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The Importance of Attention and Object Representation for Visual Processing

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Psychology

by

Julie J Kang

August 2010

Dissertation Committee:

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ABSTRACT OF THE DISSERTATION

The Importance of Attention and Object Representation for Visual Processing

by

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Doctor of Philosophy, Graduate Program in Psychology
University of California, Riverside, August 2010
Dr. George John Andersen, Chairperson

Space-based, object-based, and the grouped array theories of attention were examined using modified versions of Watson and Kramer's target judgment task. In addition, I examined how predictions from the three theories can be used in an applied context (i.e. the design of traffic signs).

There were six experiments. Experiment 1A examined the effects of spatial precuing and spatial separation on judgments for a target judgment task and found no significant results. On Experiment 1B, the precue was modified into a go/no go task. The results of Experiment 1B indicated a precue benefit. Also, the results indicated a benefit in performance for different-object judgments at large spatial separations. Experiment 2 compared between-object and within-object precues and found a different object benefit. Experiment 3 was conducted to examine whether preattentive processing is dependent on modal completion. Comparisons were made between different sign

configurations (UCR object, an amodal object, and a grouped object). The results indicated a different object benefit for the UCR sign and amodal sign. However, when the wrenches were presented on the grouped unit sign, subjects had higher accuracy for features presented on the same wrench. Experiment 4 was conducted to examine the how the connectedness of an object's representation and top down information affected performance on an object judgment task. The results indicated faster speed responses for valid precues. However, for invalid precues, responses were significantly slower for occluded as compared to continuous wrenches. This result supported the UCR object theory that a perceptual object is formed when uniform connected regions are present. Experiment 5 examined whether the connectedness of a sign affected perceptual processing in a real world setting. Symbols from traffic signs were used in three different sign configurations (continuous region, connected region, and separate regions). Subjects were faster to respond to targets located on the same as compared to different continuous regions for the connected region sign. The connected sign was processed as two separate objects rather than a single continuous object. Similar to the results of Experiment 1B, there was an advantage for making comparisons between objects rather than within a single object.

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Introduction

Vision is the process by which an observer extracts useful information from light. Evidence indicates that observers can only process a subset of information in the visual field (Broadbent, 1958). For example, studies have found that observers fail to perceive changes in objects when not attending to them (Rensink, O'Regan, Clark, 1997; Simons, Levin, 1998). This phenomenon, referred to as change blindness, suggests that the visual system requires attention to selectively process information at the exclusion of other details. In this dissertation, I define attention as the allocation of processing resources to information in the visual field (Kahneman, 1973; Eriksen & Hoffman, 1972; Jonides, 1980, 1983). The goal of my dissertation is to determine how visual information is selected for processing.

The effectiveness of vision to process information is determined in part by how well certain features are attended (i.e. colors, shapes, etc.) while irrelevant details are ignored. Previous attention studies have focused on whether information is filtered at an early or late stage of perceptual processing. Supporters of early filter attention theories hypothesized that information is filtered prior to the judgment of relevant features (Broadbent, 1958; Treisman, 1969). Alternatively, supporters of late filter theories of attention posit that information is filtered after features have been identified (Deutsch & Deutsch, 1963).

Theories of attention have also been argued to be based on locations in the visual scene (space-based theories) or based on the presence of objects (object-based theories). Three different versions of space-based theories have been proposed: the spotlight, zoom lens, and gradient theory. The different versions of space-based theories will be reviewed separately, followed by a review of the object-based theory and the grouped array theory.

According to the spotlight theory, processing resources are allocated to an attended region in the visual field. Information within this region (i.e. spotlight) is perceptually processed whereas information outside this region is not processed. The size of the spatial region has been examined using a flanker paradigm (Eriksen & Hoffman, 1972). In the study by Eriksen and Hoffman, subjects were presented with a central target surrounded by two non-target flankers. They were instructed to identify one of four possible (centrally located) targets with a lever response. The targets (M or U) were associated with a left lever response and targets (A or U) were associated with a right lever response. The non-target flankers were valid, invalid, or neutral relative to the target letter. For the valid condition, flankers were associated with the same response as the target. For example, if the target letter was “A”, a valid flanker was from the same set (i.e. U). In the invalid condition, flankers were associated with the opposite response as the target letter. For example, if the target letter was “A”, the flanker was from the opposite set (i.e. H or M). In the neutral condition, flankers did not match either of the target responses (i.e. “X”).

According to the spotlight theory, all information within the attended region is processed. Therefore, incongruent flankers should interfere with processing targets if both flankers and target are located within the attended region. Indeed, they found that response times increased when incongruent flankers were present. This result suggests that all information within the attended region was processed. In addition, the size of the attended region was estimated by systematically varying the spatial separation between the target and flankers. Response times increased when incongruent flankers were

located within 1° visual angle of the target. Flankers located outside this region did not affect performance suggesting that the extent of the spotlight is approximately 1° visual angle.

Another method to measure the spatial extent of visual attention is by manipulating the spatial separation between a precue and target (Posner, 1980). Precues orient attentional resources to the target's spatial location prior to the target's appearance. For example, a precue can be a change in luminance or an arrow that indicates the target's location. Following a precue, subjects must respond as quickly and as accurately as possible to a subsequently presented target. A precue is valid, invalid, or neutral to designating the target's location. A valid precue specifies the target's location. In contrast, an invalid precue specifies an incorrect location. A neutral precue does not specify any information about the target's location (i.e. an arrow pointing in both directions). As a result, subjects are usually faster at detecting a target with a valid precue as compared to a neutral precue (Eriksen & Hoffman, 1973, 1974; Hoffman 1975; Eriksen & St. James, 1986; Posner, 1980). This suggests that targets are processed more efficiently because the resources are concentrated at a designated location rather than distributed across the entire visual field. As a result, subjects are generally slower and/or less accurate subsequent to an invalid precue presentation. Thus, it is argued that longer latencies are due to shifting attention (i.e. spotlight) to the correct location of a target.

An alternative hypothesis to the spotlight theory is that attention operates like a zoom lens (Eriksen & St. James, 1986). According to the zoom lens theory, the spatial extent of attention is adjustable while processing resources are uniformly distributed

within the attended area (Eriksen & Yeh, 1985, 1985; Eriksen & Rohrbaugh, 1970; Downing & Pinker, 1985; LaBerge, 1983). An assumption of the zoom lens theory is that processing resources are more densely concentrated when attention is focused to a smaller region in the visual field. This is analogous to a high-power setting on a zoom lens. For these conditions, fine grain spatial information can be recovered at a faster rate of processing. Studies have found that subjects respond faster and more accurately in discrimination tasks when attention is focused to a smaller region as compared to a larger region (LaBerge, 1983). Alternatively, processing resources are diffusely concentrated when attention is widely distributed across the visual field. At this low-power setting, stimuli are processed in parallel with a corresponding decrease in efficiency (Beck & Ambler, 1973). Thus, the zoom lens analogy is consistent with an inverse relationship between the size of the attended region and the concentration of processing resources within that area (Eriksen & St. James, 1986).

The size of the attended region can be manipulated using precues that indicate the size of the target (Eriksen & St. James, 1986) or by orienting the observer to a stimulus of a specific size (i.e. letter vs. a word); (LaBerge, 1983). LaBerge (1983) investigated the size of spatial attention using a double judgment paradigm with two tasks. Task 1 served to focus attention either to a small or large area. Task 2 was used to measure the spatial extent of attention. There were two variations of Task 1. In one version, the subject must identify the central letter in a five-letter word to focus attention to a small area. In another version, the subject must categorize the five-letter word to focus attention to a larger area. Occasionally, a probe (i.e. digit “7”) would appear in one of five locations

previously occupied by the letters. The subject responded to the probe with a button press (see Figure 1).

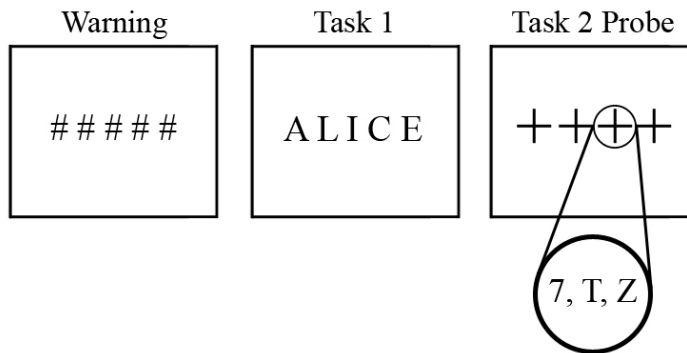


Figure 1. LaBerge's (1983) double identification task.

According to the spotlight theory, performance should be determined by the spatial distance between the target's position in Task 1 and the probe's position in Task 2. As a result, response times should increase as a function of the probe's distance from the target. In contrast, a prediction of the zoom lens theory is that performance is determined by the amount of attentional resources allocated from the previous task. Specifically, if attention was focused to a single letter then response times should increase as a function of the probe's distance to central fixation. If, however, attention was distributed to a spatial location occupied by a word rather than a letter then no change in response time was predicted across all probe locations.

Results from LaBerge's (1983) study provided evidence in support of the zoom lens theory. Responses times were dependent on whether Task 1 was a word or letter

identification task. For the word task, response times to the probe did not differ across five letter positions. For the letter task, subjects processed the probe more quickly at the centrally attended location compared to peripheral locations. These results substantiate the hypothesis that processing resources occupy a larger area in the visual field when the first target was a word as compared to a letter.

Attentional resources can also be focused to a smaller region by increasing task demands (LaBerge, Brown, Carter, Bash, & Hartley, 1991). LaBerge and colleagues (1991) employed a double identification task to manipulate the attended region. The purpose of the study was to examine whether the size of the attended region could be manipulated by varying the stimulus onset asynchrony (SOA) between the Task 1 and Task 2. According to LaBerge et al. decreasing the SOA should be a more difficult condition than longer SOA conditions. Thus, according to the zoom lens theory, processing resources should become narrowly focused (and more concentrated) with shorter SOA's.

In their study Task 1 served to focus attention to a specific size at a particular location (LaBerge, Brown, Carter, Bash, Hartley, 1991). Task 1 was a go/no go task in which subjects must either respond to the stimuli in Task 2 (go trials) or not respond (no go trials). In Task 1, subjects were presented with a row of alternating T's and Z's, with 7, T, or Z in the center location (e.g. TZTZTZTZ7TZTZTZTZ). If the center character was 7, subjects were instructed to respond to Task 2 (i.e. go trial). However, subjects were instructed to withhold responses if the center stimulus was a T or Z (i.e. no go trial). Task 2 was used to direct attention to different locations of the visual field. Task 2

consisted of a character (C, H, S, or K) flanked by eight identical characters (e.g. HHHHHHHHCHHHHHHHH). The letters C and H were associated with a left joystick response whereas S and K were associated with a right joystick response. The flankers were compatible, incompatible, or neutral relative to the central target. Compatible flankers were composed of the letters from the same set as the target. Incompatible flankers were composed of letters from a different set as the target. Neutral flankers were composed of letters that were not in either of the two letter sets. The difference in reaction time between incompatible and compatible trials (I-C) was used to indicate the effectiveness of flanker identification. An increase in I-C indicated that the flankers were more effective in interfering with target identification whereas a decrease indicated that it was less effective (Miller, 1987).

An assumption of the spotlight theory is that processing resources are uniformly distributed within the region of attention. The prediction is that a target located within any location of the attended region is processed with equal efficiency. Thus, cuing different regions within the spotlight will not affect performance for a subsequently presented target (Task 2). In contrast, an assumption of the zoom lens theory is that performance is determined by the amount of processing resources allocated to Task 2 based on the spatial extent of attention cued by Task 1. Therefore, incompatible flankers should not interfere with the subject's response to the central target when attention is more narrowly focused (i.e. shorter SOAs). Likewise, increasing the range of spatial attention (i.e. longer duration of SOA) should result in poorer performance in support of the zoom lens hypothesis suggesting that the spatial extent of attention is adjustable.

In addition to using task demands, precues have been used to investigate whether the spatial extent of attention is adjustable (i.e. zoom lens theory); (Eriksen & St. James, 1986). Eriksen and St. James presented subjects with a circular array of eight letters centered at a fixation point. One of two possible targets (S or C) could appear at one of the eight letter positions. The array was displayed for 50 ms prior to the appearance of precues. The precues were adjacent underlined letter positions that could vary from 1 to 3 positions from the target letter. Following the precue, the subject was instructed to indicate whether the center underlined letter was S or C with a lever response. The distractors could be composed of the same letter as the targets. If S was underlined, then C would serve as a distractor because it elicits a different lever response. Similarly, if C was underlined, then S would serve as a distractor. The distractors were used to investigate whether information was unintentionally processed.

Eriksen and St. James found that the spatial extent of attention varied as a function of the size of the precued region. Response times increased when more letter positions were underlined and decreased with fewer underlined positions. These results indicate two conclusions. First, that the size of the attended region is adjustable with the use of precues. The larger attended area encompassed both the central target and flanking distractors, therefore, the interfering effects of the distractors resulted in increased response times. Second, that the larger attended region results in a corresponding decrease in processing efficiency for targets associated with a larger attended region. Both interpretations of these results support the zoom lens theory. The

assumption of the gradient theory is that the spatial extent of the attended region is fixed. Therefore, the precued area (words compared to letters) should not affect performance.

To summarize, there are three assumptions of the zoom lens theory. One assumption is that the spatial extent of the attended region is adjustable. A second assumption is that the amount of processing resources is constant. A third assumption is that the processing resources within the scope of the zoom lens are uniformly distributed. A consequence of the three assumptions is responses are faster and more accurate in discrimination tasks when attention is focused to a smaller region as compared to a larger region.

Attention has also been characterized as a gradient of attentional resources. The gradient consists of processing resources that are greatest at the point of fixation and decreases outward to more peripheral regions of the visual field (Downing & Pinker, 1985; LaBerge, Brown, Carter, Bash, 1991). As a result processing capacity declines with increased distance from a centrally fixated region (Shaw, 1978; Shaw & Shaw, 1977). Like the spotlight theory, an assumption of the gradient theory is that the region of attention is circular with a diameter of one degree visual angle (Eriksen & Hoffman, 1973). Thus, an important distinction between spotlight and gradient theory is whether processing resources are distributed uniformly (i.e. spotlight theory) or distributed as a gradient.

Comparisons have been made between the spotlight and gradient theory using a paradigm with two identification tasks (LaBerge, 1980). Task 1 was used to manipulate the extent of spatial attention. Task 1 was a horizontal string of alternating 5s and 8s (i.e.

5 8 5 8 S 5 8 5). The center character was “S”, “5”, or “8”. If “S” was presented, subjects were instructed to respond to Task 2 and withhold responses if the stimulus was “5” or “8”. Task 2 was used to test predictions of the two theories. The stimulus in Task 2 was an “O” flanked by two lines (i.e. |O|) that could appear in 1 of 5 locations. Instructions were to respond to | O | and withheld responses for |C| or |0|. In other words, the response rule was to respond when “S” was followed by “O”.

There were two manipulations in the study. The first manipulation was the spatial extent of the three stimuli: warning signal, Target 1, and Target 2. The spatial extent of the stimuli was determined by the spatial separation of the letters (as measured by visual angle). The visual angles were: 1.7°, 3.4°, 5.2°, 6.9°, or 8.6°. The second manipulation was the distance between the target from Task 2 and the center position.

When a target was presented outside the spotlight, attention shifts to the target. According to the spotlight theory, the speed of the spotlight is constant. Therefore, response times should increase as a function of the spatial separation between the target in Task 1 and Task 2. However, according to the gradient theory the response time slopes should vary in relation to where the target is located within the spatial extent (i.e. gradient) of attention. Specifically, letters horizontally distributed across a narrower spatial separation would be located in the spatial region with the higher density of processing resources. Therefore, response times should be faster for targets located within a narrower spatial range compared as to a wider spatial range.

The results indicated that response times increased as a function of the spatial separation between the letters in Task 1. Response times increased for identifying the

Target 2 when precued by a longer horizontal letter string as compared to a narrower string. According to the zoom lens theory the target should be processed at a slower rate due to a wider spatial extent of attention. However, there was no interaction of eccentricity and spatial separation. These results are not consistent with the predictions of a moving spotlight of attention or a gradient of attention.

In contrast to space-based theories, an assumption of the object-based theory of attention is that attention operates on processing objects rather than spatial regions (Watson & Kramer, 1999; Duncan, 1984; Driver & Baylis, 1989; Kahneman & Henik, 1981; Shomstein & Yantis, 2002; Scholl, 2000). Supporters of the object-based theory propose that a scene is preattentively segmented into units of visual information based on uniform connected regions (UCR) with similar surface properties (i.e. texture, lightness, chromatic color). These UCR objects serve as the fundamental unit of processing visual information (Palmer & Rock, 1994) with attention limited by the number of objects that can be attended.

Another assumption of the object-based theory of attention is that all features located on an attended UCR object are processed (Neisser, 1967; Driver & Baylis, 1989; Duncan, 1984; Kahneman & Henik, 1981). As a result both distractors and target features will be processed if located on the same object. This can result in poorer performance because distractors and target features can specify different responses.

A divided attention paradigm has been used to determine whether the visual scene is organized into UCR objects (object-based) or specific regions (space-based) for attentional processing (Egley, Driver, & Rafal, 1994). In Egley et al.'s experiment (1994),

subjects were presented two equally spaced rectangles. One end of one of the rectangles was highlighted as a precue prior to the presentation of a target (i.e. dot). Subjects were instructed to respond when a target was detected. Prior to the target, precues were presented that could either be valid or invalid relative to the target's location. For valid precue trials, the precue appeared in the same location as the subsequent target. There were two types of invalid precue trials. For the first type of invalid precue trial, the precue appeared on the same object as the target but not end of the rectangle where the target was located. For the second type of invalid precue trial, the precue appeared on a different object than the target. Only trials with invalid precues were analyzed because these trials required subjects to shift attention to the target's correct location.

The results of the study indicated that subjects had faster response times for valid trials (Egaly, et. al.; 1994. For invalid conditions, subjects responded faster to the within-object condition as compared to the between-object condition. Thus, the results provide evidence in support of object-based attention.

Similarly, object-based results have also been found using a detection task (Watson & Kramer, 1994) In Watson and Kramer's study (1994), subjects were presented two adjacent wrench shaped objects (see Figure 2).

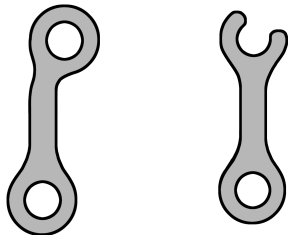


Figure 2. Watson and Kramer's wrench stimuli (1999) with two target features; an open circle and a bent-end feature.

Each wrench could be composed of four possible feature combinations: two target features (bent-end and open-end) and two distractor features (straight-end and closed-end). The spatial separation between the endpoints of the wrenches (where the features were located) and within a wrench was constant. The subjects were instructed to indicate whether one or two target features were present on a trial. The critical comparison was whether two features were located on a single object (i.e. within-object) or whether the two features are located on separate objects (i.e. between-objects).

Watson and Kramer found that performance diminished when two features were located on different objects as compared to the same object. These results were similar to the results obtained in a detection task (Egley, Driver, Rafal, 1994). Watson and Kramer concluded that the performance cost was due to dividing attention between objects rather than limitations in the spatial extent of attention.

In summary, there are two assumptions of the object-based theory of attention. The first assumption is that all features within a UCR object are selected for processing. The second assumption is that all features within the attended UCR object are processed.

Given that several studies have found evidence for both space-based and object-based theories, it is possible that humans operate with both modes of attention. A new theory---the grouped array theory---combines space-based and object-based theories. According to the grouped array theory, locations containing visual stimuli are preattentively activated (Farah & Vecera, 1994). The activated locations correspond

directly to the object's shape or silhouette. These grouped locations (i.e. array representations) are processed as objects only within the focus of spatial attention (Kramer & Jacobson, 1991).

Thus, studies testing object-based theories of attention have examined whether the object selected is a grouped array or UCR object representation (Egley, Driver, & Rafal, 1994). In the study by Egley et al. (1994), two adjacent rectangles were presented at varying distances to compare the different spatial characteristics of object representation. The subject was instructed to respond to the target's appearance as quickly as possible following a precue (i.e. dot). According to the grouped array theory, the selection of objects is mediated by its location in the visual field. Thus, the grouped array theory predicts that the spatial separation between the two rectangles should result in diminished performance. In contrast, proponents of the UCR theory propose that attention selects features based on whether it is located on an attended object, irrespective of its location in the visual field. Thus, the UCR theory predicts that the spatial separation between objects will not affect performance. The results from the study indicated that object-based effects decreased as the 2D distance between the objects increased. This suggests that object representations encode location information.

Another distinction between the grouped array theory and the UCR object theory is the definition of a preattentive object. According to the grouped array theory, objects can be defined by gestalt principles and do not require a uniform connected region. For example, a uniform surface structure with a closed boundary or a group of discrete units can be interpreted as objects by the Gestalt laws of closure and proximity, respectively.

In contrast, the object-based theory definition of a preattentive object only includes those defined by a uniform connected region. In other words, an object defined by gestalt principles will not be processed as an object. Non-UCR objects are processed after the preattentive stage.

Kramer and Jacobson (1991) examined whether the strength of perceptual objects varied according to different grouping principles. Subjects were presented with a central target (dashed or dotted line) with two adjacent distractors (dashed or dotted lines). The task was to determine whether a central target was dashed or dotted while ignoring the adjacent distractors. The distractors were compatible, incompatible, or neutral with respect to the central target. Compatible distractors were the same as the target. For example, if the target was a dotted line then the distractors were dotted lines. Incompatible distractors were different from the target (i.e. dotted lines as compared to dashed lines). The neutral distractors were neither composed of dashed nor dotted lines. The independent variable of interest was object membership---whether the target and distractors were embedded in the same object or different objects. Object membership was determined by whether target and distractors did or did not share a connected region. There were three types of object memberships: same object, different objects, and a grouped object. In the same object condition, target and distractors were connected by a common line. In different object conditions, the target and distractors were not connected by a common line but were connected to separate objects. In the grouped object condition, target and distractors were adjacent to one another with no connecting lines.

The results indicated that the response-compatibility effects were eliminated when the distractors and targets were located on separate objects. However, the effect attenuated when the distractors were weakly grouped with the targets as compared to connected by a common contour. Specifically, the interference of incompatible flankers was reduced when the features were located on connected objects compared to weakly grouped objects. These results suggest that, contrary to the UCR object theory, the strength of a perceptual object can vary according to different Gestalt principles.

In summary, there are two assumptions of the grouped array theory. The first assumption is that objects are attended but only within the focus of spatial attention. Thus, spatial information is coded with the object's representation. The second assumption is that the definition of a perceptual object can include objects formed by Gestalt principles of organization (i.e. similarity, proximity, and symmetry).

As reviewed above, space-based, object-based and grouped-array theories include different assumptions regarding what is an object and whether visual attention is based on a limited spatial extent. The present research examines several hypotheses based on these three theories of visual attention.

Hypothesis 1: According to the spotlight theory, information is selected and processed based on whether it is located within an attended spatial region. If this hypothesis is correct then information located within an attended region is processed whereas information located outside of this region is not processed.

Hypothesis 2: According to the zoom lens theory, the spatial extent of attention is adjustable while processing resources are uniformly distributed within the attended area.

If this hypothesis is correct then performance should vary according to the size of the precued region and the targets' distance from central fixation.

Hypothesis 3: According to the gradient theory, the gradient is centered on the point of fixation and declines with more peripherally located regions. If this hypothesis is correct then performance should diminish as a function of distance from central fixation.

Hypothesis 4: According to UCR object-based theory, attention involves processing information within uniform connected regions (i.e. objects). If this hypothesis is correct, then observers should be more efficient at detecting target features located within a common object (i.e. a single connected region) as compared to features located within different objects (i.e. different connected regions). All features located within an attended object should be processed regardless of the spatial distance between the features.

Hypothesis 5: According to the grouped array theory, attention involves processing information within an object but the spatial extent of attention is limited. If this hypothesis is correct, observers will be more efficient at detecting targets within a precued object but only if the precued object is located within an attended spatial region. Furthermore, object-based effects attenuate with an increase in the spatial separation between the initially attended region and target. This suggests that spatial information is coded within a preattentive object.

Hypothesis 6: According to the grouped array theory, there are varying degrees to which an object is processed preattentively based on different Gestalt principles. According to the grouped array theory, object-based effects will decrease as a function of

connectedness of an object, from (1) uniform connected region to (2) implicit objects that are formed from illusory contours to (3) discrete units that are grouped according to a principle of similarity.

The objective of the dissertation research is to compare all three theories of attention: space-based, object-based, and the grouped array theory using a target judgment task. While other studies have compared object and space-based theories, or object and grouped array theories, there have been no studies that have examined the three theories using the same paradigm. In the present study, modified versions of Watson and Kramer's target judgment task will be used to compare the three theories of selective attention. In the present research, predictions for each theory using the same paradigm were examined. In addition, I will also examine how predictions from the three theories can be used in an applied context (i.e. the design of traffic signs).

CHAPTER 1

A challenge in testing predictions from space-based or object-based theories is that an object cannot be disentangled from the location that it occupies. There are, however, several approaches to decouple these two theories. One approach is to present two overlapping object stimuli (Treisman, 1983; Duncan, 1984). Another approach is to hold constant the distance between and within objects and compare performance (Baylis, 1994; Baylis & Driver, 1995). A limitation, however, to these two approaches is that conclusions are derived from studies that often maintain a close spatial separation between the compared objects. Thus, it is possible that object-based effects may be present when judged at a close spatial separation but not present when judged at a far spatial separation. In order to draw conclusions about how attention operates on objects at different spatial ranges, the distance between judged features must vary. If the results indicate that object-based effects decrease as a function of spatial separation, then it would suggest that objects are processed within an attended spatial region (grouped array theory). If the results do not indicate an interaction of spatial separation and object-based effect, then it would suggest that perceptual objects are not encoded with spatial information.

Lavie and Driver (1996) investigated whether object-based effects require that the perceptual objects are located within an attended spatial region. They used a target judgment task and manipulated the spatial separation between the two judged features. Subjects were presented with two intersecting lines that contained two target features ---

either dots or dashes. The subject's task was to judge whether the two features were the same or different. The two features could be located on a single object with a large spatial separation or on two different objects with a close spatial separation.

Their results indicated that responses were significantly faster when the features were located on the same object as compared to different objects. However, the object-based effect did not occur when subjects were precued to one side of the display. Instead, subjects responded faster when the precue and target were located on the same side of the display (but on different objects) compared to when the features were located on the same object (but on different sides of the display). They concluded that perceptual objects were initially processed for attention --- targets were processed based on whether the features were located within the attended spatial region when directed by a precue. Other studies have found that object-based effects occurred when the subject was focused on a small region of the display (Atchley & Kramer, 1998; Kramer & Jacobson, 1991).

In Experiment 1A comparisons were made between space-based and object-based attention theories using a target judgment task. The goals of Experiment 1A were three fold. The first goal was to examine whether spatial locations or objects were processed for visual attention. The second goal was to compare the spotlight theory and zoom lens theory by examining whether the spatial extent of attention could be manipulated using precues. The third goal was to compare the assumptions of object-based attention to assumptions of the grouped array theory by examining whether an increase in the horizontal separation between objects affected performance. Typically, studies examining space-base and object-based theories require that the spatial separation between objects

and within objects are equivalent. However, in Experiment 1A, the horizontal separation between wrenches varied between 6.4 cm to 12.8 cm. Thus, as a way to control for the spatial separation, the length of each wrench was also varied (6.4 cm or 12.8 cm).

Experiment 1A also used spatial precues to investigate whether the spatial extent of attention could be manipulated using a precue to focus attention to either a small or larger area of the visual field. Consequently, the length of the precue (i.e. distance between the asterisks) was also 6.4 cm or 12.8 to examine whether the spatial extent of attention could vary. The manipulations of object length, spatial separation, and precue served to delineate between the spotlight and zoom lens theories.

Subjects

The subjects ($N = 8$) were undergraduate students between the ages of 18 to 25, with normal or corrected-to-normal vision. All subjects were paid for their participation.

Design

Experiment 1A was analyzed using a 2 (Object: same or different) x 2 (Spatial separation between wrenches: 6.4 cm or 12.8 cm) x 2 (Wrench length: 6.4 cm or 12.8 cm) x 2 (Precue size: 6.4 cm or 12.8 cm) factorial design.

Apparatus and Stimuli

Stimulus presentation and data collection were conducted on standard PC computers. The displays were presented on a SVGA color monitors and responses were recorded using a standard QWERTY keyboard. The D key was used to enter “one feature” response with the left index finger. The “L” key was used to enter “two features” response with the right index finger.

The stimuli were viewed binocularly from a distance of 52 cm. The wrenches were presented as pairs in a vertical orientation. The wrench heights were 6.4 and 12.8 cm and subtended a viewing angle of 6.84° and 13.49°, respectively. The fixed spatial separation between wrenches is to ensure that the spatial distance between and within-object features are the same when two features are present. However, in the current study, the manipulation of spatial distance between wrenches (6.4 and 12.8 cm) was also examined. The size of the wrenches was also either 6.4 or 12.8 cm. to counterbalance the distance between and within objects.

The wrenches were positioned such that outer distance of each corner was 6.4 or 12.8 cm apart. For the 6.4 cm wrench, there was a 2.4° separation between the interior edges of the closest different-object condition. The circle end of each wrench had a diameter of 1.8°. The wrench was 0.6° wide and 1.5° in length.¹

Procedure

On each trial, a fixation cross was presented to focus the subject's attention to the center of the screen. Pressing the space-bar prompted the precue to be displayed for 150 ms. The precue indicated the size of the square region containing the target features with four asterisks. The four asterisks were positioned at each location where the wrench features would appear to form a box (6.4 x 6.4 cm or 12.8 x 12.8 cm). Following the precue, two adjacent wrenches with one or two target features were displayed.

¹ A separate control study with object orientation was conducted with eight subjects. The results indicated that there was no significant effect of orientation on response time or accuracy. To reduce the number of trials, the variable of orientation was omitted from the study. Watson and Kramer also did not find an effect of orientation. The wrenches were positioned vertically for all of the following experimental trials.

Following the precue, two adjacent wrenches were displayed 150 ms. The wrenches were comprised of four possible features: two target features (bent-end, open-end) and two distractor features (straight-end, closed-end). When two features were presented on different objects they were located on adjacent positions (they were never presented diagonally). When two features were on the same object, the two features were presented on different ends of the object.

A blank screen was presented after the wrench stimuli during which subjects indicated whether one or two of the target features (open end and/or bent end) were present on each trial. After the subject responded, auditory feedback was provided (a high tone for correct responses and a low tone for incorrect responses) followed by a fixation cross indicating the next trial.

Prior to the experiment, subjects were presented with one block of demonstration trials and one block of practice trials (a block of 24 trials). For the demonstration trials, the presentation of the stimuli was 1000 ms. Performance on the demonstration trials was used to determine whether understood the task. For the practice trials, the presentation of the stimuli was 150 ms. The purpose of the practice trials was to show the subject the duration of the stimulus presentation used during the experiment. There were four block of trails. The duration of the experimental session was approximately 1 hour.

Predictions

According to the spotlight theory of attention, attention must shift in order to process information that is located outside its spatial region. Studies in which attention must shift

results in increased response time (Eriksen & Yeh, 1985). Therefore, a prediction of the spotlight theory is that response times should increase monotonically as a function of the distance between the wrenches (Hypothesis 1). There was also a predicted increase in response time for object length (Hypothesis 1). It should take more time to identify features located on objects that are 12.8 cm in length compared to 6.4 cm because of the increased distance from central fixation. The increased response time reflects the time required to shift the spotlight to the features which are located on the ends of the objects.

According to the zoom lens theory, the spatial extent of attention is adjustable while processing resources are uniformly distributed (Hypothesis 2). As a result, responses should be faster and more accurate for the small precue as compared to the large precue trials. The highest level of performance (fastest response times and highest accuracy) was predicted when the precue was small (6.4 cm) and the wrenches had a small spatial separation (6.4 cm apart). Processing efficiency is more concentrated when attention is narrowly focused with a small precue. The next highest level of performance was predicted for trials with a large precue (12.8 cm), for both the small (6.4 cm) and large (12.8 cm) spatial separation. For these trials, the scope of attention can encompass the target features. However, processing resources should be diffuse for a wide extent of spatial attention. Thus, response times should increase for both spatial separations (6.4 and 12.8 cm). The lowest level of performance was predicted for trials with a small precue and a large spatial separation between wrenches (12.8 cm apart). For these conditions subjects were expected to maintain a narrow focus of attention and search serially for the target features (LaBerge, Brown, Carter, Bash, 1991).

According to the gradient theory, processing efficiency attenuates from the point of fixation to the target (Hypothesis 3). Thus, the main effects of spatial separation and length were expected to be significant.

Object-based theories (UCR and grouped array) predict a main effect of object. Subjects should respond faster when the targets features are located on the same wrench as compared to located on different wrenches (Hypothesis 4). However, according to the grouped array theory, these object-based effects should decrease as a function of increased spatial separation between the objects (Hypothesis 5).

Data Analysis

The mean response times and percent correct were recorded and analyzed using an analysis of variance (ANOVA). Although percent correct were collected, response time was the primarily the focus of analysis. Percent correct was measured to determine whether reaction time performance was due to a speed/accuracy tradeoff. All subjects were instructed to maintain accuracy above 90% and to respond as quickly as possible. The two feature conditions were analyzed to compare responses to targets found on same or different objects.

Results

Three analyses were conducted to separate the effects of object size and spatial separation. Analysis 1 examined the effects of object (same, different) and precue (6.4 cm, 12.8 cm) with a fixed spatial separation between wrenches. There were two components to Analysis 1. Analysis 1.1 examined the effects of object and precue size on large wrenches (12.8 cm) with a large spatial separation (12.8 cm). There was no

effect of object on response times or accuracy, $F(1, 7) = 0.21$ and $F(1,7) = 1.42, p > .05$, respectively. There was no effect of precue on response times or accuracy, $F(1, 7) = 0.43$ and $F(1,7) = 4.49, ps > .05$. Analysis 1.2 examined the effects of object and precue size on small wrenches (6.4 cm) with a small spatial separation (6.4 cm). There was no effect of object on response time or accuracy, $F(1, 7) = 0.19$ and $F(1, 7) = 0.37, p > .05$, respectively. There was no effect of precue on response time or accuracy, $F(1,7) = 0.37$ and $F(1, 7) = 0.42, p > .05$, respectively.

Analysis 2 examined the effect of spatial separation for small wrenches. Comparisons were made between small wrenches at a small spatial separation (6.4 cm) to small wrenches with a large spatial separation (12.8 cm). The results indicated no significant difference in response times or accuracy, $t(7) = 1.64$ and $t(7) = 2.2919, ps > .05$.

Analysis 3 examined the effects of spatial separation for large wrenches. There was a planned comparison between features located on the same object or different object for large wrenches with a small spatial separation. There was no significant difference for either response time or accuracy, $t(1, 7) = -1.12$ and $t(1, 7) = -0.96, p > .05$, respectively.

Discussion

Experiment 1A was conducted to investigate how the spatial separation of objects and precues affect performance for a target judgment task. Specifically, the question was whether the preattentive objects or locations were selected for processing. If objects were selected for processing, the results would indicate an object-based effect. Therefore,

subjects should have better performance for target features located on the same wrench as compared to different wrenches. The results did not indicate improved performance for features on the same object. The study was also conducted to examine whether attention could be adjusted to different spatial extents with precues. The results, however, do not indicate that precues assist in processing the objects. There was no difference in performance when the subjects were presented with small precues as compared to large precues. It was unclear as to whether the subjects were not using the precues or whether the spatial extent of attention was fixed. Because there was no effect of precues it is possible that the null object-based results could be due to a diffuse attentional focus. Interpretations were difficult to make without effective precues. For the following experiment, the precue task was modified to engage attention with a go/no go paradigm.

Chapter 2

Experiment 1A used a target judgment task with precues to examine two issues. The first issue was whether attention was oriented to spatial locations or to an object. The second issue (given that attention could be oriented to spatial locations) was whether the size of the precue could orient attention to smaller or larger spatial regions. Experiment 1A results indicated that there was no effect of object. There was no benefit for identifying target features that were located on the same object as compared to different objects. The results from Experiment 1A also indicated that performance on the wrench judgment task did not improve with the use of precues. A possible explanation of the results from Experiment 1A is that subjects *were* attending to the precues, however, the size of spatial attention was constant. An alternative explanation for these results is that the precues used in Experiment 1A were not successful at engaging the subject's attention to a particular spatial location or object. The subject might not have found the precues to be informative and thus ignored them. Therefore, it is possible that the spatial extent of attention is adjustable, but that attention was diffusely distributed due to an ineffective cue. Indeed, the results indicated that subjects did not process wrenches with a smaller spatial separation more effectively than wrenches with a larger spatial separation.

Experiment 1B was conducted to investigate the effects of precue size on the target judgment task. Specifically, the question was whether precues can be used to adjust attention to different spatial extents. Experiment 1B used a go/no go task as a

precue to focus the subject's attention to a particular spatial location. Subjects were instructed to respond to the object judgment task based on the precue.

Subjects

The subjects ($N = 8$) were undergraduate students between the ages of 18 to 25, with normal or corrected-to-normal vision. All subjects were paid for their participation.

Design

Experiment 1A was counterbalanced using: 2 (Object: same or different) x 2 (Spatial separation between wrenches: 6.4 cm or 12.8 cm) x 2 (Wrench length: 6.4 cm or 12.8 cm) x 2 (Precue size: 6.4 cm or 12.8 cm) design so that all events occurred with equal probability. (Because some of these conditions were not diagnostic of the hypotheses in question, specific planned comparisons were used for the analyses).

Apparatus and Stimuli

Stimulus presentation and data collection were conducted on standard PC computers.

The apparatus and stimuli were the same as in Experiment 1A.

Procedure

The procedure was similar to Experiment 1A with the following expectations. There were two components to the experimental trial. The first component was a Go/No Go precue task. After pressing the spacebar, subjects were presented with a precue consisting of 4 "x" or "+" symbols that form a square. The precue was presented for 150 ms. When all 4 symbols matched (i.e. go precue trial), the subject was instructed to respond to the second component (see Figure 3). When one of the symbols did not match with the other 3 symbols (i.e. no go precue trial), the subject was instructed to withhold

responses to the wrench stimuli (see Figure 4). In the second component, the wrenches were displayed for 150 ms. The subject was instructed to identify how many target features (e.g. bent end, open end) were present on each trial.

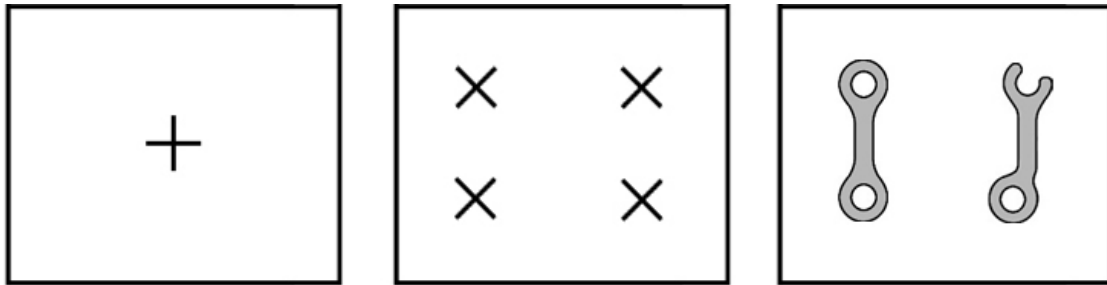


Figure 3. Experiment 1B go precue stimuli. A fixation cross, go precue, and wrench presentation.

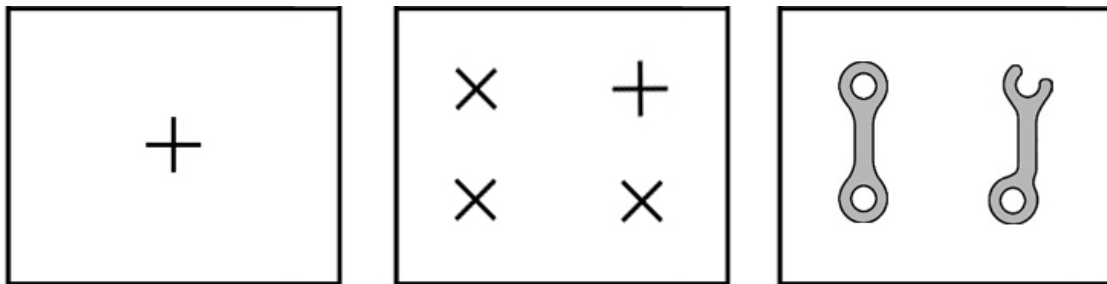


Figure 4. Experiment 1B no go stimuli. A fixation cross, no go precue, and wrench presentation.

Feedback for responding to the go/no go task was indicated by a buzzing audio cue. Failing to respond to a trial within the allotted time and response errors (i.e. entering the incorrect number of targets) were indicated by a low auditory tone. Correct responses were indicated by a high auditory tone.

There were four blocks of experimental trials (a block consisted of 480 trials). The trials were blocked by precue size. Block one consisted of small precued trials (6.4

cm). Block two consisted of large precue trials (12.8 cm). Subjects were presented with alternating blocks of small and large precue trials. The order of block presentation was counterbalanced across subjects.

Prior to the experiment, subjects were presented with one block of demonstration trials and one block of practice trials (a block of 24 trials). For the demonstration trials, the presentation of the stimuli was 1000 ms. Performance on the demonstration trials was accessed to determine whether subjects understood the task. For the practice trials, the presentation of the stimuli was 150 ms. The purpose of the practice trials was to show the subject the duration of the stimulus presentation on the actual trial. The duration of the experimental session was approximately 1 hour.

Analyses

There were three analyses conducted to examine the effects of precue size, object size, and spatial separation on selective attention. Each analysis consisted of planned comparisons. Analysis 1 was conducted to compare among the UCR object-based theory to the grouped array theory to the space-based theories. Analysis 2 was conducted to compare the spotlight theory to the zoom lens theory. Analysis 3 was conducted to compare zoom lens and gradient theories of attention.

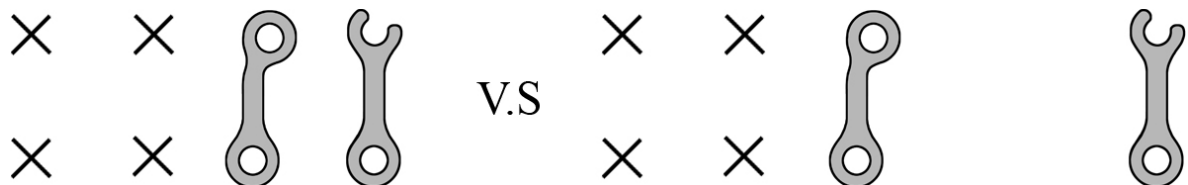


Figure 5. Analysis 1 was a comparison between small and large spatial separations for small precue followed by small wrenches.

Analysis 1

Analysis 1 examined the effect of spatial separation for small wrenches when presented a small precue (see Figure 5) and was conducted to compare among the UCR object-based theory to the grouped array theory to the space-based theories. According to the UCR object-based theory, attention involves processing information within uniform connected regions (i.e. perceptual objects) and thus subjects should respond faster to target features on the same wrench as compared to different wrenches. There should be no effect of spatial separation between the wrenches as a function of spatial separation between wrenches. Alternatively, according to the grouped array theory, attention involves processing information within an object but the spatial extent of attention is limited (Hypothesis 5). As a result there should be an interaction of object and spatial separation. Subjects should respond faster to features located on the same wrench as compared to different wrenches, however, this object-based effect should attenuate as the spatial separation between the wrenches increases. Alternatively, according to all of the space-based theories (Spotlight, Gradient, Zoom lens), subjects should have faster responses to the wrenches with a small spatial separation as compared to a large spatial separation. There was no predicted main effect for object. Nor was there a predicted interaction for spatial separation and object.

Results of Analysis 1

For Experiment 1B, Analysis 1 was a 2 (Object: same or different) x 2 (Spatial separation: small 6.4 cm or large 12.8 cm) ANOVA. There was a non significant trend of spatial separation on accuracy but not response times, $F(1, 7)=5.41, p=.052$ and $F(1,$

7)=.367, $p>.05$ (see Figure 6). Subjects were more accurate ($M = 95\%$) with a small separation as compared to a large separation ($M = 92\%$). There was also an interaction of object and spatial separation for accuracy but not response time, $F(1, 7)=13.611$, $p<.05$ and $F(1, 7)=.861$, $p>.05$ (see Figure 7). There was no significant difference in accuracy ($M = 95\%$) when there was a small spatial separation between targets located on different as compared to the same object. However, subjects were more accurate when the targets were located on different objects ($M = 95\%$) as compared to the same object ($M = 89\%$) at the large spatial separation.

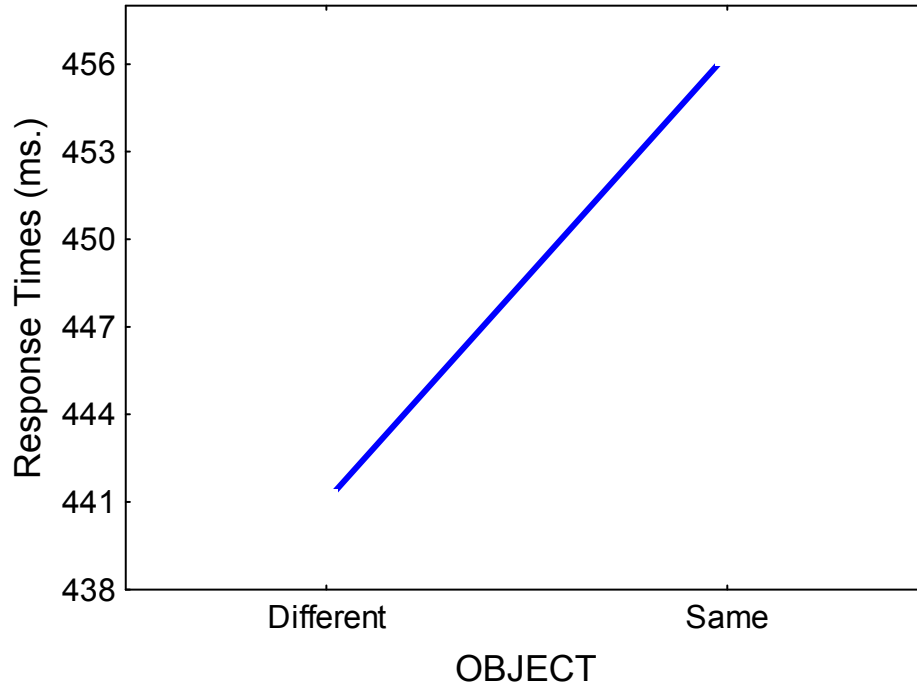
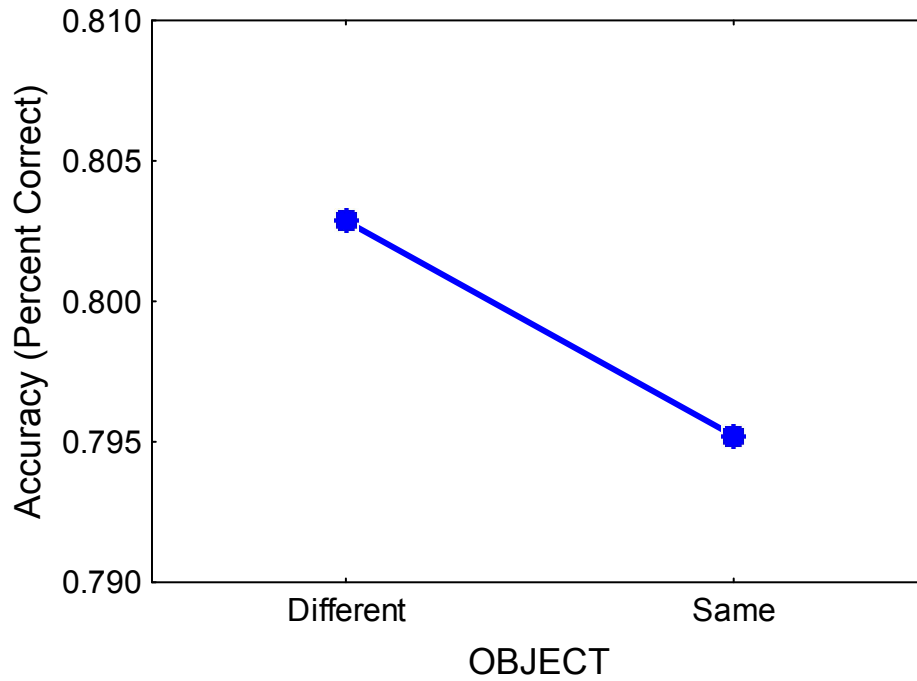


Figure 6. Analysis 1 examined trials with a small precue followed by small wrenches. There was a non-significant trend was found for accuracy but not response time. The two graphs were provided to show that there were no speed accuracy trade-offs.

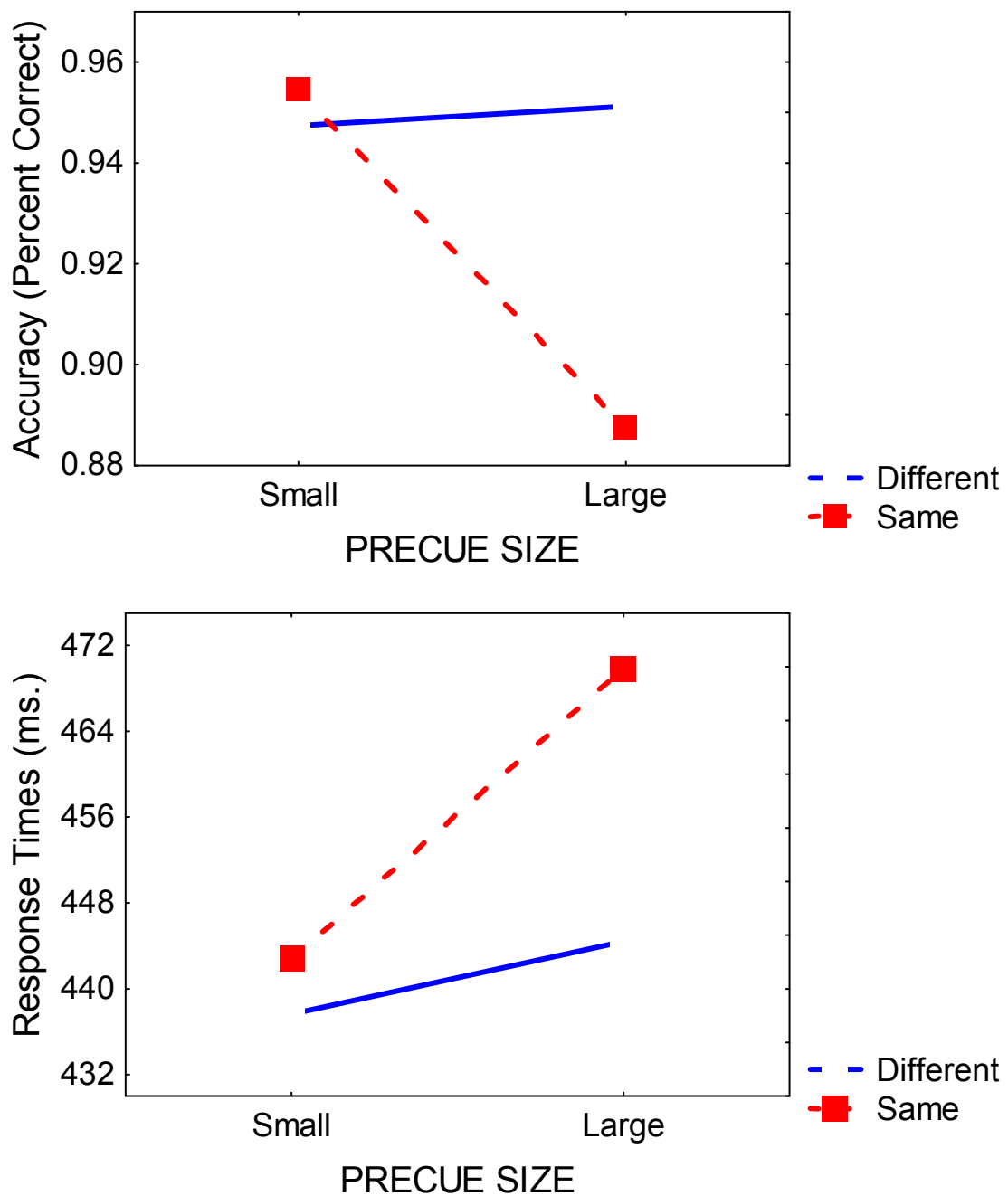


Figure 7. Analysis 1 examined trials with a small precue followed by small wrenches. There was an interaction of spatial separation for accuracy but not response time. The two graphs were provided to show that there were no speed accuracy trade-offs.

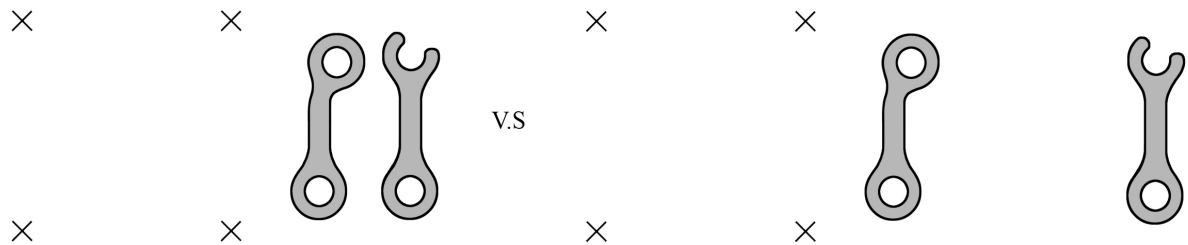


Figure 8. Analysis 2 was used to investigate the effect of spatial separation for large wrenches that are preceded by a large precue.

Analysis 2: Spotlight vs. Zoom lens

Analysis 2 examined differences in performance between large wrenches (12.8 cm) with small spatial separations (6.4 cm) and large wrenches with large spatial separations (12.8 cm) (see Figure 8). Comparisons were made to test the assumptions of the spotlight and zoom lens theories.

According to the spotlight theory of attention, information is selected and processed based on whether it is located within an attended region (Hypothesis 1). As a result no significant performance difference should occur when identifying target features on the same wrench compared to different wrenches. However, subjects should respond faster to wrenches with small as compared to large spatial separations. This increased latency would reflect the time cost for shifting attention. According to the zoom lens theory of attention, the spatial extent of attention is adjustable and processing resources are uniformly distributed within an attended region (Hypothesis 2). Under this assumption, a wrench located within any location of the attended region is processed.

For Analysis 2, the spatial extent of attention should be large. Therefore, subjects should not have faster responses to wrenches with a small as compared to large spatial separations.

Results of Analysis 2

For Experiment 1B, Analysis 2 was a 2 (Object: same or different) x 2 (Spatial separation: small 6.4 cm or large 12.8 cm) ANOVA (see Figure 9). There was a main effect of spatial separation on response time but not accuracy, $F(1, 7)=7.905$, $p < .05$ and $F(1, 7)=1.936$, $p > .05$; respectively. Subjects responded faster ($M = 440$ ms) to a small separation as compared to a large separation ($M = 522$ ms). There was no interaction of object and spatial separation on response time or accuracy, $F(1, 7)=2.4163$ and $F(1, 7)=.01497$, $p=.906$, $p > .05$.

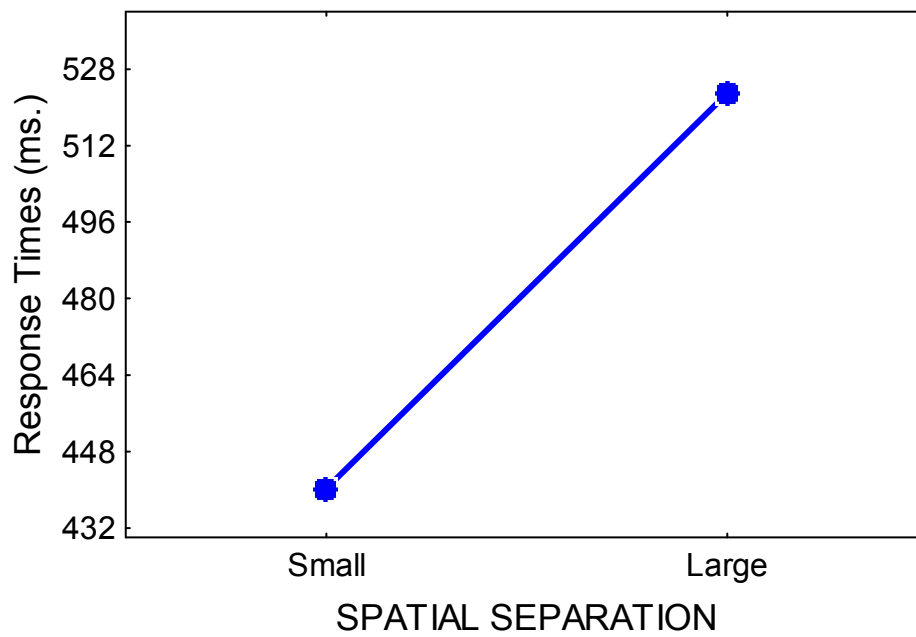
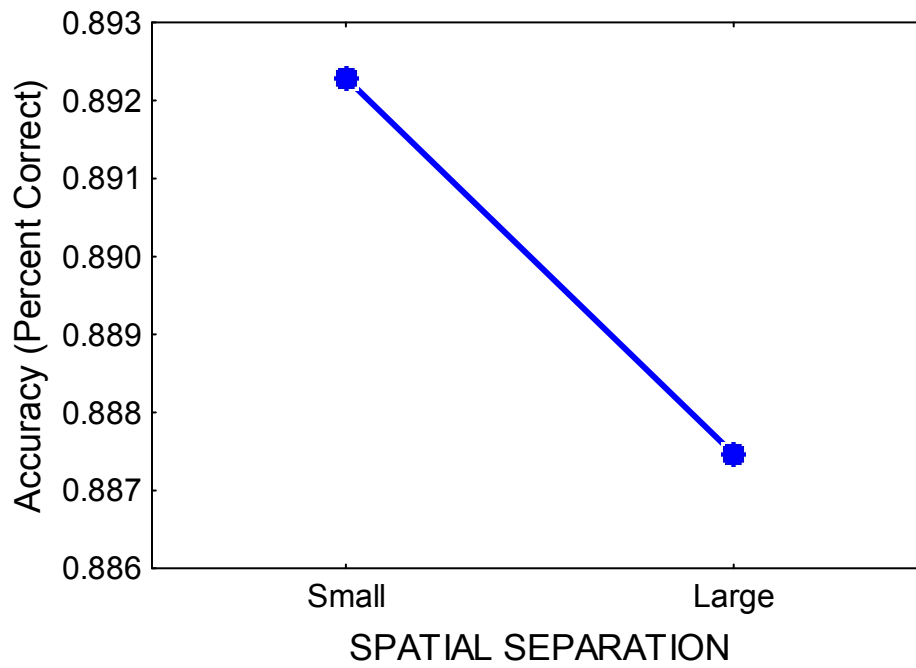


Figure 9. Analysis 2 examined the effect of spatial separation for large precues followed by large wrenches. There was a significant effect of spatial separation for response time but not accuracy.

Analysis 3 was conducted to compare the assumptions of zoom lens and gradient theories of attention. Comparisons were made between small and large precue conditions, holding the size and spatial separation of the wrenches constant. Two different analyses were conducted. **Analysis 3.1** was used to compare small to large precues for small wrenches with a small spatial separation (see Figure 10). **Analysis 3.2** was conducted to make comparisons between small and large precues for large wrenches (see Figure 11).

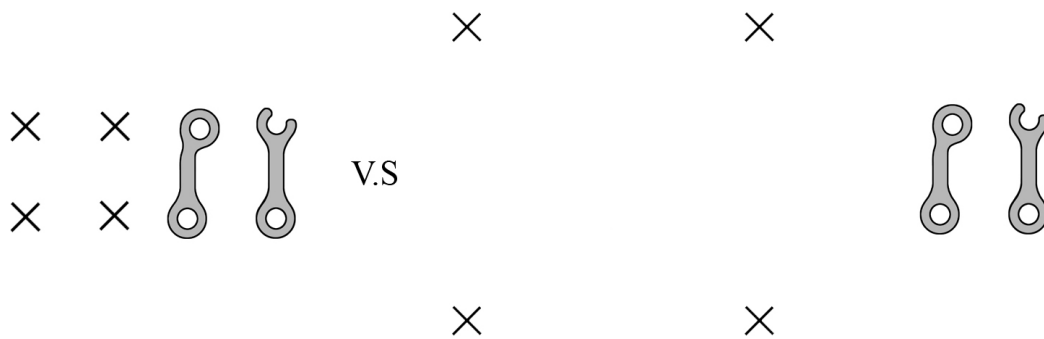


Figure 10. Analysis 3.1 compared small and large precues for small wrenches with a small spatial separation.

Predictions for Analysis 3.1 and Analysis 3.2

According to the gradient theory of attention, processing resources are greatest at the point of fixation and decline with more peripherally located regions (Hypothesis 3). For Analysis 3.1 and 3.2, there should be no difference in performance between the small precue large precue trials.

According to the zoom lens theory, the spatial extent of attention is adjustable while the processing resources are uniformly distributed within the attended region (Hypothesis 2). Consider a situation in which the precue is small. If the wrenches are

located within this attended region (i.e. small wrenches with a small spatial separation), then performance should be fast and accurate because wrenches are located within the narrowly focus of attention. Alternatively, consider a situation in which the precue is large. If the wrenches are located within this attended region (i.e. large wrenches with a large spatial separation) then performance should be lower when the precue was small. Although the wrenches are located within the attended region attention is widely distributed across a larger region. Therefore, according to the zoom lens theory performance should be lower for the small precue as compared to the large precue trials.

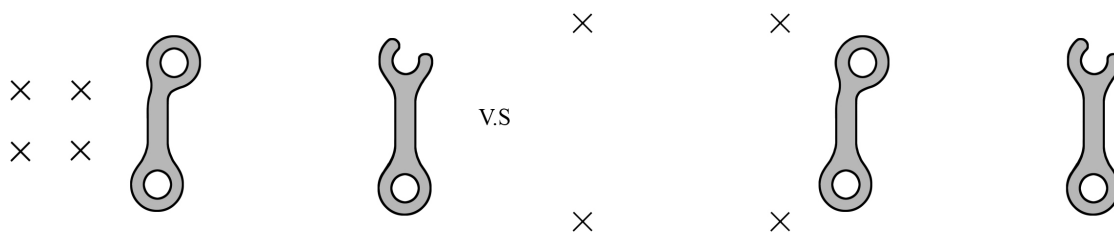


Figure 11. Analysis 3.2 compared small to large precues for large wrenches with a large spatial separation.

For Analysis 3.2, comparisons were made between small and large precues for large wrenches with a large spatial separation (see figure 14). Consider a situation in which the precue is small and the wrenches are large with a large spatial separation. According to the zoom lens theory, there is an inverse relationship between the size of the attended region and the concentration of processing resources within that area (Hypothesis 2). In the large precue trials, the attended region should be sufficiently large enough so as to encompass both wrenches as compared to the small precue trials. However, the increased size of the attended region should result in a decrease of

processing efficiency. In the small precue trials, the focus of attention is narrow, however the attended region may be too small to encompass both wrenches. Thus, according to the zoom lens subjects should have higher performance for the large precue condition as compared to the small precue condition. Although both conditions have limitations for processing the wrenches, previous studies have found that subjects perform better when the targets are located within the attended region as compared to outside the attended region. There is a greater cost for attending to objects outside the small focus of attention compared to the loss in processing efficiency for a wide focus of attention. Subjects with a narrow focus of attention (with targets located outside the small region) maintain a small focus of attention and employ a scanning strategy (Eriksen & Yeh, 1985).

Results of Analysis 3.1

For Experiment 1B, Analysis 3 was a 2 (Object: same or different) x 2 (Precue size: small 6.4 cm or large 12.8 cm) ANOVA. The results indicated a main effect of precue for response times but not accuracy, $F(1, 7)=7.905, p < .05$ and $F(1, 7)=0.00005, p > .05$, respectively (see Figure 12). Subjects responded faster when the precue was 6.4 cm ($M = 440.25$ ms) compared to 12.8 cm ($M = 522.97$ ms). There was no main effect of object on response time or accuracy, $F(1, 7)=1.936$ and $F(1, 7)=0.531, ps > .05$. In addition was there no significant interaction for response time or accuracy, $F(1, 7)=2.4163$ and $F(1, 7)=.76705, ps > .05$. The results support the zoom lens theory and suggest that attention can be narrowly focused to a smaller region, as indicated by the faster response times.

Results of Analysis 3.2

For Experiment 1B, Analysis 3.2 was a 2 (Object: same or different) x 2 (Precue size: small 6.4 cm or large 12.8 cm) ANOVA. The results indicated a main effect of precue for response time but not accuracy, $F(1, 7)=6.11$, $p<.05$ and $F(1, 7)=3.19$, $p>.05$, respectively (see Figure 13). Subjects had faster responses when the precue was 6.4 cm ($M = 420.30$ ms) as compared to when the precue was 12.8 cm ($M = 440.25$ ms). Subjects made faster response with a small precue as compared to a large precue. This result indicates that the spatial extent of attention can be manipulated using different sized precues. There was no significant main effect of object for RT or accuracy, $F(1, 7)=0.17$ and $F(1, 7)=0.00$, $p>.05$.

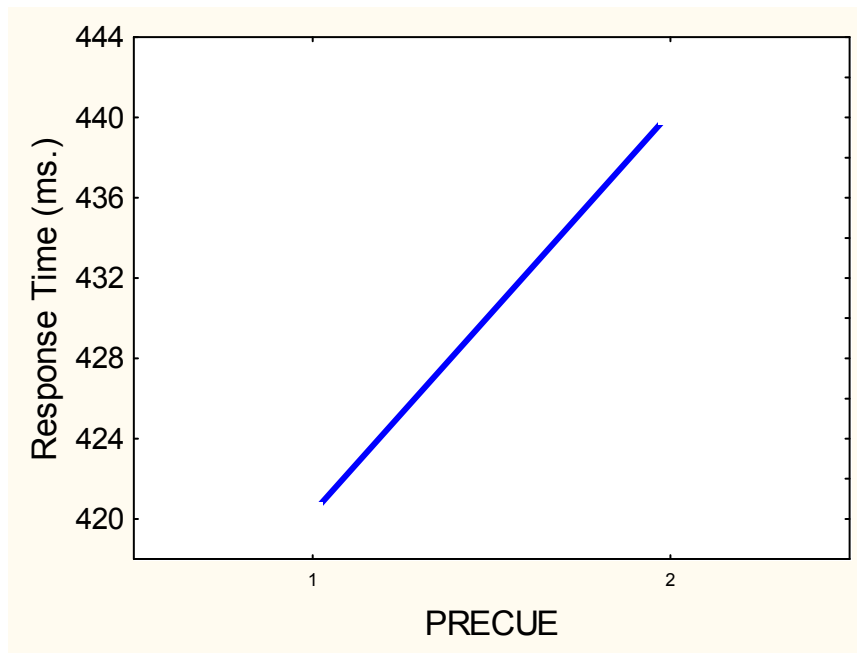
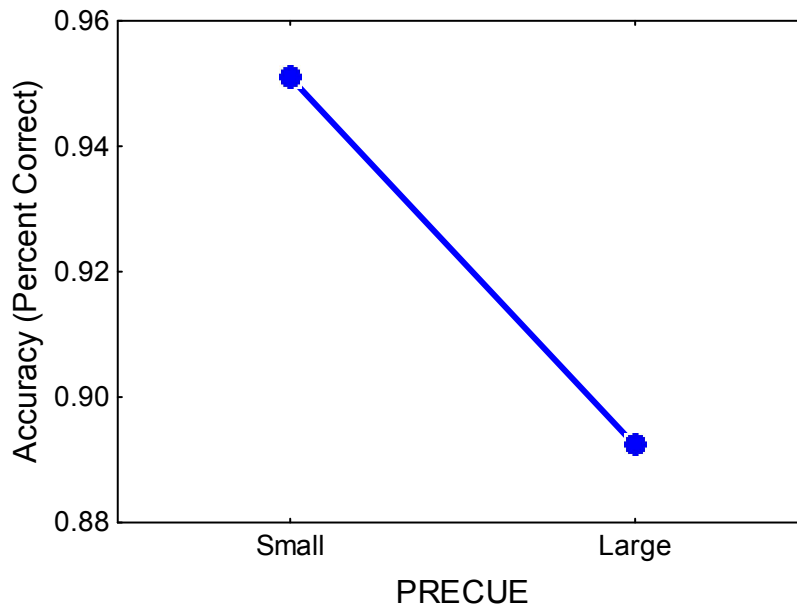


Figure 12. Analysis 3.1 compared small and large precues for small wrenches with a small spatial separation. There was a significant effect of precue size for response time but not accuracy. The graph was provided to show that there were no speed accuracy trade-offs.

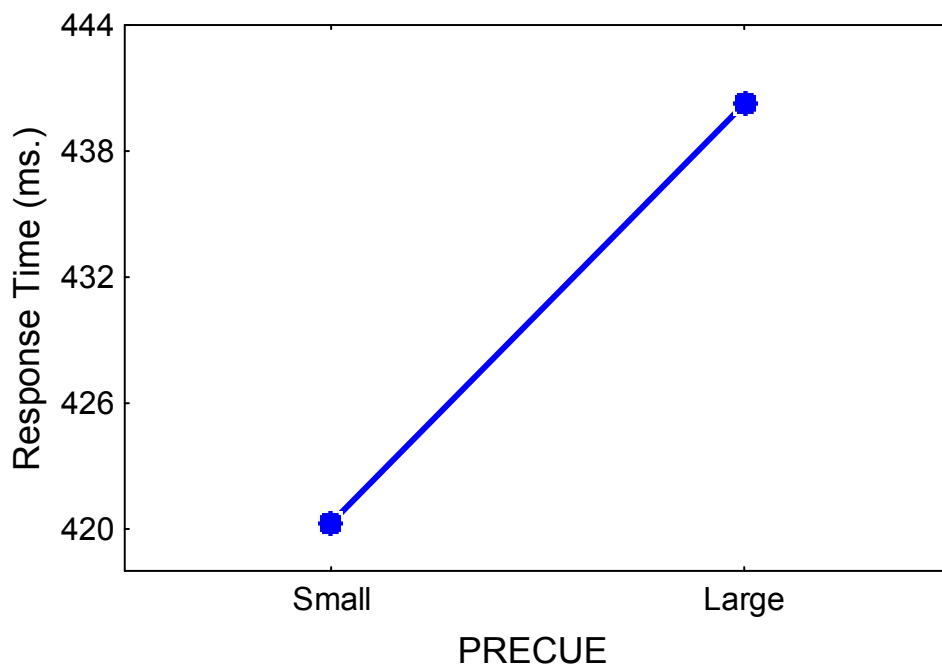
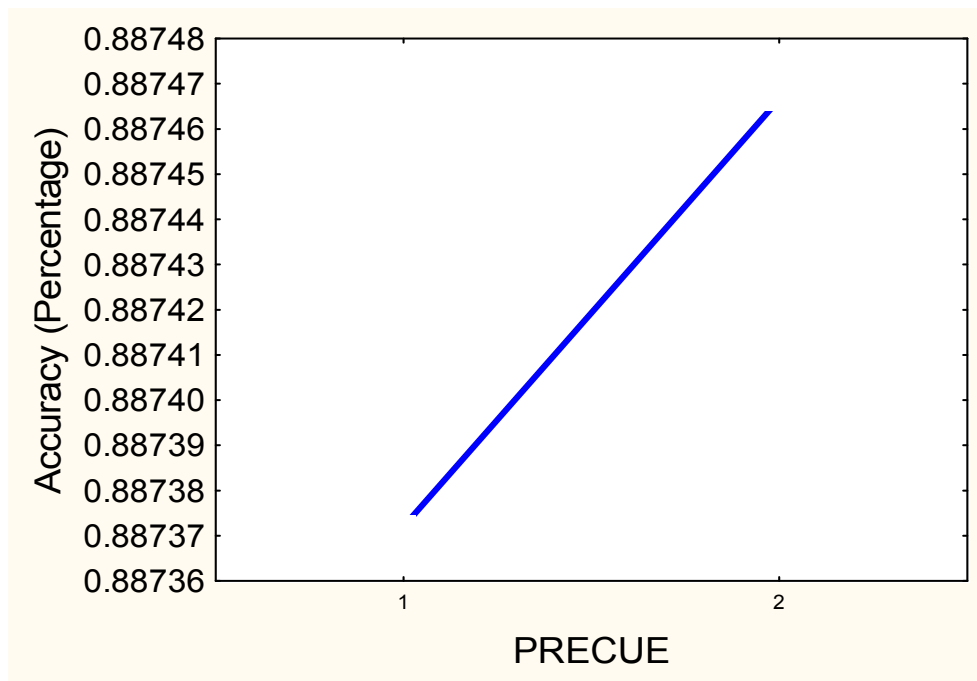


Figure 13. Analysis 3.2 compared small to large precues for large wrenches with a large spatial separation. There was a main effect of precue size for response time but not accuracy. Subjects were faster at responding to small precues compared to large precues.

Discussion

The previous experiment (Experiment 1A) was conducted to examine whether attention was oriented to spatial locations or objects. The results indicated that there was no benefit in identifying target features based on whether the two targets were located on the same object as compared to different objects. For Experiment 1A, there was no effect of precue. One possible explanation for this result is that the spatial extent of attention has a fixed size. A second explanation is that the spatial extent of attention is adjustable. There were two goals of Experiment 1B. The first goal was to examine whether attention oriented to spatial locations or objects. The second goal was to examine whether the spatial extent of attention could be adjusted using a precue. In the current study (Experiment 1B), a go/no go precue was used. The two sizes of precues were examined to compare these possible explanations for a null effect for precue in Experiment 1A.

First, performance for the go trials and no go trials were examined. Subjects were instructed to withhold responses to no go trials and respond to go trials. The data indicated that subjects had minimal errors. Subjects made an average of 2 false alarms in 480 trials. One subject's data was omitted because of high false alarm rates and low accuracy ($M = 65\%$).

Analysis 1 examined trials with small wrenches and small precues to compare the assumptions of the UCR object-based theory and the grouped array theory. The results indicated that at close spatial separations, there was no significant performance difference for target on the same wrench as compared to different wrenches. However, as the spatial separation increased between wrenches, accuracy decreased for targets located on

the same wrench. This pattern of results is not consistent with any of theories (space-based theory, UCR object-based or the grouped array theory). A possible explanation for these results is that different modes of attention are employed at different spatial separations. At smaller spatial separations, attention is spatially oriented. However, as the spatial separation increases, subjects have higher performance when the target features are located on different wrenches as compared to when the target features are located on the same wrench.

Analysis 2 examined trials with a large precue to compare the assumptions of the spotlight and zoom lens theories. Comparisons were made between small and large spatial separation when the precue and wrenches were large. The purpose of Analysis 2 was to examine whether there was a performance cost for objects that are peripherally located as compared to those located closer to the center of fixation. Indeed, performance decreased as a function of spatial separation. Since attention was precued to a large region, the increased response time was interpreted as reflecting the time cost for shifting attention to the location of the targets. These results provide evidence in support of the spotlight theory of attention. According to the spotlight theory performance should decrease as a function of spatial separation. Indeed, the results showed that subjects responded faster to smaller spatial separations as compared to larger spatial separations. Analysis 3 compared the assumptions of the spotlight/gradient and zoom lens theories by comparing performance between small and large precues. The results indicated that there was a performance benefit for providing small precues. Subjects responded faster when attention was narrowly focused with a small precue as compared to a large precue.

Chapter 3

In Experiments 1A and 1B, the precue specified the location of the targets. Experiment 2 was conducted to examine whether precues directed attention to objects and locations. To address this issue Experiment 2 used two types of precues: within-object precues and between-object precues. For within-object precues, one symbol (i.e. asterisk or plus sign) was located on one end of each wrench. For between-object precues, one symbol was located on each end of a single wrench.

Subjects

The subjects ($N = 8$) were undergraduate students between the ages of 18 to 25, with normal or corrected-to-normal vision. All subjects were paid for their participation.

Design

Experiment 2 was analyzed using a 2 (Object: same or different object) x 2 (Precue: within-object or between-object) ANOVA.

Apparatus

The apparatus and stimuli were identical to that used in Experiment 1B. The only difference was that the precue was composed of two symbols (asterisks or plus signs) as compared to four symbols.

Procedure

On each trial, a fixation cross was presented to focus the subject's attention to the center of the screen. Pressing the space-bar prompted the precue to be displayed for 150 ms. prior to the presentation of the wrenches. For a between-object precue, the two symbols

appeared at the same location as the wrench with targets --- one symbol on each end of the same wrench. For a within-object precue, the two symbols appeared at the same location as the two ends of the two wrenches. Similar to Experiment 1B, the precue indicated a go or no/go response. For a go precue, the two symbols matched (i.e. two asterisks or two plus signs). The subject was instructed to identify how many target features were present. The targets were a bent end or an open end of a wrench. For a no go precue, the two symbols mismatched (i.e. symbols were an asterisk and a plus sign.). The subject was instructed to withhold responses for no go trials. The precue was either a within-object or between object precue. A within-object precue was used to focus attention to both ends of a single wrench whereas a between-object precue was used to focus attention to the ends of two different wrenches.

For go precues, the subject was instructed to respond to the wrench task by identifying whether one or two target features were present. Feedback for responding on a no go trial was indicated by a buzzing audio cue. Failing to respond to stimuli within the allotted time and entering the incorrect number of targets was indicated by a low auditory tone. Correct responses were followed by a high tone.

Prior to the experiment, subjects were presented with one block of demonstration trials and one block practice trials (a block of 24 trials). For the demonstration trials, the presentation of the stimuli was 1000 ms. For the practice trials, the presentation of the stimuli was 150 ms. There were four blocks of experimental trials (a block consisted of 480 trials). The duration of the experimental session was approximately 1 hour.

Predictions

According to the space-based theory, precues engage attention to process information located within the attended region (Hypothesis 1). According to the space-based theory, the subject should respond faster and more accurately if the precue corresponded with the target feature(s) location, irrespective of whether the target features were located on the same object or different objects. If the precue did not correspond with the target's location, then performance should decline as compared to when the precue corresponded with the target location. The longer response times are due to the process of disengaging and shifting attention to the targets' locations.

According to the object-based theory, precues will signal objects for processing. As a result higher performance should occur if the target feature(s) are located on the cued object, irrespective of whether the precue indicate the location of the target feature(s).

Analysis and predictions

There were two comparisons: Analysis 1 made comparisons for between-object and within-object precues for one target feature trials (see Figure 14). Analysis two made comparisons for between-object and within-object precues for two targets trials.

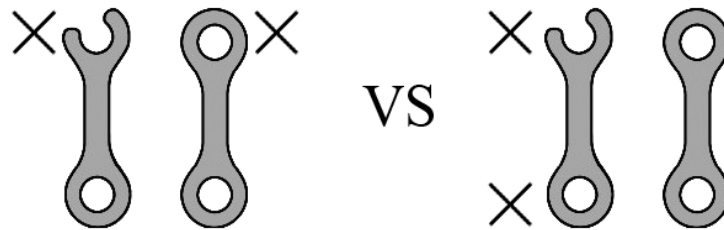


Figure 14. Analysis 1 comparing between-object and within-object precues with one target feature present.

In Analysis 1, there was a planned comparison between two conditions. In the first condition, the precues cued the ends of two wrenches ---one of the precues corresponded with the target's location (see Figure 15). In the second condition, the precues cued a wrench that contained the single target feature. According to the space-based theory, information is selected and processed based on whether it is located within the attended spatial region. Therefore, there should be no significant difference in performance because the spatial separation between and within target features were equidistant.

According to the object-based theory, performance costs should occur when attention is divided between two objects (Hypothesis 4). As a result, subjects should respond faster when both target features are located on the same wrench (condition 2) as compared to when the targets are located on different wrenches (condition 1).

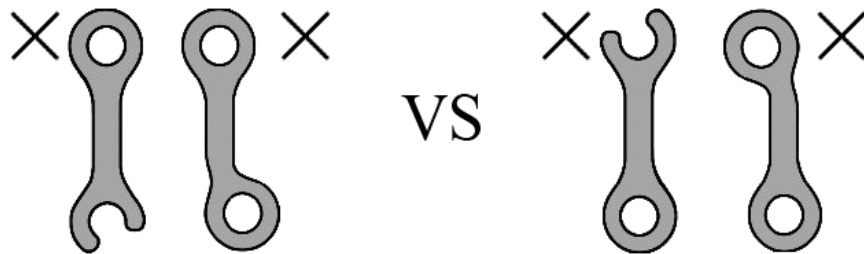


Figure 15. Analysis 2.1 comparing between-object and within-object precues with two target features present.

There were two components for Analysis 2. In Analysis 2.1, there was a planned comparison between trials in which the precue specified both the location and wrench with the target features (condition 2) as compared to when the precue only specified the wrenches (condition 1) (see Figure 16). According to space-based theory, subjects should respond faster and more accurately when the precues correctly specified the targets location (condition 2) as compared to when the precue specifies a wrench but not the location of the features (condition 1). According to object-based theory, target features for precued objects are necessarily processed (Hypothesis 4). Therefore, there should be no significant difference in performance because both wrenches were precued.

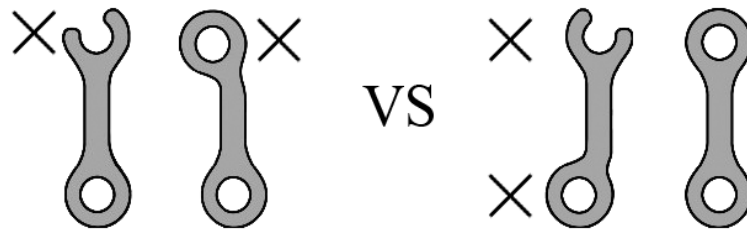


Figure 16. Analysis 2.2 comparing between-object and within-object precues with two target features between-object and two features within-object.

Analysis 2.2 examined trials in which the both the location and objects were precued. There was a planned comparison between either conditions in which the two target features were located on different wrenches (condition 1) or on the same wrench (condition 2) (see Figure 16). According to the object-based theory, costs should occur when attention is divided between two objects (Hypothesis 4). As a result, subjects should respond faster and with greater accuracy when both target features are located on the same wrench as compared to different wrenches.

According to the space-based theory, information is selected and processed based on whether it is located within the attended spatial region. For both conditions, the spatial separation between target features and within target features were equidistant. The precues also indicated the location of target features for both conditions. Therefore, no difference in performance was predicted.

Results

For Analysis 1, there was no significant difference between-object and within-object precues for response time and accuracy: $t(7) = -0.596$ and $t(7) = -0.998$, $p > .05$.

For Analysis 2.1, there was no significant difference between conditions for response time and accuracy: $t(7) = 1.529$ and $t(7) = 0.620$, $p > .05$.

For Analysis 2.2, there was a significant difference between conditions for response time but not accuracy, $t(7) = -.02.479$, $p < .05$ and , $t(7) = 1.145$, $p > .05$. Subjects were faster ($M = 450$ ms) when two wrenches were precues as compared to both ends of a single wrench ($M = 476$ ms).

Discussion

Experiment 2 was conducted to examine whether a precue could facilitate the processing of preattentive object or spatial locations using between or within-object precues. The results from Experiment 2 found mixed results. In Analysis 1, between-object and within-object precues were compared when one feature was present. The results indicated that there was no difference in performance for between and within precues. This is consistent with the space-based prediction that subjects should have faster performance when the location of the object was precued. This was contradictory to the object-based assumption that object-based effects occur because attention is divided between two or more objects. In this condition, attention was either divided between two wrenches or focused on a single wrench. The lack of a significant difference in performance was congruent with the predictions of space-based theory and incongruent with that of object-based.

The result from Analysis 2 was consistent with the prediction of object-based theory. In one condition, the precue only cued the two wrenches and not the locations of the features. In the other condition, the precues cued the two wrenches and the features

location. There was no performance difference that when both objects were precued and two features were located on each wrench. Or at the least, the results did not support the space-based theory that subjects would respond faster if the target locations were precued.

To further investigate whether attention processes object or features within an attended location, Analysis 3 was used to examine conditions in which both the objects and target locations were precued. The comparison was between features located on the same or different objects with the corresponding valid precues. In one condition, the features were located on two different wrenches and the precue were also located on two different wrenches. In the second condition, the features were located on the opposite ends of the same wrench, with the precue also corresponding to these ends. The results indicated that subjects were faster 27 ms faster when two wrenches were precues as compared to both ends of a single wrench. This result seems to indicate that there is a between-object advantage --- when the target features are located between two wrenches and the precue indicates both wrenches, subjects perform significantly faster than when the target features are located within a single wrench and the precues indicate one wrench.

Chapter 4

According to the object-based theory of attention, visual information is organized into preattentive units (i.e. perceptual objects). These preattentive units are interpreted as perceptual objects according to similar surface properties (Palmer & Rock, 1994).

However, for real world viewing conditions objects are rarely composed of regions with uniform luminance, texture, color, etc. Objects can vary in surface properties. For example, a single object can have changes in surface properties when its surface structure is partially occluded by another object. For these conditions the projected image of a single object is discontinuous. Thus, the visual system must combine the separate parts of the object to perceive a complete object - a phenomenon known as amodal completion (Schumann, 1904).

A phenomenon similar to amodal completion occurs with illusory contours (see Figure 17). An illusory contour (or modal completion) is a visual illusion in which contours are perceived without explicit color or luminance changes (Shipley & Kellman, 1990). The individual parts are perceived as a global object rather than as its component parts through Gestalt principles. Thus, objects can be perceived as a single unit, for a wide range of visual conditions, even when the shape of the object is not specified with a boundary (Wertheimer, 1912; Schumann, 1904; Kanizsa, 1955).

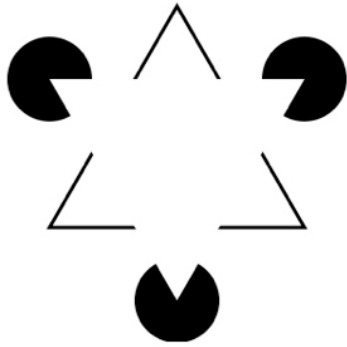


Figure 17. The Kanizsa triangle is an optical illusion of illusory contours.

Studies suggest that attention can be directed to perceptual objects defined by Gestalt principles (O'Hara & Eriksen, 1979; Kramer & Jacobson, 1991). Attention is directed to perceptual objects that are grouped according to color, movement, spatial distance, orientation, and figure/ground organization (Banks, Bodinger, Illige, 1974; Banks & Prinzmetal, 1976; Beck & Ambler, 1973; Driver and Baylis, 1989). With various forms of object representation, it is important that object-base attention theories provide an a priori definition of a preattentive object. Palmer and Rock (1994) define a perceptual object as a "uniform connected region" (UCR). According to the UCR object-based theory, perceptual objects with connected boundary are preattentively processed whereas objects formed by Gestalt rules of grouping (i.e. amodal completion) require additional processing. In contrast, an assumption of the grouped array theory is that different types of object representations can be preattentively processed. According to the grouped array theory, preattentive objects are defined by Gestalt principles such as good continuity (i.e. UCR region), closure (i.e. illusory contours), or similarity (i.e. grouped discrete units) (Farah & Vecera, 1994; Kramer & Jacobson, 1991). This less

exclusive definition of a perceptual object accounts for non-uniform luminance texture and surface properties that are often present in real world viewing condition. In summary, the UCR object theory and grouped theory can be compared by examining whether discrete units grouped by amodal completion can be preattentively processed.

As previously mentioned, real world objects are often complex---composed of discontinuous features due to occluding surfaces or changes in surface structures. Experiments, however, often use figures (e.g., line segments) that may not be considered to be real world objects (Lavie & Driver, 1996). Thus, one of the objectives of Experiment 3 was to relate object and spaced based theories to real world applications. One such application is the design of traffic signs for efficient reading.

Experiment 3 used wrenches that were on a sign configuration comparable to roadway signs. There were two object representations in Experiment 3: (1) the wrench and (2) the sign configuration. The primary aim of the experiment was to examine whether sign configuration affected performance on the wrench judgment task. The sign was manipulated by using different types of boundaries. Boundary types included a connected region, an implicitly connected region with illusory contours (i.e. an amodal object), or a region grouped by similar angles that do not form an illusory contour (i.e. grouped unit object) (see Figure 18).

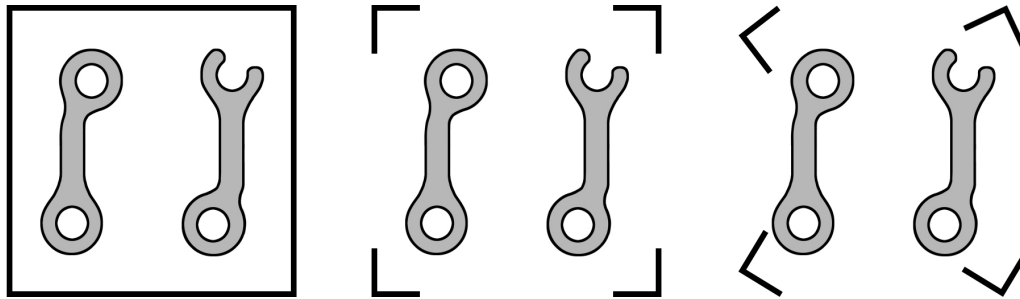


Figure 18. Experiment 3 example of a precue sign configuration. From left to right, the UCR sign, the amodal sign, the grouped unit sign.

Experiment 3 examined whether grouped unit objects and amodal objects were processed as efficiently as UCR objects. Similar processing efficiency of the two types of objects would indicate that both were preattentive representations.

Predictions

According to both object-based and grouped array theories, response times should be faster if the target features are located on the same wrench as compared to two different wrenches (Hypothesis 4, 6). However, the two theories have different predictions for sign type. An assumption of the grouped array theory is that objects formed from illusory contours are preattentively processed. Thus, response times should decline as a function of the signs representation strength. Specifically, the highest level of performance was predicted for the UCR sign, followed by the illusory contour sign (amodal sign), with the poorest performance for the grouped unit sign. According to the UCR object-based theory preattentive processing is reserved for objects formed by uniform, connected regions (Hypothesis 4). Amodal signs or grouped units signs are not preattentively processed. Therefore, subjects should have the highest level of performance (increased accuracy and decreased response time) for the connected sign condition and equally poor

performance for the UCR the grouped unit objects. The increase in response time would indicate time to group the four UCR objects (i.e. angles) into a single superordinate object.

Subjects

The subjects ($N = 8$) were undergraduate students between the ages of 18 to 25, with normal or corrected-to-normal vision. All subjects were paid for their participation.

Design

Experiment 3 was analyzed using a 2 object type (same or different) x 3 signs (UCR sign, amodal sign, or grouped unit sign) ANOVA.

Apparatus, Stimuli, and Procedure

On each trial, a fixation cross was presented to focus the subject's attention to the center of the screen. Pressing the space-bar prompted the sign configuration to be displayed for 150 ms. The sign configuration was used to indicate the size of the region (i.e. sign configuration) containing the target features. There were three possible sign configurations: a UCR box, an amodal box, and a grouped unit box. Following 150 ms, the sign configurations remained on the screen while two adjacent wrenches were displayed 150 ms. The wrench stimuli were the same as Experiment 1A, 1B, and 2. The primary difference in this experiment was that the precue sign configurations remained on the screen while the wrenches were displayed. A blank screen was presented after the wrench stimuli during which subjects indicated whether one or two of the target features (open end and/or bent end) were present in each trial. After the subject responded, an

auditory feedback was provided (a high tone for correct responses and a low tone for incorrect responses) followed by a fixation cross indicating the next trial.

Prior to the experiment, subjects were presented with one block of demonstration trials and one block practice trials (a block of 24 trials). For the demonstration trials, the presentation of the stimuli was 1000 ms. Performance on the demonstration trials was assessed to determine whether subjects understood the task. For the practice trials, the presentation of the stimuli was 150 ms. The purpose of the practice trials was to show the subject the duration of the stimulus presentation on the actual trial. The duration of the experimental session was approximately 1 hour.

Results

The results indicated a main effect of object for response times and accuracy, $F(1, 7)=5.671$ and $F(1, 7)=20.715$, $p > .05$ (see Figure 19). Subjects were faster ($M = 509$ ms) and more accurate ($M = 93\%$) when the features were located on different wrenches compared to when the features were on the same object ($M = 534$ ms) and ($M = 87\%$). However, there was no main effect for sign for response times or accuracy, $F(2, 18)=1.0$ and $F(2, 18)=0.67$, $p > .05$. There was no significant difference in performance for the connected region sign, UCR sign, or grouped unit sign.

Further analysis explored whether there was an object-based effect for each of the sign representations. For box sign, there was a main effect of object for accuracy but not response time, $F(1, 7)=7.5$, $p < .05$ and $F(1, 7)=1.6719$, $p > .05$ (see Figure 20). Subjects were more accurate ($M = 95\%$) when the wrenches were present on different wrenches as compared to the same wrench ($M = 89\%$).

For the bracket sign, there was a main effect of object for accuracy but not response time, $F(1, 7)=13.19, p<.05$ and $F(1, 7)=1.36, p>.05$ (see Figure 21). Subjects were more accurate ($M = 95\%$) when the targets were located on the same wrench as compared to different wrenches ($M = 90\%$). Grouped unit object, there was a main effect of object for accuracy but not response time, $F(1, 7)=6.566, p<.05$ and $F(1, 7)=2.24, p>.05$ (see figure 30 and 31). Subjects were more accurate ($M = 95\%$) when the targets were located on the same wrench as compared to different wrenches ($M = 88\%$).

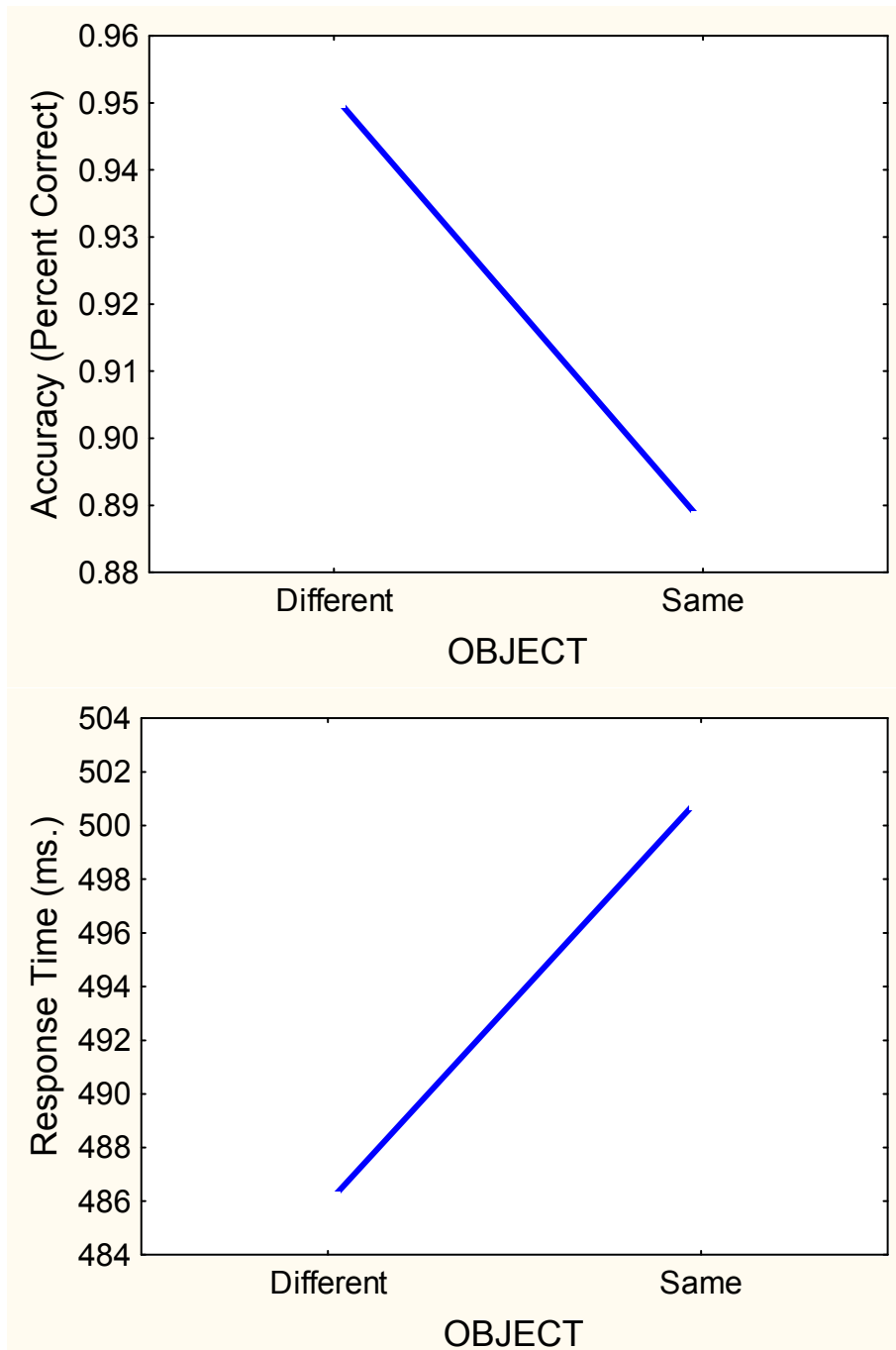


Figure 19. Main effect of object on accuracy but not response times. Subjects were 6% more accurate when the features were presented on different objects compared to the same object.

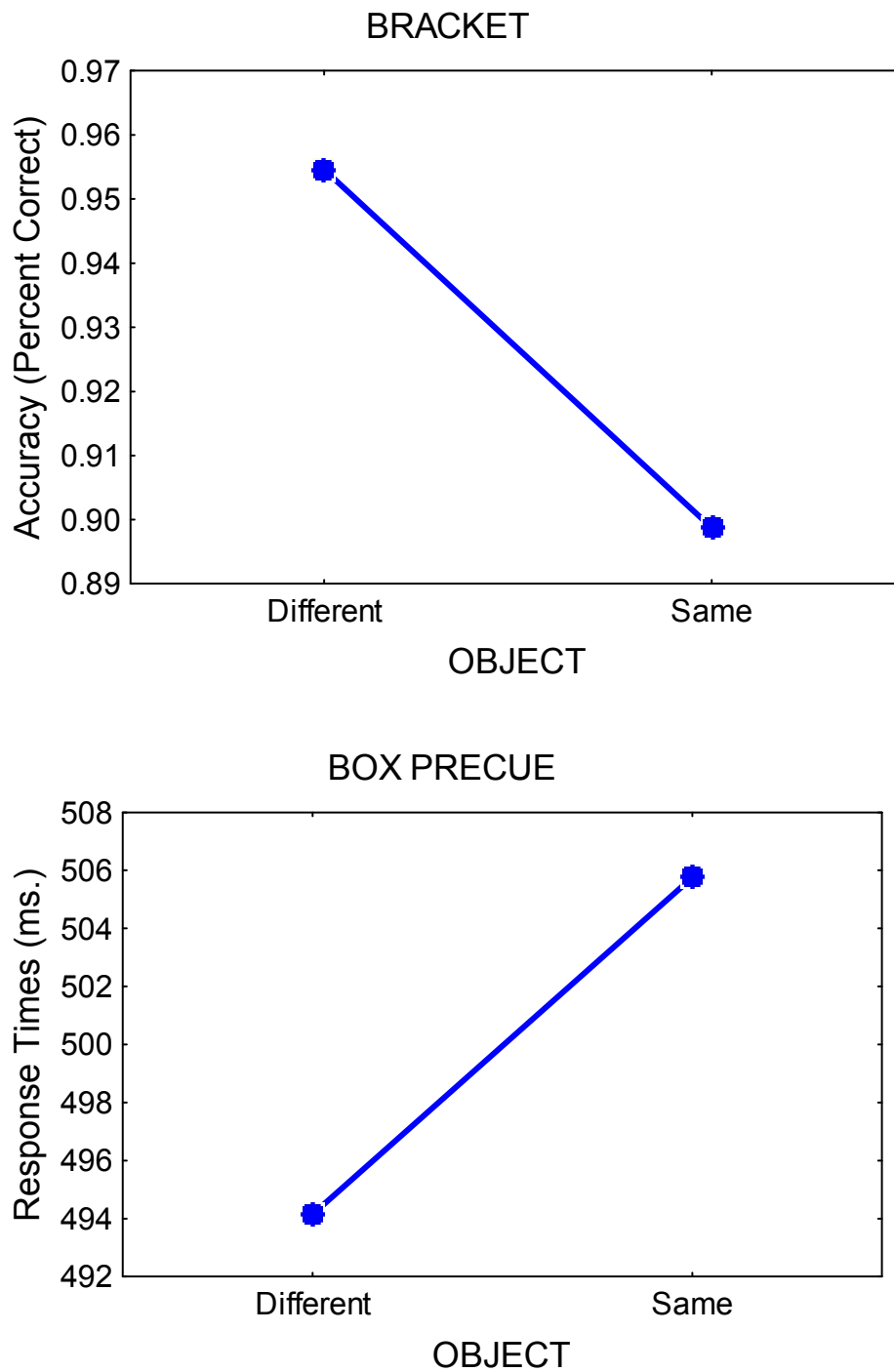


Figure 20. For box sign configurations, there was a main effect of object on accuracy but not accuracy. Subjects were 5% more accurate when the features were presented on different objects compared to the same object. Figure was provided to show that there was no speed accuracy trade-off.

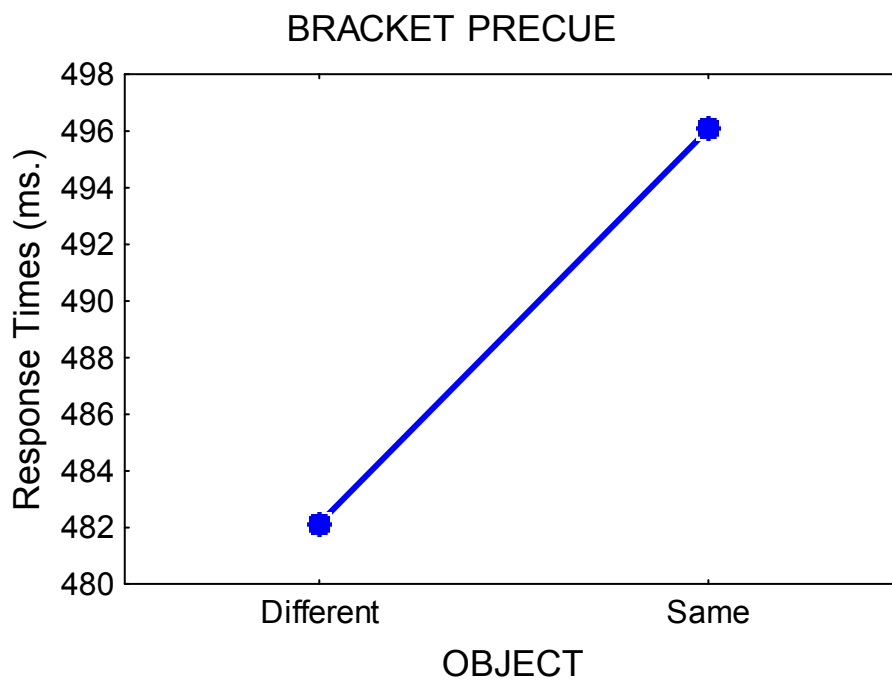
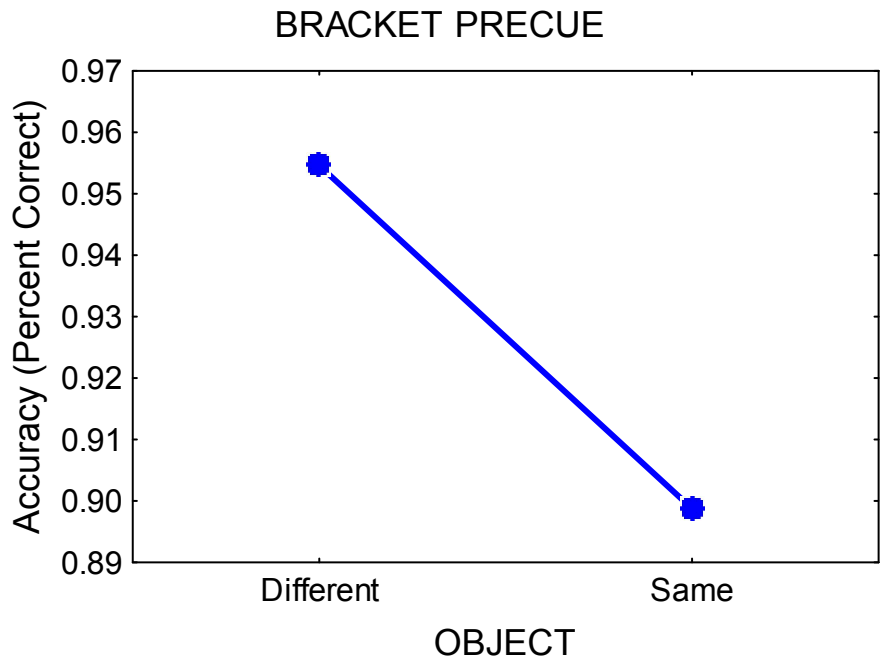


Figure 21. For bracket sign configurations, subjects were 7% more accurate when the features were presented on different objects compared to the same object.

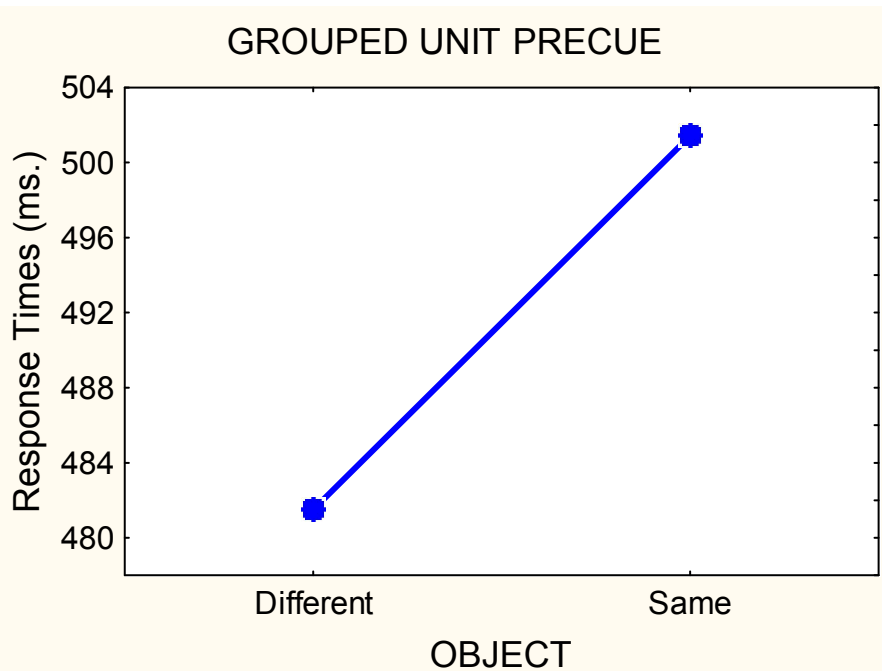
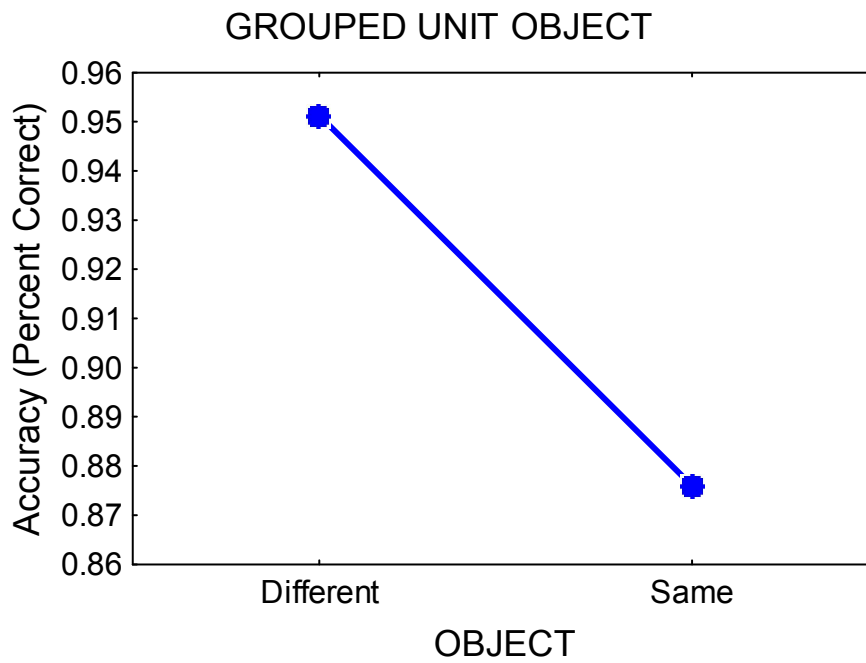


Figure 22. For grouped unit signs, there was a main effect of object for accuracy but not response time. Subjects were 7% more accurate when the targets were located on the wrench as compared to different wrenches.

Discussion

Experiment 3 was conducted to examine whether preattentive processing is dependent on modal completion. According to the UCR theory, a perceptual object is defined by a uniform continuous region in order to be preattentively processed. Amodal objects form separate UCR objects that require furthering processing to be perceived as a single object. It was predicted that there would be a significant difference in performance for the three sign conditions. Specifically, it was expected that higher performance would occur for the UCR object and poorer performance for the amodal and grouped unit signs. Alternatively, according to the grouped array theory amodal objects and grouped unit objects can be preattentively processed for visual attention. As a result there should be graded performance for the three sign configurations. The best performance was predicted for the UCR sign, followed by the amodal sign, and followed by the grouped unit sign. The results did not support the UCR theory that differences in performance would be found. Subjects were not faster nor more accurate for wrenches located on a UCR sign as compared to an amodal sign, or a grouped unit sign. Instead, the results support the grouped array hypothesis in that no performance differences occurred for the different sign configurations.

Planned comparisons were made for each sign configuration to examine whether object-based effects would be found. The results indicated an object-based effect for the box sign and the bracket sign. Subjects were more accurate at responding to features on different wrenches as compared to the same wrench. However, when the wrenches were presented on the grouped unit sign, there was an opposite effect. Subjects were more

accurate when the features were located on the same wrench as compared to on different wrenches. A possible explanation is that the precues (i.e. signs) may be been processed as objects where the wrenches were processes as the features. In Experiment 4, however, there were two possible object representations --- the sign configuration and the wrenches. In previous experiments, there was no sign configuration. It is important to note that the sign configuration was presented prior to the wrenches and remained on the screen when the wrenches appeared. If this were the case, the features (i.e. wrenches) may be easier to distinguish if they were on different wrenches rather than the same wrench.

CHAPTER 5

An assumption of object-based theory is that that a perceptual object is defined by a uniform continuous region. Therefore, only an object defined by a UCR region can be preattentively processed. However, other studies have found that the strength of a perceptual object (i.e. objecthood) can vary according to different Gestalt principles (Kramer & Jacobson, 1991). Objecthood is defined as the degree of image regularity due to properties such as closure, collinearity, and symmetry. In their study, the perceptual strength of an object varied according to whether the central line and two flanker lines were located on the same object, a different object, or grouped object. The task was to identify whether the central line (dash or dotted) was compose of the same or different feature as the flanker lines.

Watson and Kramer's results indicated that performance depended on the strength of the object's representation. When the target and flanker lines matched, they found the best performance for same object, poorer performance for the grouped object, and the worst performance for a different object condition. Likewise, they found that if target and flanker lines did not match, the same object condition resulted in the poorest performance. Their results indicate that the performance on the feature matching task was dependent on the strength of its membership to an object. The object membership was dependent on the strength of the Gestalt principle for the perceptual object. These conclusions have led some researchers to hypothesize that the grouping process may occur for each level of object representation rather than exclusively at the preattentive stage (Palmer, Brooks, Nelson, 2002). Palmer and colleagues hypothesized that some levels of representation occur preattentively while other levels of

representations occur subsequent to attentional processing. This suggests that the boundaries of subsequently processed objects may be reinterpreted using top-down knowledge.

A classic example of top-down processing is the R.C. James's illustration of a Dalmatian in a background of spots (Marr, 1982). Although it is widely recognized that goals, prior knowledge, and expectations can influence attentional processing, research using top-down information has been conducted primarily on visual search tasks (O'Hara & Eriksen, 1979; Theeuwes, Reimann, & Mortier, 2006) and not on selective attention tasks. The effect of top down information was examined using verbal precues.

Experiment 4 examined the grouping process for objects using two intersecting wrenches (see Figure 23). Two types of wrench configurations were examined. For the first configuration, the wrench with the targets occluded the other wrench. The wrench with the targets was referred to as the continuous wrench. For the second configuration, the wrench with the targets was occluded by the other wrench. It was referred to as the occluded wrench. The occluded wrench can be interpreted as one of two different configurations: composed of two UCR objects or as a single grouped object. In contrast, the continuous wrench is composed of only one UCR object. Performance on the judgment task was used to determine whether an occluded object could be preattentively processed.

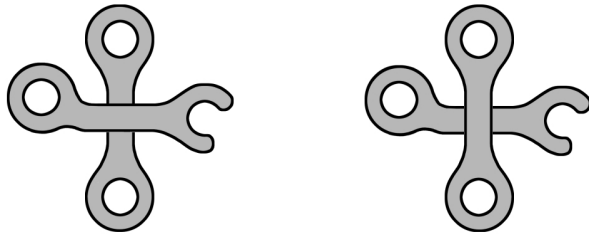


Figure 23. On the left figure, the horizontal wrench is continuous. On the right figure, the horizontal wrench is occluded.

The goals of Experiment 4 were two-fold. First, the experiment was conducted to examine the issue of object configuration studied in Experiment 3. In the previous study (Experiment 3), the preattentively processed object was the sign's configuration. Experiment 4 used a wrench as the preattentive object. The purpose of the experiment was to examine whether the perceptual strength of the wrench affected performance on a target judgment task. Comparisons were made between a continuous wrench (i.e. UCR object) and an occluded wrench (i.e. amodal object). The second goal was to determine whether preattentive processing was mediated by top down information. Experiment 4 examined whether processing object representations was affected by endogenous precues (i.e. top down processing). The question was whether the availability of top-down information would improve attentional processing (i.e. faster response times and lower error rates).

Predictions

In the experiment, there were two forms of object representation --- objects formed by amodal completion (i.e. the occluded wrench) and UCR objects (i.e. the continuous wrench). According to the grouped array theory, attention can operate preattentively on various types of object

representations (Hypothesis 6). There were no performance differences predicted for identifying features located on an occluded wrench (formed by amodal completion) as compared to a continuous wrench. Conversely, according to the UCR theory, there is a fundamental difference between UCR objects and those formed by amodal completion. UCR objects are preattentively processed, whereas, amodal objects require additional processing. However, preattentive precues provide information should assist in processing the information faster and accurately, therefore so that no differences should be found.

Where the two theories differ are their predictions for invalid precue trials. According to the UCR theory, an invalid precue should result in lower performances for occluded wrench compared to the continuous wrench. For these trials, attention must shift to the correct location/wrench and then group the two sub-components into a superordinate wrench. Subjects should be faster at identifying features located on the occluding wrench compared as to the occluded wrench (Hypothesis 4). This result is expected because the occluded object forms two UCR objects, which requires additional time to assemble the two perceptual units (i.e. two halves of the bar) into a single superordinate object (a continuous bar) (Palmer & Rock, 1994) (Hypothesis 5). Thus, performance was expected to decline due to grouping costs and the time required to redirect attention to the correct sign orientation.

According to the grouped array theory, the only predicted performance cost is the time required to shift attention to the correct wrench. Although the invalid precue does not provide top down information about the target's location, it was not predicted that

there would be a difference in performance between the continuous wrench and the occluded wrench because they are both processed preattentively.

Subjects

The subjects ($N = 8$) were undergraduate students between the ages of 18 to 25, with normal or corrected-to-normal vision. All subjects were paid for their participation.

Design

Experiment 4 was analyzed using a 2 (Precue: valid, invalid) x 2 (Objecthood: occluded, continuous) ANOVA.

Apparatus and Stimuli

Stimulus presentation and data collection were conducted on standard PC computers.

The displays were presented on a SVGA color monitors and responses were recorded using a standard QWERTY keyboard. The D key was used to enter “one feature” response with the left index finger. The “L” key was used to enter “two features” response with the right index finger.

The stimuli were viewed binocularly from a distance of 53.34 cm. The wrenches were presented in a cross formation (see Figure 24). The wrench cross height was 6.4 cm and presented at the viewing angle of 6.84° . The wrench cross was positioned such that outer distance of each corner was 6.4 cm apart. For the 6.4 cm wrench, there was a 2.4° separation between the interior edges of the closest different-object condition. The circle end of each wrench had a diameter of 1.8° . The wrench was 0.6° wide and 1.5° in length.

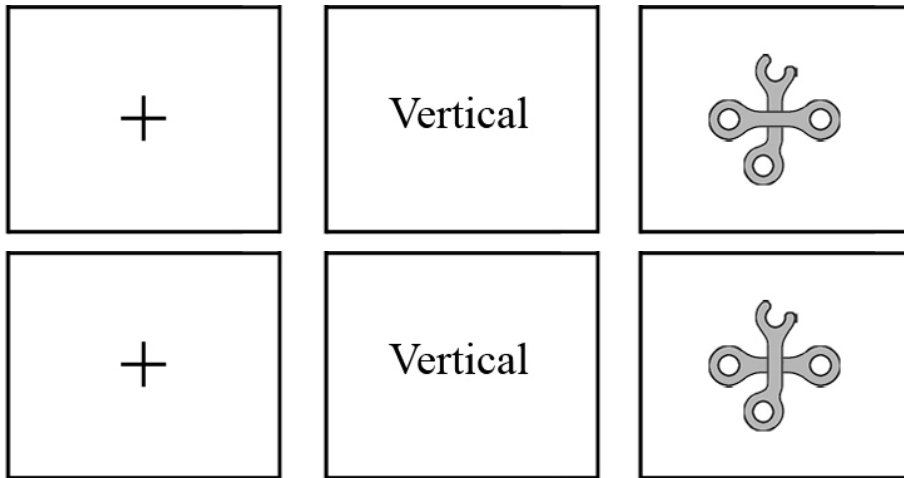


Figure 24. Experiment 4. Top figure represents a valid precue trial with an occluded wrench. Bottom figure represents a valid trial with a continuous wrench.

Procedures

There was a fixation cross at the beginning of each trial. The subject was instructed to press the space button to begin each trial. After the button press, there was an auditory precue of a recorded voice stating “horizontal” or “vertical”. The volume and duration of both audio files were equal. The auditory precue provided top down information by stating the orientation of the wrench with the features (horizontal or vertical) (see Figure 26). A horizontal precue indicated that target(s) were located on the horizontally oriented wrench. A vertical precue indicated that target(s) were located on the vertically oriented wrench. After the precue, the subject was presented with two intersecting wrenches. There were one or two target features presents. If two target features were present, they were always present on the same wrench. A precue was either valid or invalid. For 90% of the trials, a valid precue matches the orientation of the wrench containing the features.

For example, a horizontal precue was preceded by stimuli with target features located on the horizontal wrench. An invalid precue does not match the orientation of the wrench features. For example, the precue was “horizontal” and was followed by stimuli with target features located on the vertical wrench. A vertical precue indicated that target(s) were located on the vertically oriented wrench. The target appeared on the precued wrench for the valid precue conditions.

For the invalid precue conditions the target features were on the wrench of the opposite orientation. There were two types of invalid precue conditions. For the first condition, the occluded wrench was precued but the target(s) were located on the continuous bar. For the second condition, the continuous bar was precued but the target(s) were located on the occluded bar. The wrenches were on the sign configuration after an ISI of 250 ms. Once a response was entered, the screen returned to the fixation cross.

Prior to the experiment, subjects were presented with one block of demonstration trials and one block practice trials (a block of 24 trials). For the demonstration trials, the presentation of the stimuli was 1000 ms. Performance on the demonstration trials was assessed to determine whether subjects understood the task. For the practice trials, the presentation of the stimuli was 150 ms. The purpose of the practice trials was to show the subject the duration of the stimulus presentation on the actual trial. The duration of the experimental session was approximately 1 hour.

Results

There was a main effect of precue on response time but not accuracy, $F(1, 7)=6.196$, $p<.05$ and $(1, 7)=1.212$, $p>.05$, respectively (see Figure 25). Subjects had faster responses for valid precues ($M=556$ ms) as compared to invalid precues ($M = 680$ ms). There was an interaction of precue and objecthood on response time but not accuracy, $F(1, 7)=7.232$, $p<.05$ and $F(1, 7)=0.024$, $p>.05$ (see Figure 26). For valid precues, there was no difference between continuous and occluded wrenches. Subjects were able to respond quickly when provided the correct top-down information. However, for invalid precues, performance diminished for the occluded wrenches. Subjects had slower responses for the occluded wrenches ($M=698$ ms) as compared to the continuous wrenches ($M=661$ ms).

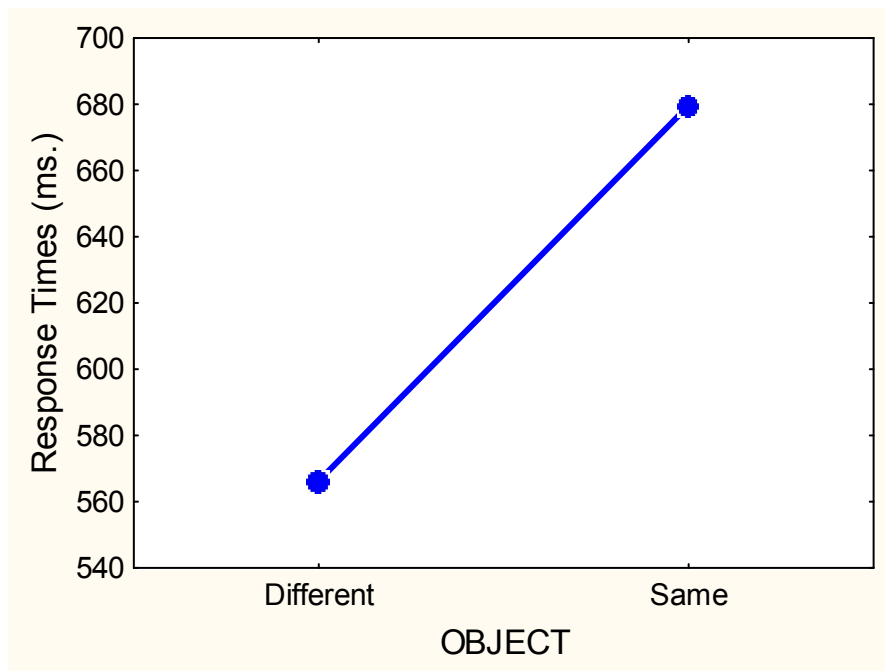
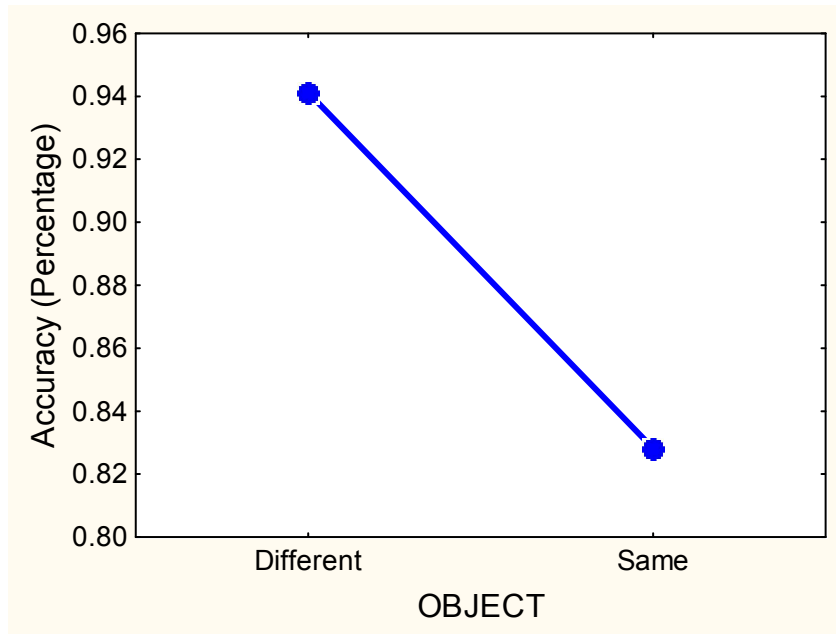


Figure 25. There was a main effect of object for response time but not accuracy.

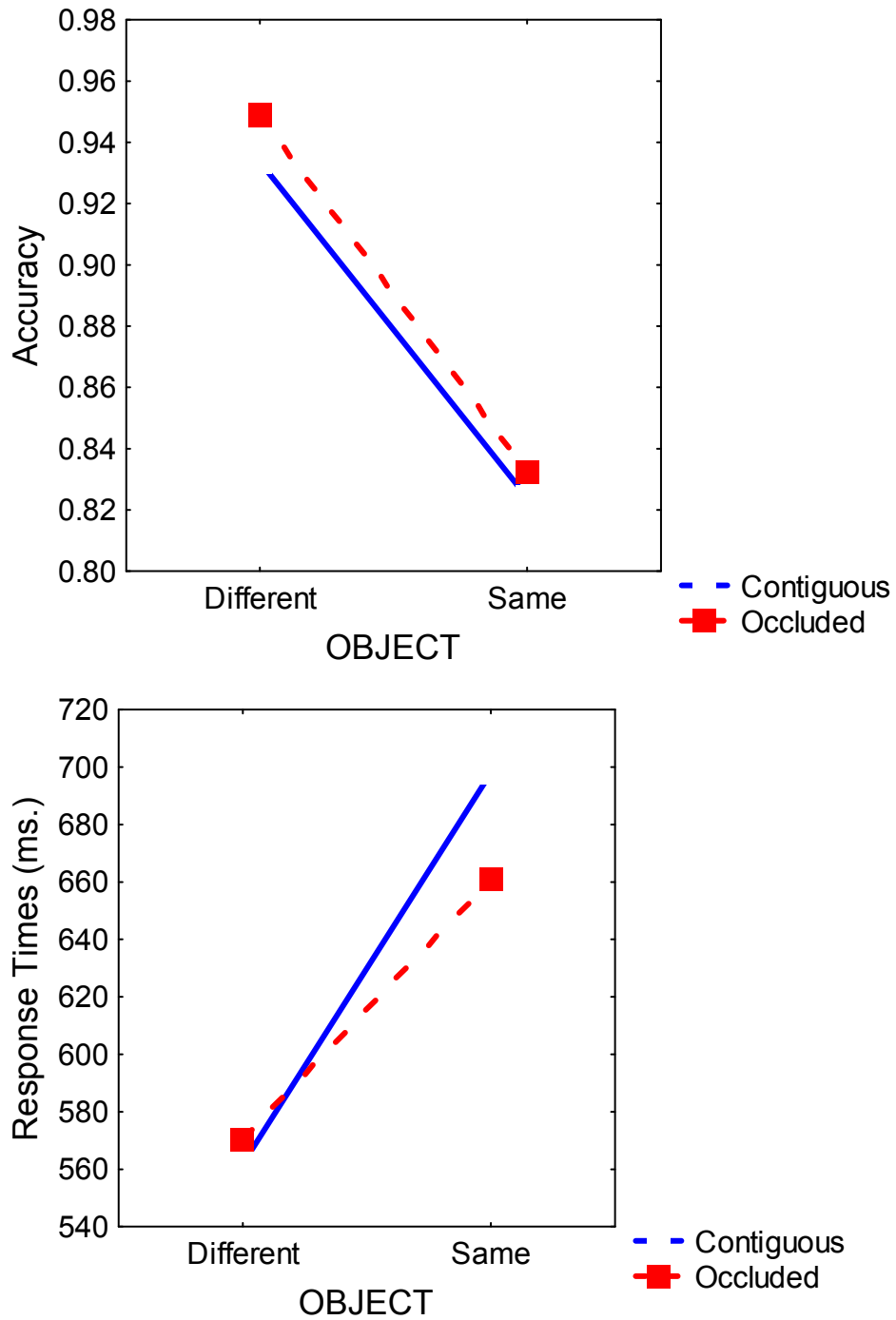


Figure 26. Significant interaction of objecthood and precue for response times but not accuracy.

Discussion

Experiment 4 was conducted to compare the assumption of UCR object-based theory and the grouped array theory. The purpose was to examine how the connectedness of an object's representation and top down information affected performance on an object judgment task. The results indicate that subjects were faster in their responses with valid precues as compared to invalid precues and indicates that subjects were able to use auditory precues to improve performance for a visual task. Thus, top down information provided by an endogenous precue could improve performance for preattentive processes.

When the precues were invalid, however, responses were significantly slower for occluded wrenches as compared to continuous wrenches. This finding suggests that the top-down information from precues can be used to group an occluded wrench (i.e. two UCR objects) as a single continuous object. However, if the top-down information was not provided (i.e. invalid precue), then an occluded wrench was processed as two UCR objects and then grouped. This interaction of precue and object support the UCR object theory and suggest that a perceptual object is formed uniform connected regions. Specifically the finding suggests that the increased response time reflects the additional processing required for perceiving the two halves of the occluded wrench and process them as a single object.

CHAPTER 6

The ability to process task relevant information is important for real world tasks. For example when in traffic, drivers must extract relevant information in a cluttered scene. Consider the scenario in which a driver reads a traffic sign. The driver must perceive and process the relevant features of the sign (i.e. text, symbols, and shapes), monitor the path of oncoming vehicles, watch for pedestrians, and negotiate a safe driving route. These tasks require the driver to select information in the presence of irrelevant features, objects, and events. An inattentive driver may miss targets or impending collision events if their attention is not directed to the correct information at the correct time. Thus, the study of attention is important for understanding how to improve driver safety.

If attention has been defined as the allocation of processing resources to a particular region or object, then inattention can be defined as the omission of processing due to a lack of resources. For the case of driving, inattention can occur when the driver must divide his/her attention between reading a posted sign and performing other driving-related tasks. This can lead to serious consequences. A recent report from National Highway Transportation Safety Administration (NHTSA) study cited driver inattention as a contributing factor in 20 to 30 percent of all vehicular highway crashes (Wang, Knipling, & Goodman, 1996). One explanation for driver distraction is that the driver has exceeded his/her capacity for processing information.

Signs are an important source of information for drivers. Traffic signs are used to indicate different messages to the driver such as the driver's current location, the rules and

regulations of the road, and warnings about impending dangers. Traffic signs can be composed of any combination of numbers, color, words, and symbols in several different sign configurations (i.e. shapes). Thus, one application of visual attention research is the design of roadway signs to facilitate the selection of task-related information. Real traffic symbols were used in Experiment 5 to investigate object-based and grouped array theories of attention.

The goal of Experiment 5 was to investigate two issues. The first issue was whether a preattentive object is defined by a uniform connected region (UCR object-based theory) or Gestalt grouping principles (grouped array theory). The independent variable used to investigate objecthood was whether the target appeared on a connected region, connected region, or separate regions (see Figure 30). The second issue was whether connectedness would affect preattentive processing. Specifically, if two “objects” with the same surface characteristics were connected by a uniform continuous surface, would the features on the two objects be processed as a single object.

Subjects

The subjects ($N = 9$) were undergraduate students between the ages of 18 to 25, with normal or corrected-to-normal vision. All subjects were paid for their participation.

Design

Experiment 5 was analyzed using a 3 (Sign: continuous region, connected region, separate regions) by 2 (Object: different, same) ANOVA.

Apparatus and stimuli

The apparatus was identical to that used in the previous experiments. The stimuli for the experiment were traffic symbols. Four traffic symbols served as targets (light house,

telephone, man, and plane) (see Figure 28) and four traffic symbols served as distractors (i.e. woman, walking man, gas station, P) (see Figure 29). The target and distractors groups were counterbalanced between subjects. The traffic symbols were located on three different types of sign configurations: a continuous region, connected region, separate regions. The height of each sign configuration was 29.99 cm. The width of the bars was 12.81 cm. The height of the traffic symbols were 10.81 cm.

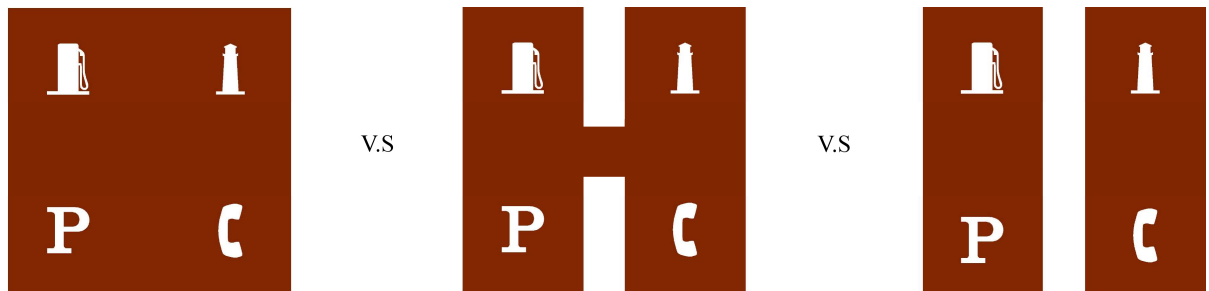


Figure 27. Sign configurations for Experiment 5 (continuous region, connected region, separate regions).

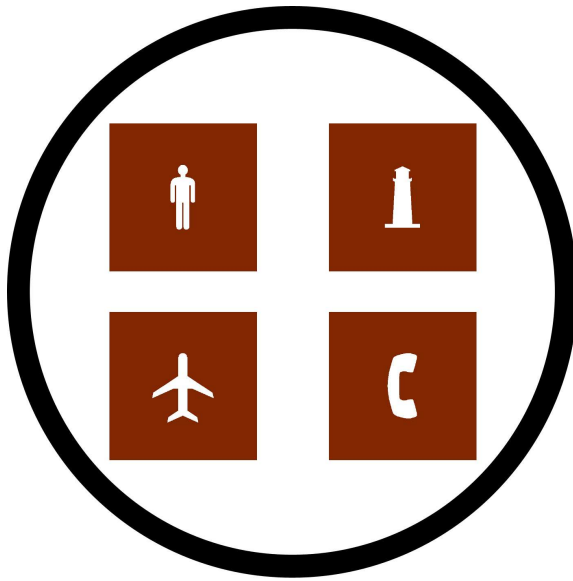


Figure 28. Traffic symbols used as targets.



Figure 29. Traffic symbols used as distractors. The target and distractor groups were counterbalanced between subjects.

Procedure

Prior to the experimental trial, the subject was trained to identify the target symbols. In the training trial, one traffic symbol was presented on the screen at a time. The subject was instructed to verbally respond whether the symbol was a target or distractor. All subjects were able to correctly identify the target symbols with 100% accuracy.

At the beginning of each trial, a fixation cross was presented to focus the subject's attention to the center of the screen. Pressing the space-bar prompted a precue to be displayed for 150 ms. For each trial, four traffic symbols appeared on a sign configuration. The task was to identify whether one or two targets symbol were present in the scene. If two targets were present, they were adjacent to one another and not diagonal to control for spatial separation between and within objects.

The symbols appeared on a different sign configuration (continuous region, connected region, separate regions) (see Figure 27). A blank screen was presented after the wrench stimuli during which subjects indicated whether one or two of the target features were present in each trial. After the subject responded, auditory feedback was provided (a high tone for correct responses and a low tone for incorrect responses) followed by a fixation cross indicating the next trial.

Prior to the experiment, subjects were presented with one block of demonstration trials and one block practice trials (a block of 24 trials). For the demonstration trials, the presentation of the stimuli was 1000 ms. Performance on the demonstration trials was assessed to determine whether subjects understood the task. For the practice trials, the

presentation of the stimuli was 150 ms. The purpose of the practice trials was to show the subject the duration of the stimulus presentation on the actual trial. The duration of the experimental session was approximately 1 hour.

Predictions

One issue examined in Experiment 5 was whether a preattentive object is defined by a uniform connected region or different Gestalt principles (grouped array theory).

According to the UCR object-based theory, preattentive objects are defined by a uniform continuous region (Hypothesis 4). A prediction of the object-based theory is that performance should decrease (increased response time and decreased accuracy) as a function of the sign's connectedness. The uniform region and connected region are both are preattentively perceived as a single UCR object. Therefore, subjects should have the best performance for both those conditions. Subject should perform the worst for the separate region condition.

According to the group array theory, there are varying degrees to which an object is processed preattentively based on different Gestalt principles (Hypothesis 6).

According to this theory, object-based effects should decrease as a function of connectedness of an object (i.e. sign configuration). The best performance was predicted for the connected region sign, the second best performance was predicted for the connected region, and the lowest performance was predicted for the separate regions.

The second issue was the role of connectedness on preattentive processing of objects. Specifically, if two "objects" with the same surface characteristics were connected by a uniform continuous surface, would the features on the two objects be

process as a single object. This question was examined by comparing whether the connected region was processed as a single object (UCR theory) or processed as two UCR objects and then grouped into a single object (grouped array theory). According to the grouped array theory, there should be an object-based effect for the separate region condition (see Figure 30). Performance should be higher if the two target symbols are located on the same bar as compared to on a different bar of the connected region. According to the grouped array theory, there are graded levels of objecthood. Therefore, subjects should perform the best when the two features are located on the same bar for the separate regions and the connected region. Performance should diminish when each feature is located on a different bar of the separate region condition.

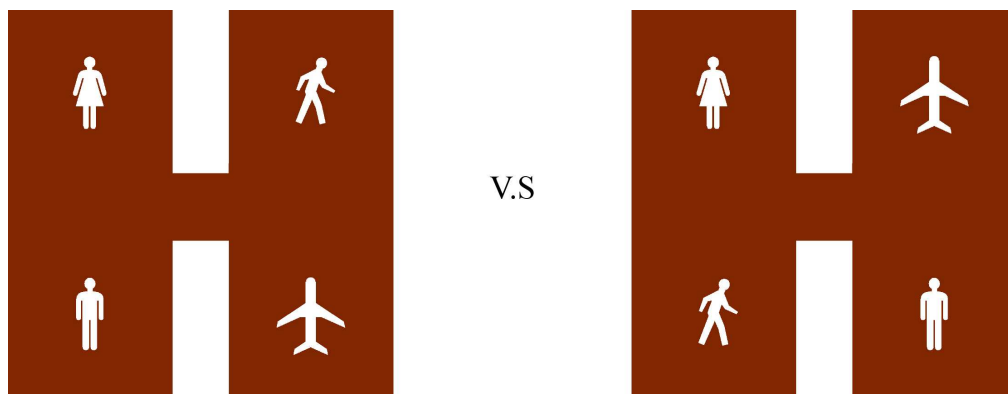


Figure 30. Connected region signs. Comparisons between features located on the same and different arm of the connected region. Left figure has one target on each bar (plane, man). Right figure has two features on the same bar.

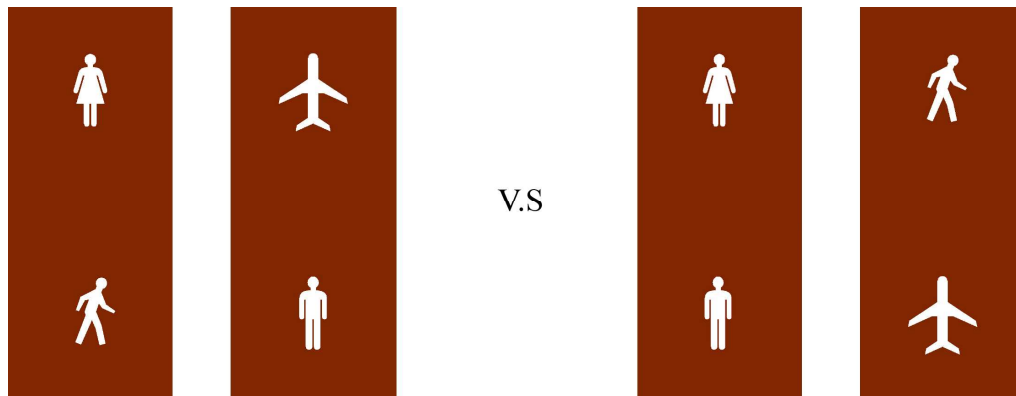


Figure 31. Separate region signs. Left figure has two targets on one bar (plane, man). Right figure has one feature on each bar.

Results

For Analysis 1, there were no significant results. There was no significant main effect of sign for accuracy or response time, $F(2, 16)=1.508$ and $F(2, 16)=0.459$, $ps>.05$. There was no significant main effect of object for accuracy or response time, $F(1, 8)=0.052$ and $F(1, 8)=3.879$, $ps>.05$. There was no significant interaction for accuracy or response time, $F(2, 16)=0.085$ and $F(2, 16)=0.564$, $ps>.05$.

Further analyses were conducted to examine whether there were object-based differences for signs. Comparisons were made for the two bar sign condition for object-based effects. There was no significant main effect of object for response time or accuracy time, $F(1, 8)=1.783$ and $F(1, 8)=0.050$, $ps>.05$. Comparisons were also made for the H-sign condition. There was a significant main effect of object for response time but not accuracy, $F(1, 8)=8.182$, $p<.05$ and $F(1, 8)=0.095$, $p>.05$ (see Figure 32). Subjects were faster to respond to targets on different continuous regions ($M = 349$ ms) as compared to the same continuous region ($M = 370$ ms).

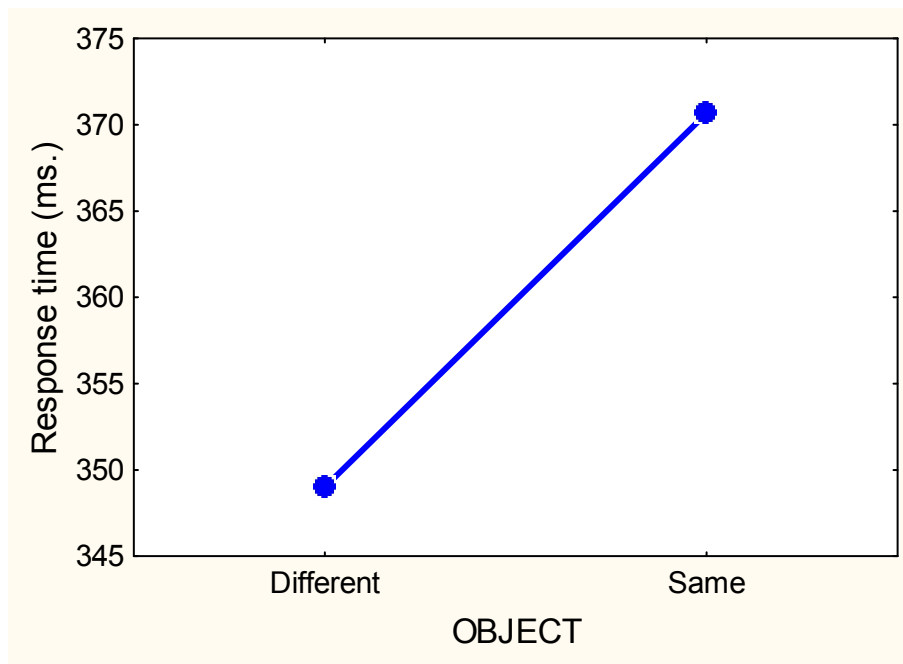
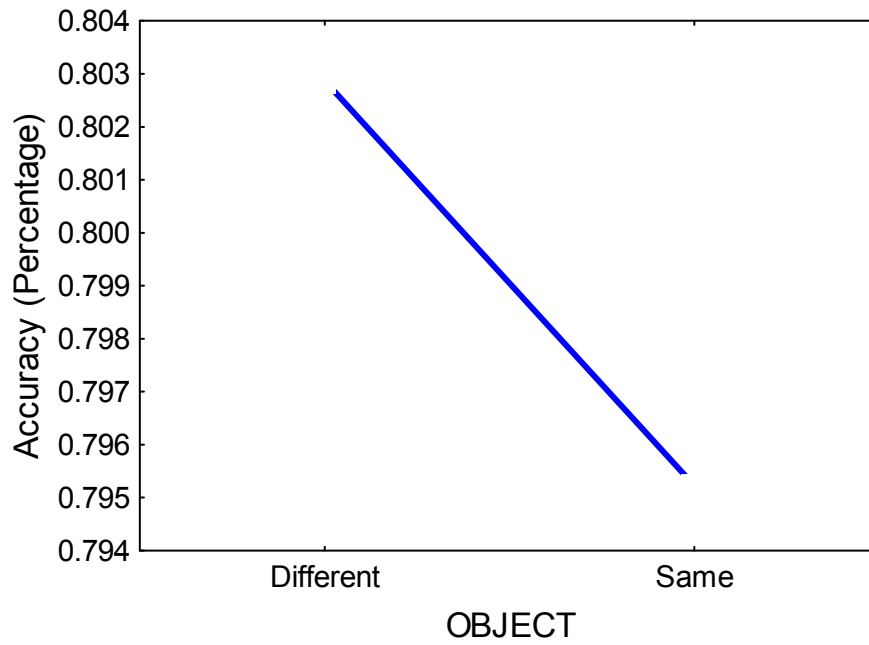


Figure 32. The effect of object for response time but not accuracy for a connected region.

Discussion

The purpose of a traffic sign is to convey information to the driver both quickly and accurately. Often times a driver must encounter multiple messages. An example of this type of circumstance is when a driver must process a sign that indicate the direction as well as signs that convey regulatory information. Thus, it is essential that the information is conveyed in a manner in which the driver is able to optimally process the information. It is also equally critical that the driver exclude processing information that is unimportant for their purposes. Experiment 5 was motivated by the question of how drivers process traffic symbols according to how the information is presented. Experiment 5 examined whether the connectedness of a sign affected perceptual processing in a real world setting. Symbols from traffic signs were used in three different sign configurations. The purpose of using different sign configurations was to examine whether placing target symbols within the same sign would optimize visual processing. The results indicated that for the connected region, subjects were faster to respond to targets located on the same as compared to different continuous regions. This result suggests that the connected region is processed as two separate objects rather than a single continuous object. Similar to the results of earlier experiments there was an advantage for making comparisons between objects rather than within a single object.

General Discussion

The general discussion will be divided into four sections: current state of attention research, overview of the results of the experiments, the use of exogenous precues for visual information processing, performance benefits for different objects and the implications of the results to transportation research.

Current state of attention research

There is general agreement in the attention literature that attention is required to facilitate the selection of objects. However, there is no clear consensus in the literature regarding what information is used in the selection process. One possible reason for the different findings is that different experimental methodologies have been used. Space-based attention studies manipulate the spatial separation of targets and distractors. The results typically indicate that performance diminishes as a function of the separation between a target and other related information in the visual scene. Object-based studies use simple objects and instruct the subject to make comparisons to features located either between or within the object(s). The spatial separation between and within objects is fixed so that comparisons can be made between space-based and object-based theories. The results indicate that subjects have faster responses to targets located on the same object. The interpretation of this result is that the visual scene is preattentively segmented into objects which are then processed for attention. In order to make comparisons between object-based and space-based theories, a modified version of Watson and Kramer's wrench feature judgment task was used. Subjects were presented with two adjacent wrenches with one or two possible target features present. The subject's task was to identify whether one or two target features were present on the wrenches. Watson and Kramer found an object-based

effect ---subjects were faster and more accurate at responding to two features when they were located on the same object as compared to different objects. This result of a same-object advantage has been replicated for both identification tasks (Kramer, & Watson, 1996; Watson, & Kramer, 1999) and detection tasks (Egley & Baylis, 1989; Egley, Driver, & Rafal, 1994; Lavie & Driver, 1996).

The main objective of this research was to understand how dividing attention between objects results in performance decrements for a variety of precue conditions for different object representations. The current experiments investigated two general issues. The first issue was to determine what type of information is important when attending to a visual stimulus was processed for visual attention (an object or spatial region). Comparisons were made between space-based and object-based attention theories by examining how information is processed when the features are divided between two different objects. The second issue was examining whether exogenous precues or endogenous precues can affect preattentive processing of visual information and determine whether preattentive processing is based on either spatial locations or perceptual objects.

Summary of Experiment Results

The proposed research was intended to examine hypotheses from several attention theories. However, there was not a clear pattern of results and therefore will not be addressed in the general discussion. The results of experiment will be presented and the conclusions will be discussed.

Experiment 1A and 1B examined two issues. The first issue was whether attention was oriented to spatial locations or to an object. The second issue (given that

attention could be oriented to spatial locations) was whether the size of the precue could orient attention to smaller or larger spatial regions. Subjects were presented two adjacent wrenches. They were instructed to indicate whether one or two target features were present on a trial. The critical comparison was whether two features were located on a single object (i.e. within-object) or whether the two features are located on separate objects (i.e. between-objects). The primary manipulations in Experiment 1A were the spatial separation of wrenches. The wrench size also varied (small or large) as a counterbalance to the spatial separation. The results indicated no significant effect on performance when the spatial separation or the object size was varied. However, it was possible that the null results were due to subjects not attending the precue. The motivation for Experiment 1b was to examine the same issues as Experiment 1A by using a go/no go precue to ensure that subjects were attending to the precue. Subjects were presented 4 symbols similar to Experiment 1A. However, subjects had to detect a unique symbol among the set of four as a cue to not respond to the display. The results of Experiment 1B indicated that there was, indeed, a precue benefit. Subjects were more accurate when the precued spatial region was the same size as the region the area containing the wrenches. These results suggest that subjects were spatially oriented to the precued location. The results also indicated a performance benefit for features on different wrenches at large spatial separations.

Experiment 2 was used to compare between-object and within-object precues. The purpose of the study was to examine whether the results from Experiment 1B were due to the use of spatial precues. For Experiment 2, there were two types of precues ---

those that precued between two objects and those that precued within an object. The results were mixed. Analysis 1 was conducted to compare the UCR object-based theory to the grouped array and space-based theories. The results suggest that attention operates consistent with the space-based theory at small separations. However, as the spatial separation increased between wrenches, accuracy decreased for targets located on the same wrench. There was a different object benefit at large spatial separations. Analysis 2 was conducted to compare the spotlight theory to the zoom lens theory. The results indicated that when attention was precued to a larger region, there was a performance cost for objects that were peripherally located as compared to those located toward the center of fixation. The results suggest that attention operated like a spotlight and that the increased time to respond reflected the cost for shifting attention to the location of the targets. Analysis 3 examined conditions in which both the objects and target locations were precued. The purpose was to compare zoom lens and gradient theories of attention. The result was a different object benefit, as found in Experiment 1B. Subjects were faster at responding when the precue denoted two features on different wrenches as compared to two features on the same wrench.

Experiment 3 was conducted to examine whether preattentive processing was dependent on the modal completion of a sign configuration. This study was different from the others in that a sign configuration was presented before the wrenches and remained visible until the wrenches disappeared. Sign configurations could be composed of a UCR object, an amodal object, and a grouped object. The results of Experiment 3 suggest that for the UCR sign and amodal sign, subjects were more accurate at

responding to features on different wrenches as compared to on the same wrench. The different-object benefit was again observed. However, when the wrenches were presented on the grouped unit sign, an object-base effect occurred with greater accuracy when the features were presented on the same wrench compared to different wrenches.

Experiment 4 was conducted to compare the UCR object-based theory and the grouped array theory of attention. The purpose was to examine the how the connectedness of an object's representation and top down information affected performance on an object judgment task. The connectedness of the object's representation was determined by whether the wrench was occluded or continuous. The top-down information was a verbal precue indicating the orientation of the wrench with the target features. The results indicated a precue advantage. Subjects responded faster when the precue correctly indicated the orientation of the wrenches with the target features. However, when the precue was invalid, responses were significantly slower for occluded wrenches as compared to continuous wrenches. The results provided evidence consistent with the UCR object theory that a perceptual object is formed by a uniform connected region. If the object is not connected, as is the case with the occluded wrench, the assumption is that the two sub-components of the wrench must be grouped to form a continuous object. This additional grouping process is reflected in the increased response time.

The main objective of this research was to understand how dividing attention between objects results in performance decrements for a variety of precue conditions for different object representations. The previous experiments (1A, 1B, 2, 3, and 4)

investigated how an observer can select task relevant information from a specified region and a specified object. The purpose of Experiment 5 was to examine whether the connectedness of a sign affected perceptual processing in a real world setting. Symbols from traffic signs were used in three different sign configurations (connected region, H-sign, and 2 bars). The results indicated that for the H-sign, subjects were faster to respond to targets located on the same as compared to different continuous regions. This finding suggests that the H-sign was processed as two objects with a connected region rather than a single object. Similar to the results of the previous experiments there was an advantage for making comparisons between objects rather than within a single object.

Exogenous Precues for Visual Information Processing

The results of the experiments, considered together, suggest two conclusions. The first conclusion is that there is a performance benefit when exogenous precues are provided. Subjects were faster in responding when the precue was small as compared to large, regardless of whether the spatial region of the precue matched the spatial region of the targets. For example, in Experiment 1b, the result indicated that subjects responded more rapidly when the precue was small as compared to large, even though the wrench occupied a large spatial region (i.e. large wrenches at a large spatial separation) (Experiment 1B). Subjects were faster when a verbal precue informed the subject as to the orientation of the wrench with the target features (Experiment 4). However, when the precue was ambiguous such as in Experiment 2 (providing both within and between-objects), the results were mixed. When a between-object precue was presented, there was no significant difference when the precue corresponded or did not correspond with the

feature's location (in support of the object-based theory). A local analysis was conducted for single target trials and compared performance for between object and within object precues. The result indicated no significant difference, and thus did not provide evidence of object-based attention.

Different Object Benefit

The second and perhaps more interesting result was an advantage that occurred in many of the experiments. Subjects responded more rapidly and accurately when the features were located on different objects as compared to the same object. Surprisingly, this result was found even when the spatial separation of wrenches was twice as large (12.8 cm.) as the spatial separation within an object (6.4 cm.) (Experiment 1B).

According to the space-based theory, subjects should respond faster spatial separation between features was 6.4 cm as compared to 12.8 cm. In this case, the spatial separation between targets was closer for the within-object condition. According to the object-based theory, subjects should respond faster when the features are located on the same object; irrespective of the spatial separation of the targets. Therefore, both the space-based and object-based theory predicted higher performance when the spatial separation within an object (6.4 cm.) as compared to 12.8 cm. The result is opposite of what was found. The results indicated that subject had higher performances at a larger spatial separation between objects and features. Thus, the results were contrary to all of the current theories of visual attention: space-based, object-based, and the grouped array theory. Therefore, an examination of the literature of object-based effects was conducted to gain an understanding of why a same object performance cost was obtained.

On possible explanation for the same object cost is that presenting the two features on the same object may be difficult to process due to scaling discrepancy. For example, when the subject is precued to a spatial location (prior to the presentation of the objects) the subject is constructing a spatial representation of the scene (according to the space-based theory) or object (according to the object-base theory). If the precue facilitates the encoding of features located within a spatial location (or object), then perhaps the scaling for processing the precued location or both objects is larger than that of the individual features within an object. Thus, the cost for processing features on the same object is because the subject must rescale their focus of attention to a single object to process its features. In contrast, if the precue is followed by features present on different objects the visual system constructs two distinct representations of the objects and does not rescale. As a result there is a greater cost when the features are on the same object as compared to when the features are on different objects. Another possible explanation is that the results were not due to a different object benefit but rather, a same object cost. Further studies with a control condition would have to be conducted in order to further investigate this issue.

Implications of Research to Transportation

The results of the present study can be applied to real world situations such as the design of traffic signs. One important finding from the studies is the same object cost. The results from the present studies indicated that presenting two features on the same UCR object can result in lower performance as compared to two features are presented on different objects. It was speculated that this result could be due, in part to the scale of the

precue presented prior to the task. It is important to note that all of the studies used a precue. Precues are typically not presented in real world scenarios. However, precues aside, it may be important to consider the interaction between the scaling and the presentation of information on different objects. If a driver's attention is directed an area or object --- perhaps, may be beneficial to present the information on the same scale. If the scaling is different, there may be a performance cost for rescaling attention. This cost for rescaling attention may be greater than even that of shifting attention between objects, as found in the present studies.

References Cited

- Atchley, P. & Kramer, A. F. (1998). Spatial cuing in a stereoscopic display: Attention remains "depth-aware" with age. *Journals of Gerontology: Series B: Psychological Sciences and Social Sciences*, 53B, 318-323.
- Banks, W. P., Bodinger, D. & Illige, M. (1974). Visual detection accuracy and target-noise proximity. *Bulletin of the Psychonomic Society*, 4, 411-414.
- Banks, W. P. & Prinzmetal, W. (1976). Configurational effects in visual information processing. *Perception & Psychophysics*, 19, 361-367.
- Beck, J. & Ambler, B. (1973). The effects of concentrated and distributed attention on peripheral acuity. *Perception & Psychophysics*, 14, 225-230.
- Breitmeyer, B. G. & Ganz, L. (1976). Implications of sustained and transient channels for theories of visual pattern masking, saccadic suppression, and information processing. *Psychological Review*, 83, 1-36.
- Broadbent, D. E. (1958). The effects of noise on behaviour. *Perception and Communication*, (pp. 81-107). Elmsford, NY: Pergamon Press.
- Davis, G., Driver, J., Pavani, F., & Shepherd, A. (2000). Reappraising the apparent costs of attending to two separate visual objects, *Vision Research*, 40(10), 1323-1332.
- Deutsch, J. A. & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review*, 70, 80-90.

- Driver, J. & Baylis, G. C. (1989). Movement and visual attention: The spotlight metaphor breaks down. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 448-456.
- Duncan, J., Humphreys, G., & Ward, R. (1997). Competitive brain activity in visual attention. *Current Opinion in Neurobiology*, 7(2), 255-261.
- Duncan, J. (1980). The demonstration of capacity limitation. *Cognitive Psychology*, 12, 75-96.
- Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General*, 113, 501-517.
- Egley, R., Driver, J., & Rafal, R. D. (1994). Shifting visual attention between objects and locations: Evidence from normal and parietal lesion subjects. *Journal of Experimental Psychology: General*, 123, 161-177.
- Eriksen, B. A. & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, 16, 143-149.
- Eriksen, C. W. & Hoffman, J. E. (1973). The extent of processing of noise elements during selective encoding from visual displays. *Perception & Psychophysics*, 14, 155-160.
- Eriksen, C. W. & Hoffman, J. E. (1974). Selective attention: Noise suppression or signal enhancement? *Bulletin of the Psychonomic Society*, 4, 587-589.
- Eriksen, C. W. & Rohrbaugh, J. W. (1970). Some factors determining efficiency of selective attention. *American Journal of Psychology*, 83, 330-342.
- Eriksen, C. W. & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception & Psychophysics*, 40, 225-240.

- Eriksen, C. W. & Yeh, Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance*, 11, 583-597.
- Folk, C. L. & Remington, R. (2006). Top-down modulation of preattentive processing: Testing the recovery account of contingent capture. *Visual Cognition. Special Issue: Visual search and attention*, 14, 445-465.
- Hoffman, J. E. (1975). Hierarchical stages in the processing of visual information. *Perception & Psychophysics*, 18, 348-354.
- Hoffman, J. E. & Nelson, B. (1981). Spatial selectivity in visual search. *Perception & Psychophysics*, 30, 283-290.
- Hoffman, D. D. & Richards, W. A. (1984). Parts of recognition. *Cognition. Special Issue: Visual cognition*, 18, 65-96.
- Hummel, J. E. & Biederman, I. (1992). Dynamic binding in a neural network for shape recognition. *Psychological Review*, 99, 480-517.
- Kahneman, D. and A. Henik, Perceptual organization and attention, in: M. Kubovy and J. R. Pomerantz (eds.), *Perceptual Organization*, 181-211, Hillsdale, NJ: Erlbaum, 1984.
- Kahneman, D. & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, 80, 237-251.
- Kramer, A. F. & Jacobson, A. (1991). Perceptual organization and focused attention: The role of objects and proximity in visual processing. *Perception & Psychophysics*, 50, 267-284.
- LaBerge, D. (1983). Spatial extent of attention to letters and words. *Journal of Experimental Psychology: Human Perception and Performance*, 9, 371-379.

- LaBerge, D. & Brown, V. (1989). Theory of attentional operations in shape identification. *Psychological Review*, 96, 101-124.
- LaBerge, D., Brown, V., et al. (1991). Reducing the effects of adjacent distractors by narrowing attention. *Journal of Experimental Psychology: Human Perception and Performance*, 17, 65-76.
- Lavie, N. & Driver, J. (1996). On the spatial extent of attention in object-based visual selection. *Perception & Psychophysics*, 58, 1238-1251.
- Law, M. B. & Abrams, R. A. (2002). Object-based selection within and beyond the focus of spatial attention. *Perception & Psychophysics*, 64, 1017-1027.
- Marr, J. (1982). Determinism. *Behavior Analyst*, 5, 205-207.
- Miller, J. (1987). Priming is not necessary for selective-attention failures: Semantic effects of unattended, unprimed letters. *Perception & Psychophysics*, 41, 419-434.
- Moore, C., Yantis, S., Vaughan, B. (1998). Object-Based Visual Selection: Evidence From Perceptual Completion. *Psychology Science*, 9, 104-110.
- Mortier, K., Donk, M. & Theeuwes, J. (2003). Attentional capture within and between objects. *Acta Psychologica*, 113, 133-145.
- Murphy, T. & Eriksen, C. (1987). Temporal changes in the distribution of attention in the visual field in response to cues. *Perception & Psychophysics*, 42, 576-586.
- Neisser, U. (1967). *Cognitive Psychology*. East Norwalk, CT: Appleton Century Crofts.
- Palmer, S. & Rock, I. (1994). Rethinking perceptual organization: The role of uniform connectedness. *Psychonomic Bulletin & Review*, 1, 29-55.

- Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, 32, 3-25.
- Rensink, Ronald A.; O'Regan, J. Kevin; Clark, James J. (1997), To see or not to see: the need for attention to perceive changes in scenes , *Psychological Science* 8 (5): 368-373.
- Basri, Ronen. Handbook of Pattern Recognition and Computer Vision (2nd Edition), Chen, C.H., Pau, L.F., Wang, P.S.P. 1999, World Scientific Publishing Co., 925-
- Scholl, B. J. (2001). Spatiotemporal priority and object identity. *Cahiers de Psychologie Cognitive/Current Psychology of Cognition*, 20, 359-371.
- Scholl, B. J. (2001). Objects and attention: The state of the art. *Cognition. Special Issue: Objects and attention*, 80, 1-46.
- Schumann, K. 1904. Zingiberaceae. Pp. 1–458 in *Das Pflanzenreich*, 4/46, ed. A. Engler. Leipzig: W. Engelmann.
- Shaw, M. L. (1978). A capacity allocation model for reaction time. *Journal of Experimental Psychology: Human Perception and Performance*, 4, 586-598.
- Shaw, M. L. & Shaw, P. (1977). Optimal allocation of cognitive resources to spatial locations. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 201-211.
- Shipley, T. F. & Kellman, P. J. (1990). The role of discontinuities in the perception of subjective figures. *Perception & Psychophysics*, 48, 259-270.
- Shomstein, S. & Yantis, S. (2002). Object-based attention: Sensory modulation or priority setting? *Perception & Psychophysics*, 64, 41-51.
- Simons, Daniel J.; Levin, Daniel T. (1998), Failure to detect changes to people during a real-world interaction, *Psychonomic Bulletin and Review* 5: 644-649.

- Dalmatian photo by R. C. James, in R. L. Gregory, *The Intelligent Eye* (McGraw-Hill, New York, 1973), p. 14.
- Theeuwes, J., Reimann, B., & Mortier, K. (2006). Visual search for featural singletons: No top-down modulation, only bottom-up priming. *Visual Cognition*, 14, 466-489.
- Treisman, A. M. (1969). Strategies and models of selective attention. *Psychological Review*, 76, 282-299.
- Treisman, A. (1982). Perceptual grouping and attention in visual search for features and for objects. *Journal of Experimental Psychology: Human Perception and Performance*, 8, 194-214.
- Treisman, A. (1988). Features and objects: The Fourteenth Bartlett Memorial Lecture. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology*, 40A, 201-237.
- Treisman, A., Kahneman, D. & Burkell, J. (1983). Perceptual objects and the cost of filtering. *Perception & Psychophysics*, 33, 527-532.
- Vecera, S. P. (1994). Grouped locations and object-based attention: Comment on Egly, Driver, and Rafal (1994). *Journal of Experimental Psychology: General*, 123, 316-320.
- Vecera, S. P. & Farah, M. J. (1994). Does visual attention select objects or locations?. *Journal of Experimental Psychology: General*, 123, 146-160.
- Wang, J. S., Knipling, R. R., & Goodman, M. J. (1996, October). The role of driver inattention in crashes; new statistics from the 1995 Crashworthiness Data System. Proceedings of 40th Annual meeting of the Association for the Advancement of Automotive Medicine, Vancouver.

- Kramer, A F. & Watson, S.E. (1996). Object-based visual selection and the principle of uniform connectedness. In *Converging operations in the study of visual selective attention*. (pp. 395-414).
- Watson, S. E. & Kramer, A. F. (1999). Object-based visual selective attention and perceptual organization. *Perception & Psychophysics*, 61, 31-49.
- Wertheimer, M., 1912. "Experimentelle Studien uber das Sehen von Bewegung" (Experimental Studies of the Perception of Motion) in *Zeitschrift fur Psychologie* 61, 1912, 161-265.

Appendix A

Experiment 1a

Accuracy (percent)

	Mean	Standard deviation
Different	0.942532852	0.038593008
Same	0.896671509	0.086326128
Large spatial separation	0.930818579	0.057153909
Small spatial separation	0.908385782	0.066611018
Large precue	0.913234859	0.064887171
Small precue	0.925969503	0.05901958

Response time (ms)

	Mean	Standard deviation
Different	467.5115631	35.90675722
Same	480.291411	44.61168845
Large spatial separation	466.2224063	40.22221605
Small spatial separation	481.5805678	39.36747024
Large precue	473.371092	42.6742885
Small precue	474.4318821	40.45410617

Appendix B

Experiment 1b

Accuracy (percent)

	Mean	Standard deviation
Different	0.941805039	0.041560105
Same	0.949644955	0.036126634
Large spatial separation	0.945398458	0.040773096
Small spatial separation	0.942732892	0.041245194
Large precue	0.945728187	0.040326412
Small precue	0.945459018	0.040459888

Response time (ms)

	Mean	Standard deviation
Different	467.3598256	36.05108056
Same	473.1814277	40.894705
Large spatial separation	471.9983123	38.46754332
Small spatial separation	467.9127048	39.56846587
Large precue	471.029651	38.83402353
Small precue	470.0479494	39.32970007

Appendix C

Experiment 2

Accuracy (percent)

	Mean	Standard deviation
Condition 1	0.941884983	0.037148448
Condition 2	0.948668188	0.028161982
Condition 3	0.925396247	0.083060382
Condition 4	0.915978993	0.060739949
Condition 5	0.894344942	0.062071721

Response time (ms)

	Mean	Standard deviation
Condition 1	447.8589038	97.20865274
Condition 2	449.4594797	99.11960451
Condition 3	457.3610629	95.49491052
Condition 4	450.1931714	98.21764176
Condition 5	475.6173445	118.7047496

Appendix D

Experiment 3

Accuracy (percent)

	Mean	Standard deviation
Different	0.951063964	0.02704934
Same	0.887452068	0.07097818
Box	0.935201017	0.048613168
Bracket	0.92304594	0.053350452
Distorted	0.903397006	0.068229585

Response time (ms)

	Mean	Standard deviation
Different	485.9330969	68.40624086
Same	501.0860176	85.93026101
Box	490.8887983	72.71393533
Bracket	491.3685312	76.24810085
Distorted	496.191578	81.32065113

Appendix E

Experiment 4

Accuracy (percent)

	Mean	Standard deviation
Valid	0.941193967	0.047302206
Invalid	0.890642507	0.209635926

Response time (ms)

Valid	566.2567709	180.9246936
Invalid	679.6249097	223.3641205

Appendix F

Experiment 4

Accuracy (percent)

	Mean	Standard deviation
Valid	0.941193967	0.047302206
Invalid	0.890642507	0.209635926

Response time (ms)

Valid	566.2567709	180.9246936
Invalid	679.6249097	223.3641205

Accuracy (percent)

	Mean	Standard deviation
Connected regions	0.773767754	0.096406427
Continuous regions	0.799044332	0.096121478
Separate regions	0.80769394	0.105176229
Different	0.789307005	0.094045995
Same	0.798174593	0.09500993

Experiment 5

Response time (ms)

	Mean	Standard deviation
Connected regions	362.4034205	148.5766726
Continuous regions	359.8468783	154.6995672
Separate regions	367.8493513	157.8344275
Diff	360.6478771	150.1750522
Same	364.4129392	152.2826077