect to occur, the observer must segment the silhouettes into two objects. In Experiment 2a, the same silhouettes as in Experiment 1 were used in a cuing task. This would provide excellent convergent evidence with Experiment 1 to explore whether UC silhouettes are segmented in the representation used by object-based attention. In Experiment 2b, the same cues and targets were used, in the same locations, but with the silhouettes removed. This provided a control to see if the silhouettes were the basis for whether object-based effects are found in Experiment 2a.

Experiments 3a and 3b explored the same question as Experiments 1 and 2, using a different form of segmentation. In Experiment 3a, a cuing task was used with self-splitting figures (Kellman & Shipley, 1991). Self-splitting figures use segmentation cues to be perceived as two objects or shapes, despite the fact that they are UC. This type of stimulus has never been used in an object-based attention study. The stimuli were UC in Experiment 3a, and the stimuli in 3b were identical, except that they had faint borders instead of being UC. The purpose of Experiment 3b is to determine whether the stimuli used in 3a can bring about the object effect when they are already segmented. It can also provide a magnitude of the object effect that can be compared to Experiment 3b to determine whether segmentation cues are as effective as objects delineated with boundaries. The process of segmentation is dependent on lower-level cues in Experiment 3, and the final determinant of segmentation in Experiments 1 and 2 is object recognition, a higher-level process.

EXPERIMENT 1

Experiments 1 and 2 explored the relationship between object recognition and the object effect. This explored the visual system's representation of objects, as well as giving us some idea of the level in the visual system at which object-based attention operates. Object recognition is the area of visual science that attempts to understand how the human visual system represents objects and identifies them based on representations in memory. Simply stated, it is access to the information that an object has been seen before, the classification of it into a category and naming it.

Those researching object-based attention need an empirically-based operational definition of an object. This experiment tested whether object-based attention would be better considered UC region-based attention. It also tested how object recognition affects the object effect. In this experiment, silhouettes of two overlapping objects created from the outlines in photographs, were used to create UC regions that are perceived as two objects. Experiments 1 and 2 explored whether object-based attention processes the silhouettes as if they are one object or two. Object recognition is typically considered one of the highest levels of visual processing, but Peterson (1994, 2001, 2003) has shown numerous times that it can affect earlier visual processes, like figure/ground assignment and perceived depth. One purpose of this experiment is to see if it affects object-based attention, as well.

One group of researchers has explored uniform connectedness and the object effect before. As discussed in the previous section, Watson and Kramer's (1999) study tested the magnitude of the object effect in perceptual objects composed of multiple uniformly connected regions against objects composed of a single uniformly connected region. They found that multiple UC regions (two wrench ends and a grip) are not processed as one object when they make up a perceptual object (a wrench) unless the task is biased, through priming or through the use of a task that requires participants to pay special attention to the object as a whole. The present experiment explored the relationship between UC regions and the representation of an object in attention from the opposite perspective. Does object-based attention process one uniformly connected region that is perceptually two objects (e.g., a silhouette of a bird sitting on a post) as one object or as two? The current research is different from Watson and Kramer's in a few critical ways. In technical terms, Watson and Kramer studied how grouping UC regions affects object-based attention, and the present study explored how segmenting a single UC region affects object-based attention. The previous research (as well as Behrmann et al., 1998) tested if non-UC stimuli that are perceived as single objects are processed as separate objects. The current study explored whether UC stimuli that are perceived as separate objects are processed as single objects or as separate objects. Another important difference between Watson and Kramer's study and the present one is that they used the shape of the object itself as the target stimulus, and the present research used targets that do not appear to be part of the object.

The reader may wonder why one might expect that the object-based attention system would process the stimulus in a different way than it is represented in conscious perception. First of all, Woodman and Luck's (2003) data shows that this can happen. The mechanism underlying the object effect may operate at a lower level of the visual system than object recognition. In that case, if top-down influences do not affect the object-based attention system, the attentional system may use a lower-level representation than the final percept. To give an example that involves actual visual areas, if the process that underlies the object effect occurs in V1 (or another visual area lower than the inferotemporal cortex, where it is typically agreed that object recognition occurs; Bruce, Desimone, & Gross, 1981), and if recognition is irrelevant in V1, the UC stimulus may not be processed as two objects.

Experiment 1 is a divided attention study, with two targets appearing inside a silhouette of two objects. Participants discriminated the shape of the targets to determine if they were the same or different. The object effect in this experiment would be shorter RTs and better accuracy when both targets are in the same object, rather than one target in each object. The most important findings from this experiment involve whether the object-based attention system responds as though one UC region is an object or as though multiple UC regions can be processed as a single object (i.e., the bird is one and the post is another object). If the representation of the objects in the visual system is segmented, that is, if the representation is the same as we perceive consciously, then the object effect would occur. If it is not segmented, the object effect would not occur. This would mean that the UC region is the representation used.

Methods

Participants

Thirty-five undergraduates (18 male and 17 female) from the research participant (RP) pool in the psychology department participated in the experiment for course credit. Sample size calculations were done to determine the number of participants. The calculations were based on the results of Lamy and Egeth (2002), because the primary difference between their experiment and the present experiment is the stimuli. The present experiment used the same task and timing parameters they used. Only right-handed participants with normal or corrected-to-normal vision who have no history of attention deficit disorder were utilized.

Stimuli and Apparatus

Participants' acuity was checked with a Master Orthorater. Stimulus presentation and data collection were carried out on computer using commercial software with a viewing distance of 42 inches, held constant by using a chinrest. The viewing distance was chosen so that the targets that were farthest apart could be easily seen.

The targets were presented in UC silhouettes of two recognizable objects in a familiar configuration (see Figures 2 and 3 for the silhouettes used). A fixation point (0.27^o x 0.27^o) was centered on one spot for each silhouette, at the most central location to each of the four possible target locations. When possible, this was in a location where it would not provide an illusory contour that would properly segment the objects (the only one that might is the spoon/fork stimulus). The targets were always the same distance from each other and always the same distance from fixation. However, these distances varied from one stimulus to another. There are eight silhouettes total (see Figures 2 and 3). The computer monitor/keyboard, the mug/sunglasses, and the sponge/ bottle of dish soap used the same target-to-target distance (3.1^o from the outside of one target to the outside of the other target). The targets in the child with gift and the pair of people were slightly farther apart (5.3^o), and those in the spoon/fork, pelican on post, and stapler/tape dispenser were slightly closer together (2.0^o). The silhouettes themselves ranged from 8.0^o wide x 9.8^o tall to 12.8^o wide x 4.0^o tall.

The silhouettes were black on a gray background. The targets were white circles (0.35^o x 0.35^o) and squares (0.27^o x 0.27^o), with an equal number of pixels in the circles as is in the squares. Most of the targets were oriented in a square around fixation, and the rest were in a diamond (i.e., the targets in the computer monitor/keyboard and the stapler/tape dispenser), depending on the orientations of the two objects in the silhouette. In some cases (pelican on post and mug/sunglasses), a between-object shift was vertical and in other cases (spoon/fork, sponge/bottle of dish soap, pair of people, and child with gift) a between-object shift was horizontal. In the two silhouettes in which the targets are oriented diagonally, the shifts of attention did not cross hemifields.

Procedure

The stimuli were named by each participant, before running in the experiment, to ensure that participants perceived the silhouettes as two objects. This process implicitly emphasizes that the participants should see the silhouettes as two separate objects. When participants named only one of the objects in the silhouette (or called the monitor and keyboard a computer), they were told that it is possible to see the silhouette as one object or two, the other object was named, and they were asked if they could see both.

Participants were instructed to keep their eyes on the fixation point while the two targets appeared, then to respond as soon as they saw the second target. There were 20 practice trials and 256 experimental trials. If they made two errors on the practice trials, or did not understand the instructions, they completed another set of practice trials. There were an equal number of trials with each silhouette, and with each pair of locations. Half of the trials had the same targets and half had different targets. Trials were randomly presented, to prevent order effects. The initial stimulus screen (depicting the silhouette with the fixation cross) was presented for 1000 ms. The first target appeared for 200 ms (the timing parameters were chosen based on the results of Lamy & Egeth, 2002), followed by the second target for 2000 ms or until the participant responded. Reaction times (RT) were measured from onset of the second target until the response, and accuracy was measured as well.

Results

See Table 1 for results of object rating. The mug/glasses was named wrong 5 times, and the sponge/soap was named wrong 3 times. Trials in which the RTs are less than 150ms and greater than 2.5 standard deviations from the mean (i.e., the mean for the condition) were removed from analysis. Two separate 8 (silhouette) x 2 (within- or between-object target locations) within-subjects ANOVAs for RT and for accuracy were performed, one on the same targets condition, and the other on the different targets condition. Analyses were collapsed across target order (i.e., which of the two targets appears first) and target location (which two out of the four possible target locations were used

Accuracy

There were no significant differences between any conditions in the same response condition. Mean accuracy was 91.9%. There were no significant differences between any conditions in the different response condition. Mean accuracy was 94.6%. The accuracy data suggests a ceiling effect.

Reaction Time

There was a significant difference between stimuli in both same response $F(7,238) = 9.73$, $p < .001$ and different response $F(7,238) = 4.42$, $p < .001$ conditions. The main effect of within- and between-object target location conditions was not significant in either same or different response conditions. The interaction between the within-and between-object target location condition and stimuli was significant for both same $F(7,238) = 4.92$, $p < .001$ (see Figure 4a) and different $F(7,238) = 2.07$, $p < .005$ response conditions (see Figure 4b). Tukey's pairwise comparison revealed the following hypothesis-relevant results. In the different response condition, there was no object effect. In the same condition, there was an object advantage in the mug/glasses ($p < .05$) and the pelican on post ($p < .05$) silhouettes.

Discussion

The results showed that there is no overall effect of object-based attention in UC silhouettes when a discrimination task is used. This suggests that the UC region might not be segregated in the representation of an object used by object-based attention. However, the results may be due to the task, because the object effect is not always found in discrimination studies (Davis & Holmes, 2005; Goldsmith & Yeari, 2003; Lamy & Egeth, 2002). The interaction between the within- and between-object conditions reveals that in two of the stimuli, there was an object effect in the same condition. This suggests that the silhouettes may be segmented in object-based attention, in some situations. See the general discussion for more discussion of these results. Experiment 2 will test whether the representation of an object in object-based attention is segmented when the task is to simply detect a target using a cuing task.

EXPERIMENT 2A

Experiment 2a was a cuing study using the same silhouettes as were used in Experiment 1. The use of the same stimuli was intended to provide convergent evidence for the findings of Experiment 1 using a different task. This convergent evidence is important because the object effect is found in different circumstances with cuing studies, than it is found with divided attention studies in the literature (Davis & Holmes 2005; Lamy & Egeth, 2002).

In cuing studies, the object effect is a shorter RT when cue and target appear within a single object, as compared to when cue and target are in two different objects. As in Experiment 1, if the object effect is found, it would mean that object-based attention can operate on stimuli that are perceptually segregated as two objects by the higher-level visual information. This would further suggest that the representation of an object in the visual system is formed after UC regions are segmented. If it is not found, it would mean that object-based attention cannot utilize higher-level segregation cues, despite the observer's perceptual experience of segregated objects. This would also suggest that the object effect operates before object recognition, and that there are no top-down influences that provide recognition-based information to object-based attention.

Methods

Participants

Thirty-one undergraduates participated in this experiment, with the same restrictions as in Experiment 1. A sample size calculation was also done for this experiment, revealing the need for 27 participants.

Stimuli and Apparatus

The same silhouettes were used that were used as stimuli in Experiment 1, with a small white line (0.13^o x 0.27^o) as the cue and a square (0.27^o x 0.27^o) as the target. The apparatus was the same as in Experiment 1.

Procedures

The task was a detection task. Participants were instructed to keep their gaze on the fixation cross throughout each trial, and to press the response key as quickly as possible when a target appeared. The initial stimulus screen (depicting the silhouette with the fixation cross) was presented for 1000 ms, then the cue appeared for 50 ms to signal the onset of the target. The stimulus screen was presented for another 150 ms followed by the target screen (or a screen with no target, in catch trials) for 1500 ms or until the participant's response (see Figure 2b). There were 8 practice trials and 448 trials. On 11% of the trials no target appeared. Cues were valid on 66% of the trials and invalid on 22%, with half the invalid trials requiring a within-object shift and half requiring a between-object shift of attention. RT to target onset was measured.

Results

See Table 2 for familiarity data. The silhouettes were overall very familiar to the participants. The mug/glasses silhouette was initially named wrong 4 times, and the sponge/soap was named wrong 2 times. The data from participants with more than 15% false alarms was not used, because they might not have performed the task correctly. Nine participants were removed from the analysis for this reason, resulting in the 31 participants reported in the results section. Average false alarms were 4%. Trials in which the RTs were less than 150ms and greater than 1500ms were removed from analysis, resulting in 1% of trials being excluded from analysis. Two 8 (silhouette) x 2 (target locations) within subjects ANOVAs were performed, one on valid and invalid conditions, and the other on a cost estimate based on a difference score. The cost estimate compared invalid within-object trials to invalid between-object trials, using a difference score subtracting the valid RTs for that silhouette from the invalid-within and invalid-between RTs. The silhouettes were considered in the analysis because of the possibility of an effect of direction of shift. Analyses were collapsed across target locations.

Comparisons of the valid and invalid conditions revealed a significant 25 ms valid cuing effect, with RTs to validly cued targets less than RTs to invalidly cued targets (349 and 374ms respectively) $F(1,30) = 68.4$, $p < .001$. There was an effect of silhouette, $F(7,210) = 5.10$, $p < .05$ (See Figure 5a) and no interaction. Costs were less for the invalidly cued within-object condition (21ms) than for the between-object condition (31 ms) $F(1,30) = 32.78$, $p < .001$. This result is evidence of an object effect. There was an effect of silhouette, $F(7,210) = 5.03$, $p < .001$ (see Figure 5b) with the greatest costs in the child/gift, people, and stapler stimuli. There was an interaction between cost and silhouette, $F(7,210) = 2.35$, $p < .05$ (see Figure 5b). Tukey's pairwise comparison revealed the following hypothesis-relevant results. In the cost data, there was an object advantage in the mug/glasses ($p \leq .05$) and the monitor/keyboard ($p < .05$) silhouettes.

Discussion

The object effect was found in Experiment 2a, whereas it was not found in Experiment 1. This may be attributable to the differences in the task; task effects have also been seen in the literature (Davis & Holmes, 2005; Goldsmith & Yeari, 2003; Lamy & Egeth, 2002; see the general discussion for more information about these differences). However, the task used in Experiment 1 was chosen specifically because it was similar to that used by Lamy and Egeth, who did find an object effect. The difference between the results of Experiment 1 and Experiment 2a may also be related to the interaction between the silhouette condition and within- and between-object target locations, because some of the silhouettes showed the object effect and some did not. There will be more discussion of these different results in the general discussion. Experiment 2b was conducted to see if the silhouettes were the cause of the effect, or if it can be attributed to the cue and target locations (e.g., visual hemifield) and directions that attention had to shift (He, Cavanaugh, & Intriligator, 1996; Previc, 1990).

There are a number of possible explanations for the differences between the results for each silhouette. Ambiguity about the borders between the objects may have affected the results. The ambiguous amount of overlap between the individual objects may explain the lack of meaningful findings from the “people” silhouette. The shoulders of the individual people could have been anywhere, and it could be considered ambiguous. However, there is no such ambiguity involving the target locations in the other silhouettes, making this unlikely to affect the overall results. It is possible that the bow on top of the gift in the child/gift silhouette was perceived as a third object. This would have made half of the trials that were coded as within-object trials into between-object trials for any participants who perceived the bow as a third object. Pairwise comparisons showed that there was no object effect in either of these two silhouettes in any of the data sets (Experiment 1 same and different, and Experiment 2a)

Other possible explanations include concavities between cue and target locations, shift distance, and direction of shift. There are also some conceptual possibilities, like the degree of conceptual relatedness between the objects making up the silhouette and the degree of similarity. The results of the small-distance silhouettes (fork/spoon and pelican), medium-distance silhouettes and long-distance silhouettes (people and child/gift) balance each other out. Distance to shift had no consistent effect on the cost results. Similarity of the objects used to make up a silhouette should be considered as a potential explanation for the results, because the silhouettes with similar objects (fork/spoon, people and stapler/tape dispenser) all have null results. However, if participants process the objects in the silhouettes enough to conceptualize and compare their similarity, it is almost certain that they segregated the objects perceptually. If the object similarity had an effect on object-based attention, the data would be expected to show the opposite results - the similar-object silhouettes would be segregated.

Conceptual relatedness of the two objects that make up a silhouette could possibly be involved. The three that could be argued to be unrelated (child/gift, mug/glasses, and pelican on post) have different results, but the discrimination task in two of them (the mug/glasses, and pelican on post) resulted in the object effect (in the same condition only). The child/gift had no significant results, but that may be explained by the bow being perceived as a third object. The more conceptually unrelated objects may be better segregated due to their unrelatedness. However, this should follow the same logic as for similarity.

There are intervening concavities in half of the between-object shifts in the child/gift, the mug/glasses and the monitor/keyboard silhouette. Two of these were among the three silhouettes in which there was an object effect. The monitor/keyboard showed an object effect in only the cuing results (Experiment 2a). The mug/glasses had a marginally significant effect in the cuing data and a significant object effect in the discrimination same data but not in the discrimination different data. Concavities might explain some of the data, but the pelican had no intervening concavities between the cues and targets, so concavities do not explain the data fully.

EXPERIMENT 2B

Experiment 2b explored whether the results found in Experiment 2a were due to the silhouettes or the fact that a detection task was used. This experiment also provides a control to determine whether the varying distances and directions attention shifted in Experiment 2a affected the RTs. The exact shifts of attention can be compared from Experiment 2a (with objects) to Experiment 2b (without objects). It is not expected that there would be an effect of direction of shift or shift distance, based on the results of Denney and Brown (2004). They did a cuing task that involved different distances and directions to shift and found no effects. The results of Experiments 2a and 2b were expected to be the same, except that the object effect was found in Experiment 2a and it was not expected in 2b, since there were no objects.

Methods

Participants

Thirty-one undergraduates participated in this experiment, with the same restrictions as in the previous experiments. A sample size calculation was done for this experiment, as well, revealing the need for 12 participants, but the same number as in Experiment 2a was used, so that the two experiments can be better compared. This experiment used an independent set of participants.

Stimuli and Apparatus

The same stimuli were used as in Experiment 2a, except that there were no objects surrounding the cues and targets. The apparatus was also the same.

Procedures

The procedures of Experiments 2a and 2b were identical, except that there were fewer trials in 2b. Without an object, invalid trials were not classified as within or between objects reducing by half the number of trials needed. Of the 224 trials, cues were valid on 66% of the trials and invalid on 22%.

Results

Participants with more than 15% false alarms were excluded from the analysis, resulting in the removal of seven participants. The average false alarm rate was 6%. Trimming RTs greater and less than 2.5 standard deviations from the mean resulted in 1% of trials being excluded from analysis. A 2 (valid or invalid cuing) x 8 (stimulus configuration) within-subjects ANOVA was done on the RTs. There was a 30 ms cuing effect, with RTs to validly cued targets shorter than RTs to invalidly cued targets (352 ms and 391 ms, respectively), $F(1,30) = 78.57$, $p < .001$. There was an effect of stimulus configuration, $F(7,210) = 5.06$, $p < .001$ (see Figure 5c) with trends for the RTs to targets in the child/gift and the people silhouettes being longer than the others, and RTs to targets in the fork/spoon and the pelican being shorter. This suggests distance effects, which affected both the valid and invalid RTs. There was no interaction between validity and stimulus configuration.

Comparisons of Experiments 2a and 2b:

The RT data was compared to the data from Experiment 2a in a 2 (experiment) x 2 (valid vs. invalid) x 8 (stimulus configuration) ANOVA. There was an effect of valid cuing, with RTs to validly cued targets shorter than to invalidly cued targets (348 ms for valid and 380 ms for invalid) $F(1,64) = 155.13$, $p < .001$. There was no effect of experiment on RTs. There was an interaction between validity and experiment, with the valid conditions being similar in both experiments (352 ms for no-object and 349 ms for silhouette) and the invalid conditions being different (386 ms for no-object and 374 ms for silhouette) $F(1,64) = 6.65$, $p < .05$. There was an effect of stimulus configuration, $F(7,448) = 10.11$, $p < .001$, which did not differ between the two experiments. There was no interaction between stimulus configuration and experiment. There was a small but significant interaction between validity and stimulus, $F(7,448) = 2.54$, $p < .05$ (see figures 5a and 5c). The three-way interaction was not significant (see Figures 5a and 5c for a RT comparison).

The cost data from the silhouette experiment was compared to cost data from the no-object experiment. This was done to compare the exact shifts of attention between the experiments. Note, however, that there is no such thing as a between-object shift of attention in the no-object experiment, so the within-object and between object distinction in the no-object experiment is only for the purposes of comparison with the silhouette experiment. A 2 (validity) x 2 (experiment) x 8 (silhouette) ANOVA compared the cost data from the silhouette experiment to the cost data from the no-object experiment. The main effect of cost was not significant. There was an effect of stimulus, $F(7,420) = 4.37$, $p < .001$ and there was an effect of experiment, $F(1, 60) = 5.27$, $p < .05$, with overall cost in the no-object experiment being greater than costs in the silhouette experiment (39 ms and 26 ms, respectively). There was an interaction between cost and experiment, $F(1,64) = 10.77$, $p < .005$ (see Figure 5d). There was no significant interaction between stimulus and experiment, between cost and silhouette, and no three-way interaction (see Figures 5b and 5d for a cost comparison).

Discussion

The effect of valid cuing was expected, and the lack of difference in RT between Experiments 2a and 2b suggests that the participants who ran in each experiment were not different overall. The interaction between validity and experiment was surprising. It is a difference in the magnitude of the validity effect between the experiments. The effect of valid cuing is greater in the no-object experiment than in the silhouette experiment. This could be a result of the presence of something else (e.g., the silhouette) in the field of view. The presence of additional visual information may facilitate detection of the target in the silhouette experiment. This makes sense because the targets were white on black in the silhouette experiment and white on gray in the no-object experiment. The fact that there is no interaction between stimulus configuration and experiment in the cost or RT data suggests that there may be a meaningful explanation of the stimulus differences. It suggests that the directions of shift and distances must be driving the differences between the silhouettes, and not the concavities or any effect of silhouette meaning (e.g., similarity of the objects, or their conceptual association).

The invalid within and invalid between data were compared to the no-object data, and the data fits with the hypotheses. There was a bigger difference between the cost data for the silhouette experiment than for the no-object experiment. This finding reflects the presence of the object effect in the experiment with objects and the absence of such an effect in the experiment that had no objects. Since there was an effect of experiment when the within-object cost data was compared to the no-object “within-object” data, and not in the comparison of the between-object data, the object effect in the silhouette experiment seems to be a facilitation of within-object shifts of attention over between-object shifts of attention.

EXPERIMENT 3A

The previous experiments used object recognition as their defining parsing strategy. This is not sufficient to resolve the questions asked in this research. Object-based attention may not be affected by object recognition, and object recognition may be too late in visual processing for segmentation based on object recognition to affect object-based attention. Therefore, Experiments 3a and 3b tested whether the object effect occurs in UC stimuli that are distinguished by lower-level segmentation cues. Another reason that Experiments 3a and 3b are important is that more segmentation cues than simply recognition (e.g., concavities) may be involved in perception of the silhouettes in Experiments 1 and 2, and it is advisable to test these segmentation cues directly. (While the results of comparisons of Experiments 2a and 2b suggest this is not the case, this finding is not definitive and still should be tested further). The overall purpose of Experiments 3a and 3b, as in Experiments 1 and 2a, is to test whether the UC region or the conscious percept is the same as the representation used by the object-based attention system.

It is important to note that the stimuli used are self-splitting figures, and that illusory contours form the only boundaries perceived between the rectangles and the ovals. These particular self-splitting figures are also reversible figures, and observers in a pilot study saw the ovals on top for about the same duration that they saw the rectangles on top. When the figure perceptually reverses, the location of the illusory contours changes accordingly.

Therefore, Experiment 3a used a different form of segmentation to test the generalizability of the results found in Experiments 1 and 2a. The hypotheses for this experiment were the same as for Experiment 2a.

Methods

Participants

Thirty-four participants (19 females and 14 males) ran in this experiment, based on sample size calculations. Fourteen trained observers were used (primarily graduate students in psychology and undergraduate lab assistants who had run in vision experiments before), as well as 20 naïve participants, because the need to perform the task properly was critical. The reason for this was the necessity for the participants to self-initiate a trial while a reversible figure is perceived in a specific way. Participant motivation issues were important; see the procedures and results sections for an explanation of how this difficulty was dealt with. The same restrictions on participation were used as in the other experiments.

Stimuli and apparatus

The stimulus was perceived as two pairs of objects, rectangles diagonally overlapping elongated ovals (see Figure 6b). The stimuli were made from two pairs of objects; a pair of rectangles (5.4^o x 0.89^o) and a pair of long, narrow ovals (5.2^o x 1.3^o at the widest part, see Figure 6b). The rectangles were parallel, and crossed the parallel ovals in two places, making a diagonal grid. Cues and targets always appeared in the center of an intersection of one rectangle and oval, so that they were perceived as located in either an oval or a rectangle. The targets were on the center line of both the oval and the rectangle. Each location was equidistant from two others, the one on the same oval and the one on the same rectangle. The cue was a small white bracket (or v; 0.18^o tall x 0.16^o wide; see Figure 6a) appearing just on the other side of the target location, relative to fixation. The target was a small circle (0.18^o x 0.18^o). The stimuli were black on a dark gray background. The dark gray background was used because pilot work showed a lighter background led to bright afterimages that made it very difficult to see the illusory contours and to see the two possible organizations. The cue and target were white.

Procedures

The trained observers were read the same script as the naïve observers. It was explained what illusory contours are and what reversible figures are, with traditional examples provided on the computer monitor. The trained observers were trained on the reversible figures by looking at the stimulus used in the study for 30 seconds and timing with a stopwatch how long the stimulus was seen in each organization. Participants ran in two blocks of trials over two days, run in counterbalanced order. They were instructed to initiate each trial when the bars were on top during one block and when the ovals were on top during the other block. During the instructions, the participants were asked to report which organization they saw the stimulus in when they first saw the stimulus. During debriefing, the participants were asked which of the conditions was easier (oval or rectangle on top).

Participants ran in two blocks of 188 trials, with seven practice trials each time. Participants ran in the blocks (ovals on top and rectangles on top) in counterbalanced order in one experimental session. There were fewer trials in this experiment than in Experiment 2, because of the difficult and time-consuming nature of the task in 3b. There was a 1000 ms pause after the participant initiated the trial. The cue appeared for 50 ms, there was an interstimulus interval (ISI) of 150 ms, and then the target appeared for 1500 ms or until the participant's response (see Figure 6a). Participants responded to the onset of the target, and RT was measured. Eleven percent of the trials were catch trials when no target appeared. Cues were valid on 66% of the trials and invalid on 22%, with half the invalid trials requiring a within-object shift and half requiring a between-object shift of attention. RT to target onset was measured.

Results

Five naïve participants were removed from analyses according to the same criteria as were used in the previous cuing experiments. The trained observers were all used, despite the fact that three of them did not meet the false alarm criterion. Two of the three who did not meet criterion were vision scientists. The reason for the criterion was to ensure that the participant was trying to do the cuing task properly. One criterion for the choice of the trained observers was willingness to do the task properly, so we did not eliminate them. The mean false alarm rate for the trained observers was 10%, and the mean false alarm rate for the naïve observers was 6%. Trials were removed for the same reason as in the previous studies; 1% were removed from the data of the trained observers, and 1% were removed from the data of the naïve observers.

When participants did not perform the task correctly, the objects that are perceived as on top, and therefore the objects that the targets are in, are not the ones that the data collection codes them as. This means that a perceptual within-object shift would be coded as a between-object shift. The oval on top and rectangle on top conditions were analyzed separately, organized by which condition is reported as more difficult by each participant. This means that the analyses were not “oval on top versus rectangle on top”, but “easier condition versus harder condition.” Participants are more likely to start trials without waiting for the proper organization during the more difficult condition. These two factors (e.g. naïve versus trained observers and easy versus hard condition) are expected to provide sufficient information to determine whether the task was performed properly (especially by the naïve participants) and whether the difficulty affected the results.

A 2 (valid vs. invalid) x 2 (condition difficulty) x 2 (training) x 2 (order) ANOVA was conducted on the RT data. There was a 31 ms cuing effect $F(1,30) = 62.38$, $p < .001$, with valid

RTs of 335 ms and invalid RTs of 366 ms. There was an effect of condition difficulty, $F(1,30) = 5.36$, $p < .05$, with RTs to the targets in the most difficult condition being 360 ms and RTs to the targets in the easier condition being 342 ms. There was an effect of training, with trained observers' average RT being 328 ms and naïve observers' average RT being 373 ms. There were no other statistically significant results.

A 2 (within-object vs. between-object) x 2 (condition difficulty) x 2 (training) x 2 (order) ANOVA was conducted on the cost data. The only statistically significant result was an interaction of cost, training, condition difficulty and order, $F(1, 30) = 4.80$, $p < .05$. Tukey's pairwise comparison revealed that the only condition that had an effect was the harder condition for the untrained observers who ran in the bars on top condition first. That condition found the object effect.

Discussion

The fact that an object effect was not found in Experiment 3a could suggest one of two things. The lower-level segregation cues may not be sufficient to produce segregation in object-based attention, or the stimuli or task may have affected the results. Experiment 3b tested these possibilities.

EXPERIMENT 3B

Experiment 3b is a control experiment with two purposes. The first is to see if the object effect is found with stimuli that are nearly identical to the stimuli that were used in Experiment 3a, except that they are not UC and to see if these new stimuli replicate the literature by producing an object effect,. The second purpose of this experiment is as a control to compare with Experiment 3a. The stimuli used in Experiment 3a were self-splitting figures (see Figure 6a), and the stimuli used in 3b were slightly modified versions of them (see Figure 6b). Self-splitting figures (Kellman & Shipley, 1991) are uniformly connected areas that are perceived as two separate surfaces due to segmentation operations. Three powerful lower-level segmentation cues are L-shaped intersections, linear continuity, and concavities (Driver & Baylis, 1995; Grossberg, 1997). Self-splitting figures use these segmentation cues as well as visual interpolation in a phenomenon called figural scission (Koffka, 1935; Metelli, 1970). Experiment 3b used two stimulus conditions, one where two black ovals occlude two black rectangles and one in which the rectangles occlude the ovals. Cues and targets appeared in the center of the intersection of the rectangle and oval. It was expected that a typical cuing effect and object effect would be found.

Methods

Participants

Thirty-three undergraduates (12 males and 21 females) participated in this experiment. The same restrictions on participation were used as in the other experiments.

Stimuli and Apparatus

The apparatus were the same as in Experiments 1 and 2. The viewing distance was 51 inches. The stimuli and apparatus were identical to Experiment 3a except that the borders distinguishing which shapes are on top were removed (see Figure 6b). There was a faint dark gray line (one pixel wide and dotted, but it does not appear dotted at the viewing distance used) serving as an outline border between the ovals and the rectangles. In one block of trials, the ovals were on top, and in the other the rectangles were on top.

Procedure

The procedures were identical to Experiment 3a, except that the participants ran in both sessions in the same day.

Results

Four participants were removed from analysis due to their high false alarm rate, resulting in 33 participants. The average false alarm rate was 5%. One percent of trials were removed from analysis because the RTs were more or less than 2.5 standard deviations from the average per condition. A 2 (valid vs. invalid) x 2 (top stimulus: bars vs. ovals) ANOVA was carried out on RTs. There was a 40 ms cuing effect, with valid RTs shorter than invalid RTs (402 ms vs. 442 ms respectively) $F(1,32) = 74.1$, $p < .001$. There was no effect of top stimulus, and there was no interaction between the two variables. Another 2 (within- vs. between-object shifts) x 2 (bars on top vs. ovals on top) ANOVA was run on the cost variable. Costs for within-object shifts were less than for between object shifts of attention (47 ms vs. 55 ms respectively) $F(1,32) = 8.1$, $p < .005$. There was no effect of top stimulus or interaction between top stimulus and cost.

The results were otherwise analyzed in the same way as Experiment 3a. The results of the naïve observers in Experiment 3a were compared to the data from Experiment 3b in a 2 (experiment) x 2 (within vs. between) x 2 (easy vs. hard) mixed ANOVA. This was to compare the magnitude of any object effect when the objects were subjectively perceptually segregated (as in Experiment 3a) with when they were physically segregated (as in Experiment 3b).

Comparisons of Experiment 3a and 3b

A 2 (validity) x 2 (experiment) ANOVA was carried out on the RT data, using only the naïve observers. An effect was found of validity, $F(1, 50) = 121.84$, $p < .001$, with RTs to validly cued targets less than RTs to invalidly cued targets (378 ms and 418 ms respectively).There was an effect of experiment, $F(1,50) = 5.28$, $p < .05$, with RTs in experiment 3a (UC; 373 ms) less than RTs in experiment 3b (not UC; 424 ms). There was no interaction between validity and experiment.

A 2 (validity) x 2 (experiment) ANOVA was carried out on the cost data. There was an effect of cost, $F(1,50) = 8.42$, $p < .01$, with costs in the invalid within condition (41 ms) being less than costs in the invalid between condition (47 ms). An effect was found of experiment, $F(1,50)=2.88$, $p<.05$, with costs for Experiment 3a (UC; 34 ms) less than costs for Experiment 3b (not UC; 54 ms). There was no interaction between cost and experiment.

<u>Discussion</u>

There was a validity effect and an object effect in this experiment, as predicted. This data replicates the literature on object-based attention and the object effect, and suggests that these new stimuli are sufficient to elicit the object effect.

No object effect was found in Experiment 3a. Occasionally the participants reported that the reversible figure reversed in the middle of a trial, so that may have reduced the effect in the results. When compared to the results of Experiment 3b, however, there was an overall object effect. This object effect is very small (6 ms). There is no interaction, which is surprising because each experiment has different cost results when analyzed separately. This can be explained, however, by the small magnitude of the object effect. The object effect in the non-UC Experiment (3b) is only 8 ms, and the same difference (between the magnitude of the within-object and between-object shifts of attention) in Experiment 3a (UC) is 5 ms, so overall the effect was driven by the non-UC experiment, but the numbers were so close that there was no interaction. Due to the small magnitude of the 5 ms object effect in the collated data, I believe that the data from Experiment 3a, which says that there is no object effect when the stimuli is UC can be accepted.

The magnitude of the object effect is surprising. Although significant, the small (8 ms) object effect found in Experiment 3b with non-UC stimuli may reflect a lessening of the status of the objects used in this experiment as objects by the visual system- they may simply be less object-like than the traditional two rectangles used in object-based attention experiments. Only speculations can be made about why the object effect was so small. In this case, the uniform connectedness and the faintness of the borders may have reduced how object -like the objects used were to the object-based attention system.

GENERAL DISCUSSION

This study was designed to explore the representation of an object that object-based attention operates on. The representation could be based on a UC region representation or on the object that is perceived. The first experiment investigated how object-based attention operates on a UC silhouette that is recognized as two, whether as one (It is one UC region) or two (it is recognized as two) objects, in a discrimination experiment. There was no object effect. Experiment 2a tested the same question with a cuing experiment. In this experiment, an object effect was found. Experiment 2b utilized the same paradigm as 2a with no silhouettes, to explore the differences between Experiments 1 and 2a, as well as some silhouette-related differences that were found. This experiment suggested that the silhouette differences may be based on spatial factors like direction and distance between the cue and target. Experiment 3a tested the same overarching research question with a different stimulus type, self-splitting figures, which utilize basic segmentation cues. No object effect was found in Experiment 3a. Experiment 3b tested the stimuli used in Experiment 3a with borders included, and there was an object effect.

Why does attention seem to operate one way in some circumstances and another way in other circumstances? These experiments suggest that there were unexpected factors at work. As well as providing an answer to the research question, they have uncovered a related line of questions that have an impact on how future experiments should be created. Overall, the results support the hypothesis that object-based attention can operate on a representation of UC stimuli that have been segregated; however, there seem to be limited circumstances in which this occurs (see below). The circumstances found in the present study that affect whether a UC stimulus is segregated include certainty about the location of the target relative to the segregated perceptual edge. The circumstances may also be task-related; a simple task may be necessary, which does not require focused attention on the target while attention is in the process of shifting. While the study was not designed to explore these circumstances, they became evident from the pattern of results across the study.

In other circumstances, object-based attention seems to operate on a representation based on UC regions. The fact that the representation used can be either UC or segregated is not as surprising as it initially seems, because Watson and Kramer (1999) and Chen (1998) found with grouping UC regions, that the representation used can be situationally dependent. Chen found that it was dependent on the instructions given regarding whether two abutting regions were to be considered one item or not. Watson and Kramer manipulated the percept with an additional task that caused it to be important to group the separate UC parts of an object. This study indicates the need for more experimentation in this area.

There are a few possible reasons that silhouettes do produce the object effect in one experiment (Experiment 2a) and do not in another experiment (Experiment 1). First of all, there was an interaction in Experiment 1, such that there was an object effect with two silhouettes, there just was not one overall. The results of the discrimination experiment may not be relevant to the object effect in UC stimuli (i.e., to the hypothesis). This may be related to the mixed findings in the literature using discrimination tasks to study object-based attention. Several different manipulations have been shown to eliminate, or obscure the object effect. Davis and Holmes (2005) found that the use of outline stimuli and intervening luminance edges affect whether the object effect is found in discrimination studies. Goldsmith and Yeari (2003) found that when the focus of attention is restricted to fixation, for example, when there is an endogenous cue in a discrimination study, the object effect does not occur. However, when attention encompasses the whole object, as usually occurs in exogenous cuing studies, the object effect is found. They found that this is not due to the cue type, but to the focus of attention. When attention has a tight focus that does not encompass the whole object, the object effect is not found. Law and Abrams (2002) found that use of a short stimulus onset asynchrony (SOA) can cause the object effect to not occur, in discrimination studies.These are examples of other discrimination studies in which the object effect is not found.

Lamy and Egeth's (2002) Experiment 3, the experiment from which the task was replicated by Experiment 1, explored the hypothesis that a shift of attention is crucial to the object effect. In one experiment, they presented one target, then, after a variable ISI, a second target appeared in either the same object or a different object. The participants judged whether the targets were the same or a different size. RTs were faster when the targets were in the same object. In their Experiment 4, Lamy & Egeth required participants to make a size judgment of a target with a distractor present. A cue appeared, then a target was presented in the same position. On two-thirds of the trials, a distractor appeared in the same or another object. Participants made a size judgment while trying to ignore the distractor. The presence of a distractor affected RTs, but RTs were the same irrespective of which object the distractor was in. In this experiment (Experiment 4), when the task was best performed without shifting attention, the object effect was not found. Lamy and Egeth found the object effect in Experiment 3, in which the task was best performed when participants attended first to the first target, then shifted to the second target. However, this effect was found to be dependent on the SOA as well. They found the best object effect at 200 ms, which is the SOA used in the current discrimination study.

An alternate explanation of the task effect in Experiment 1 may be that the task required focus on the shape of the targets. This may have affected the shape processing of the silhouette that the targets appeared in. Since participants had to process the shapes of the targets in detail to perform the task, this may have changed the focus of attention from diffusely focused on the whole display to narrowly focused on each target. As in Goldsmith and Yeari's (2003) experiment, the focus of attention may have been narrowed to the point that it no longer encompassed the entire silhouette, and therefore the silhouette produced no attention-related effects. This may have eliminated the object effect. There is, however, another competing explanation of why there were different findings across the two experiments with silhouettes. Each silhouette had its own characteristic RTs and costs, which varied widely. The object effect may have been diminished by these variations in the discrimination experiment. This can explain the findings of the discrimination experiment, but it is also necessary to consider the differing results between the two cuing experiments with UC figures.

Why were the results different in these two experiments (Experiments 2a and 3a) with the same task? A different segmentation strategy was used to segment the self-splitting figure, so the differences may be due to that, and not to any failure of the experiment. However, the task for that experiment (Experiment 3a) was also comprised of two separate tasks. Participants first had to wait for the reversible figure to reverse before initiating the cuing task. The task of waiting for the reversible figure to be in the right organization was emphasized as the most important part of the experiment, so that participants would perform this task properly. This was vitally important, because how the participant saw the reversible figure determined the cue-target location relationship, i.e., it determined which condition the trial fell into - the within-object or between-object condition. The emphasis on perceiving the proper organization may have affected the results of the cuing task. Also, due to the reversible nature of the illusory contours in the self-splitting figure, the location of the cue and target was in an ambiguous part of the stimulus. The purpose of the locations chosen for the cue and target locations was to control the cue and target locations and directions of shift – so they would be constant through all conditions of the experiment. The non-UC stimuli in Experiment 3b differed from the UC self-splitting figures not only by the fact that there were borders, but also in the fact that observers did not have to wait for a particular organization before initiating a trial. The other major difference between the two experiments was the potential ambiguity of the cue and target locations due to the reversibility of the UC stimuli.

The differences among the silhouettes are more difficult to account for. There are several possible explanations for the differences among the silhouettes in Experiment 1 and 2a. One of the challenges is ambiguity in the image itself. Due to the differences in these silhouettes, it would be useful in a follow-up experiment to have a variety of silhouettes with different shift directions and distances to narrow down what the differences are. Experiment 1 showed no object effect, but silhouette-specific effects may have overshadowed the effect of interest. Experiment 2a showed a large silhouette-specific effect, but did show the object effect. In future experiments, care should be taken to control intervening luminance edges and have a more balanced representation of every possible direction of shift.

Implications of the Results for Perceptual Organization

The results provide interesting insights into the representation of an object in the object-based attention system. The object-based attention system can operate on a uniformly connected region that is perceived as two objects as two units, not one. This supports the hypothesis that object-based attention can operate on a segregated representation. Watson and Kramer (1999) and Chen (1998) both found similar results; that object-based attention can operate on a grouped representation as one object. Similar to Watson and Kramer and Chen, the present experiment also found that the representation used is dependant on the circumstances. This is consistent with the idea that perceptual organization and object-based attention interact. They may operate in cascade, in parallel, or there may be important top-down influences from one process to the other.

This data has interesting implications for the functional aspects of object-based attention. It is a flexible process, which suggests that object-based attention can function differently in varying situations. Attention may be sensitive to the context of the situation: the goal of the viewer, the amount of processing resources that are free. In situations in which the figure/ground segmentation cues are ambiguous, attention can utilize the UC representation. These things may determine which representation is used in a certain circumstance. One possible (testable) function for this flexibility is that when the scene can be viewed only for a short time (e.g., when driving on the freeway, in visual masking experiments) object-based attention can still function.

Conclusions

The data, though different for every experiment, suggests that object-based attention is capable of operating on a representation of a UC object that is perceptually segregated. It still remains to be seen what forms of segregation work with object-based attention, but higher-level segregation strategies related to object recognition can define an object. However, with this segregation strategy, the object effect is small in magnitude. This suggests the possibility that the object-likeness of separate parts of UC figures is not complete. Ambiguity about which object cues and targets belong in and the size of the attentional focus can both interrupt the segregation of UC figures.

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Table 1

Familiarity Ratings for Experiment 1

Stimulus	Average	Standard deviation
Monitor/keyboard	1	0
Child with gift	3.49	1.61
Pelican/post	1.51	0.69
Fork/spoon	1	0
Mug/glasses	2.24	1.79
Sponge/dish soap	2.41	1.46
Two people	1.83	1.06
Stapler/tape dispenser	1.11	0.31

Table 2

Familiarity Ratings for Experiment 2a

Stimulus	Average	Standard deviation
Monitor/keyboard	1	0
Child with gift	3.88	1.81
Pelican/post	2.00	1.93
Fork/spoon	1.75	2.12
Mug/glasses	3.29	2.93
Sponge/dish soap	3.38	2.20
Two people	1.88	1.73
Stapler/tape dispenser	1.75	2.12

Figure Captions

Figure 1. This set of objects depicts a stapler and tape dispenser in various states of uniformity and connectedness. a) The stapler is uniformly connected, as is the tape dispenser. b) The stapler and tape dispenser make up a single UC region. c) The stapler is made up of several UC regions; while it is connected, it is not uniform.

Figure 2. a) The trial sequence for Experiment 1. The silhouette appears for 1000 ms for fixation, the first target appears for 204 ms and remains up when the second target appears for 2000 ms or until the participant responds. b) The trial sequence for Experiments 2a and 2b. The silhouette appears for 1000 ms (in 2a; There is a 1000 ms pause once the participant begins each trial in 2b) then a cue appears for 50 ms, after which it disappears for a 150 ms ISI and the target appears for 1500 ms or until the participant responds.

Figure 3. Silhouettes used in Experiments 1 and 2a; the other two silhouettes can be seen in figure 2.

Figure 4. a) Mean reaction times from “same response” condition in Experiment 1 for within and between object shifts of attention. b) Reaction time data from “different response” condition in Experiment 1 for within and between object shifts of attention. Error bars represent standard error of the mean.

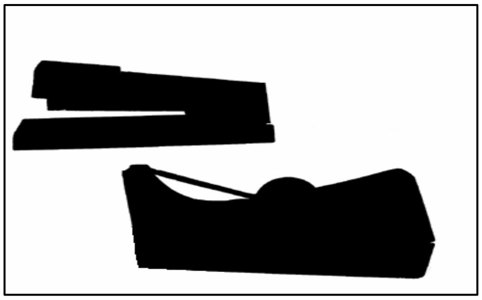
Figure 5. a) Mean reaction times from Experiment 2a (with silhouettes) for validly and invalidly cued targets. b) Costs for Experiment 2a (with silhouettes). Costs represent the difference between the valid and the invalid within and between conditions. c) Mean reaction time for Experiment 2b (no-object) for valid and invalidly cued targets. d) Costs for Experiment 2b (no-object) for within and between object invalid conditions. Note that the designation of within and between is meaningless for this graph, because there were no objects in this experiment, but they

are separated in the graph for comparing directions of shift and target locations. Error bars represent standard error of the mean.

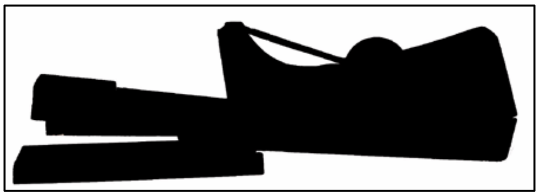
Figure 6. a) The stimuli used in Experiment 3b, and the trial sequence for both experiments. 1000 ms after the participant initiates the trial, a cue appears for 50ms, after which it disappears for a 150ms ISI and the target appears for 1500ms or until the participant responds. The self-splitting figure does not disappear between trials. b) The stimuli used in Experiment 3a.

Figure 7. a) Mean reaction times from Experiment 3a (Not UC) and 3b (UC). b) Costs for Experiment 3a (Not UC) and 3b (UC). Error bars represent standard error of the mean.

Figure 1a



b



c

Figure 2

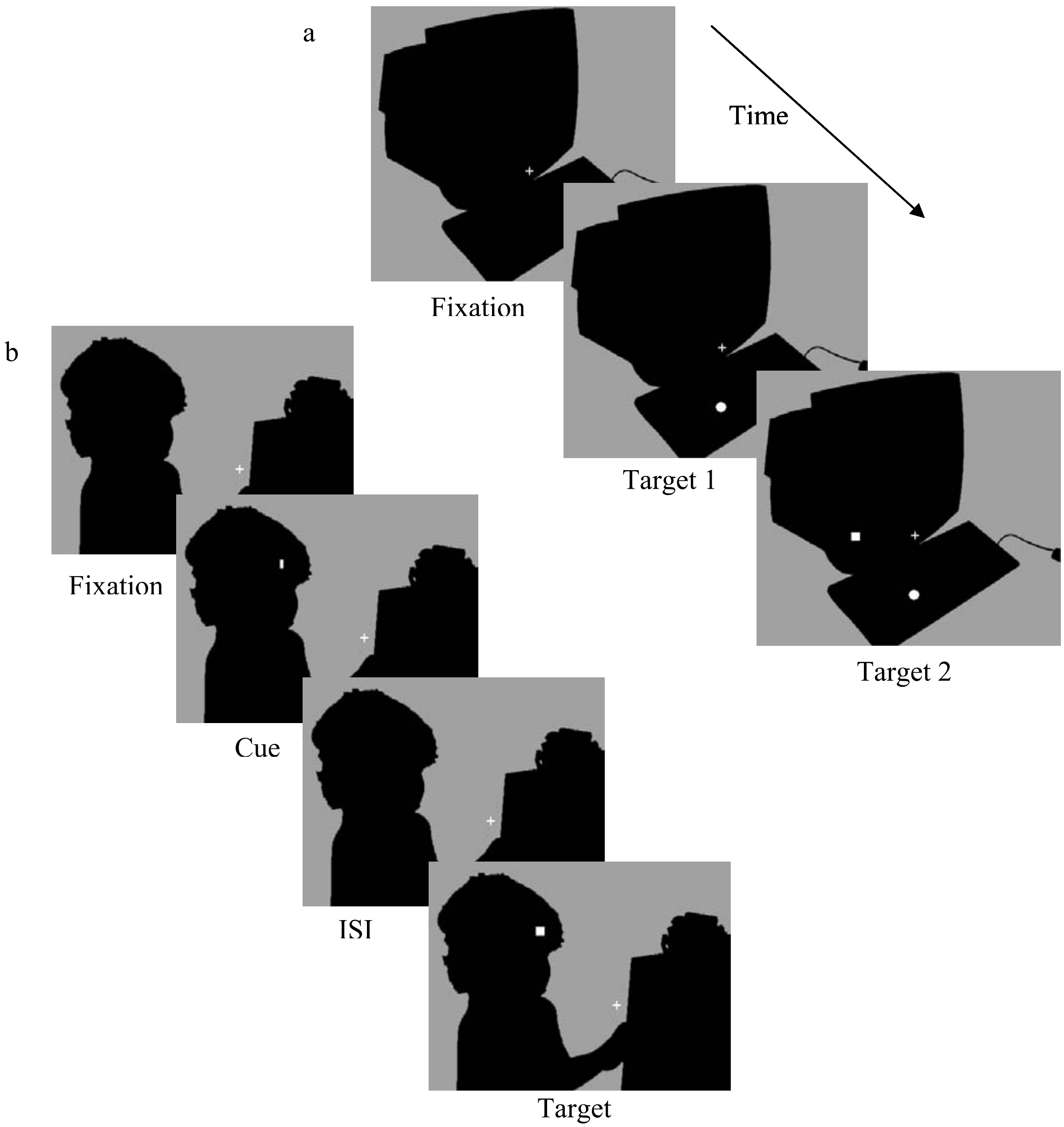


Figure 3

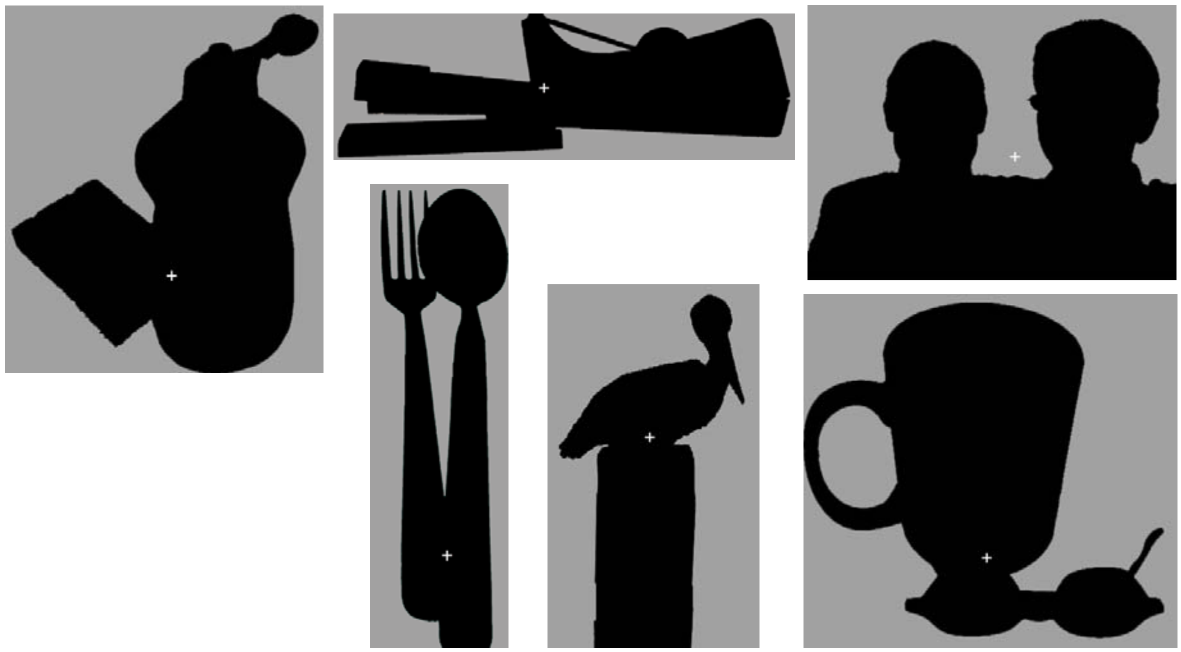
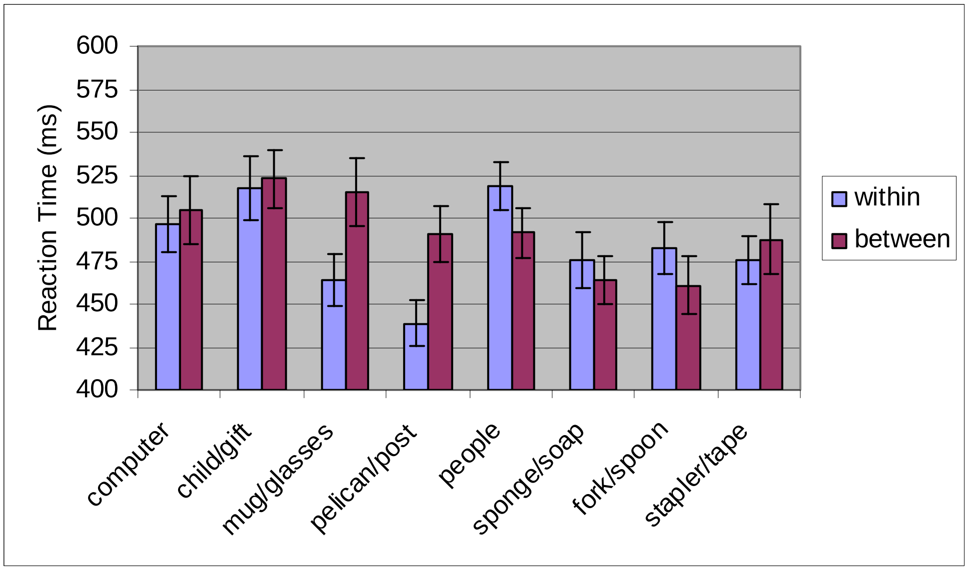


Fig 4 a


600
575
550
525
500
475
450
425
400
Reaction Time (ms)
computer
child/gift
mug/glasses
pelican/post
people
sponge/soap
fork/spoon
stapler/tape
within
between

b

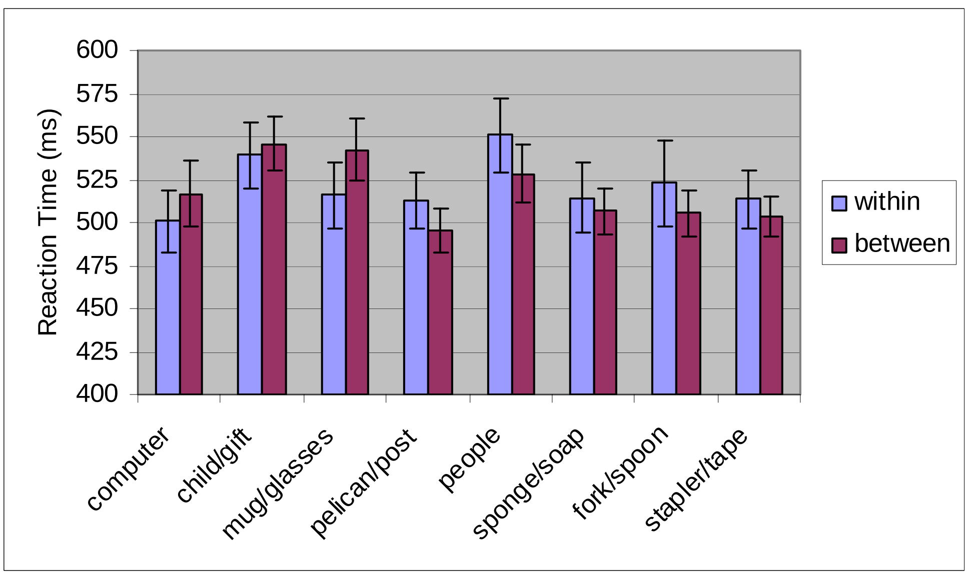

600
575
550
525
500
475
450
425
400
Reaction Time (ms)
computer
child/gift
mug/glasses
pelican/post
people
sponge/soap
fork/spoon
stapler/tape
within
between

Figure 5

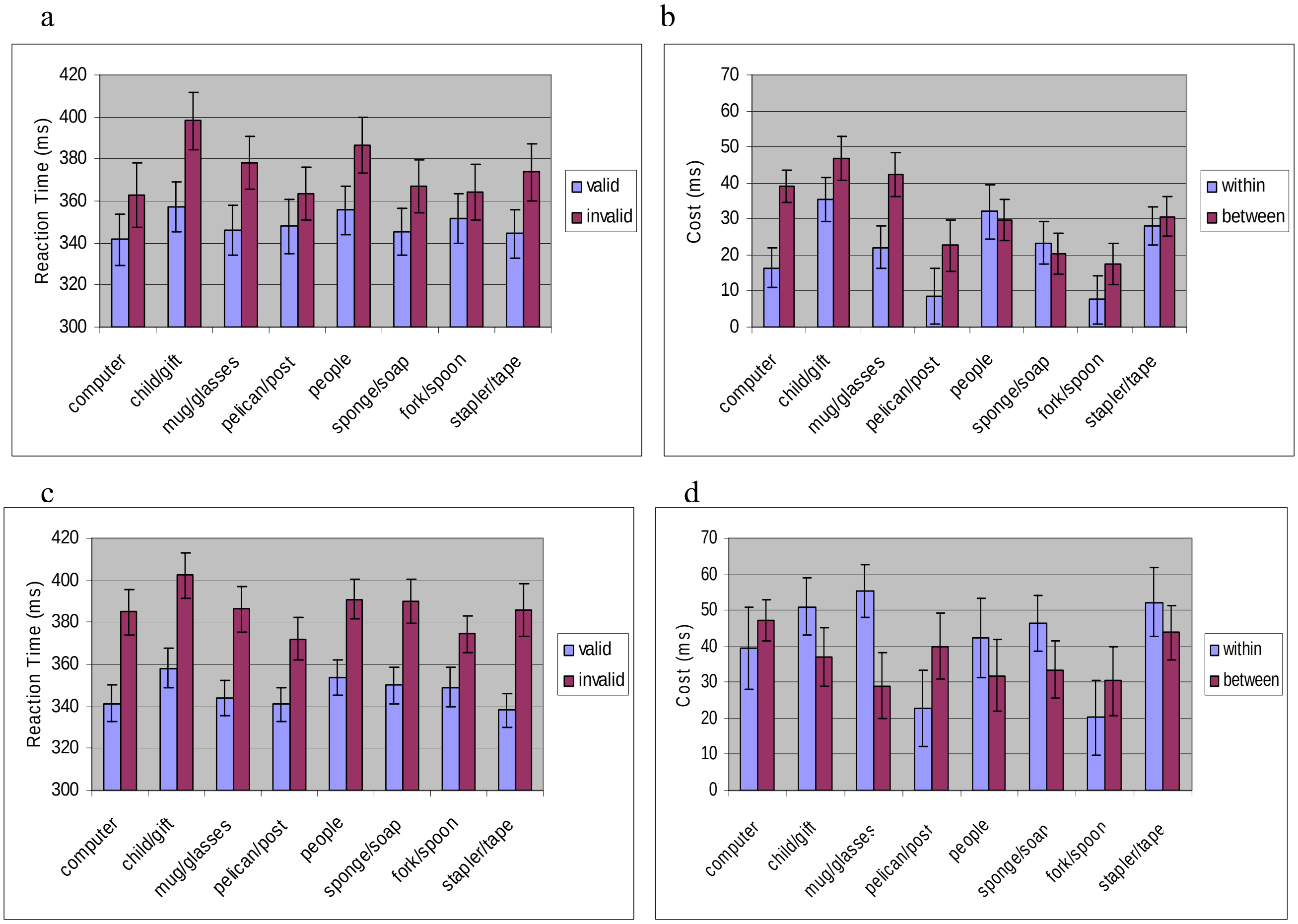

a
Reaction Time (ms)
420
400
380
360
340
320
300
valid
invalid
computer
child/gift
mug/glasses
pelican/post
people
sponge/soap
fork/spoon
stapler/tape
b
Cost (ms)
70
60
50
40
30
20
10
0
within
between
computer
child/gift
mug/glasses
pelican/post
people
sponge/soap
fork/spoon
stapler/tape
c
Reaction Time (ms)
420
400
380
360
340
320
300
valid
invalid
computer
child/gift
mug/glasses
pelican/post
people
sponge/soap
fork/spoon
stapler/tape
d
Cost (ms)
70
60
50
40
30
20
10
0
within
between
computer
child/gift
pelican/post
people
fork/spoon
stapler/tape

Figure 6

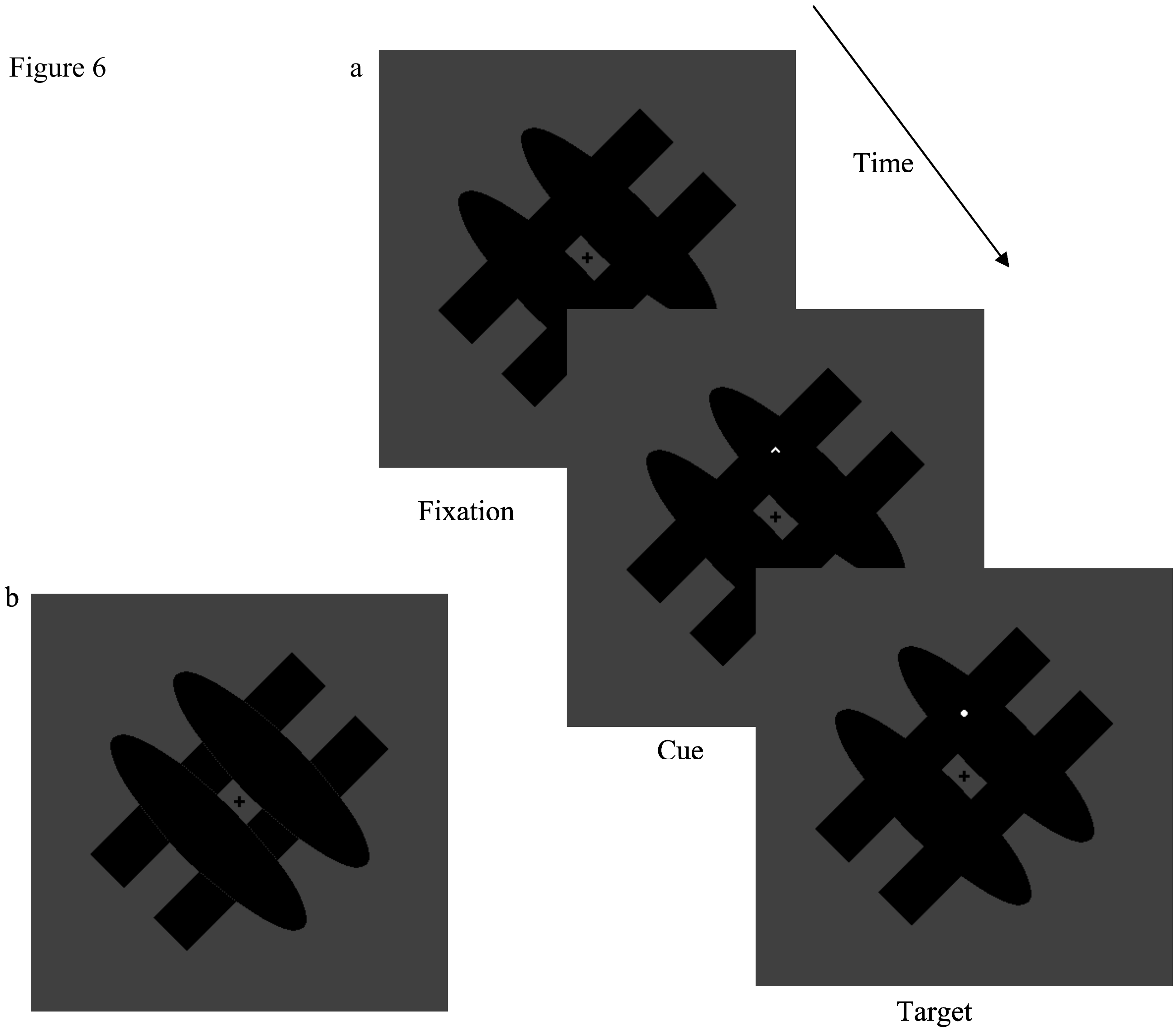
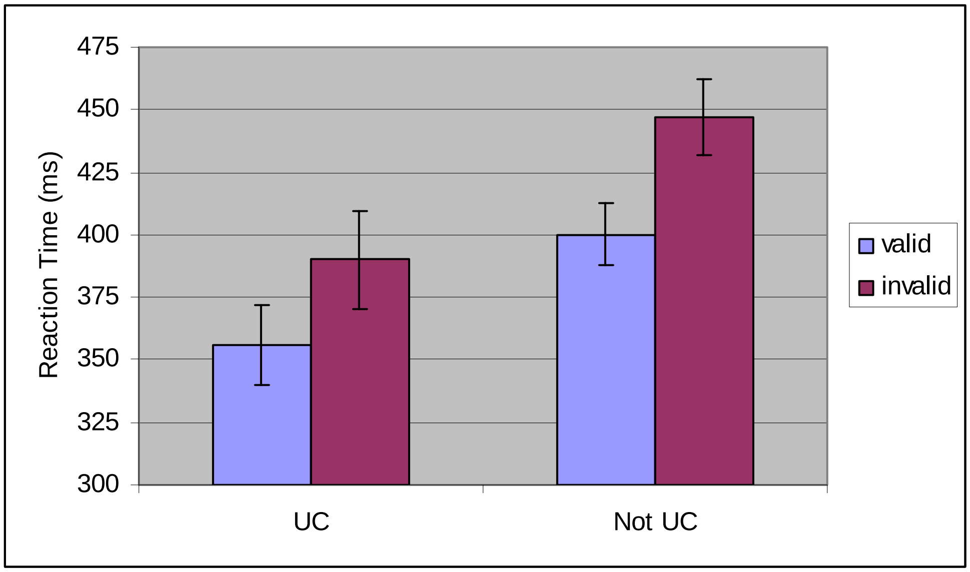
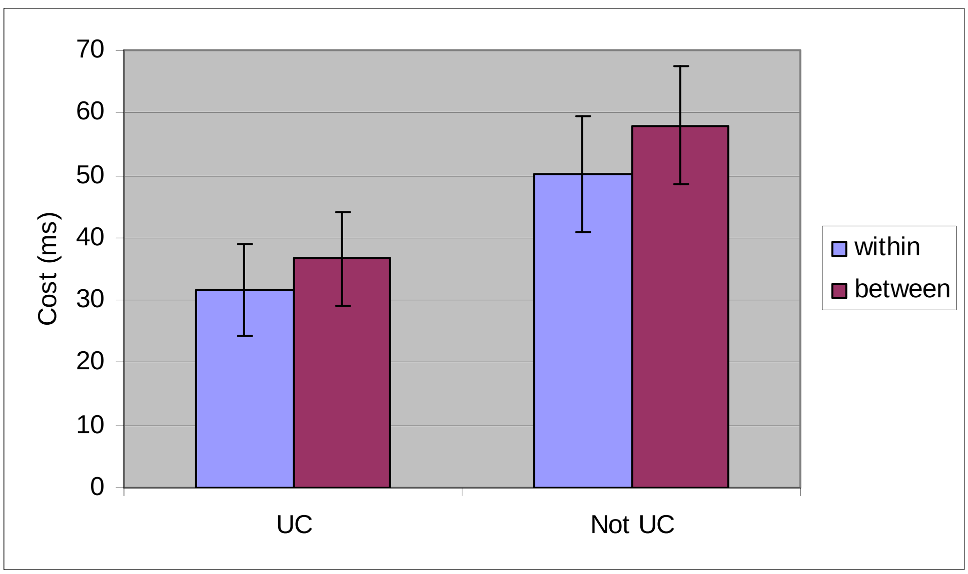


Figure 7

a


Reaction Time (ms)
475
450
425
400
375
350
325
300
UC
Not UC
valid
invalid

b


Cost (ms)
70
60
50
40
30
20
10
0
UC
Not UC
within
between