MOTION AND ATTENTION

by

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ABSTRACT

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The present study examined whether differential motion could influence the spread of attention across an object. In particular, we examined whether the type of motion exhibited by an object would impact the reaction time in which a participant made a judgement on the location of a target or the accuracy of their judgment. We did not find significant effects of motion type upon reaction time. We did find that accuracy was significantly greater for validly cued targets than for invalidly cued targets. Further investigation may be needed to demonstrate the impact of motion upon the spread of attention across an object.

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INTRODUCTION

Humans have an amazing capacity to receive and process information. Specifically, we attain a vast wealth of information about the world through our visual perception. The retina is capable of immense parallel processing (i.e. the ability to process large amounts of information simultaneously). On the other hand, the relative capacity of visual cognition is much more limited. Attention is responsible for determining what information is processed and what is not, and consequently plays a key role in perception and cognition (Mcmains & Somers, 2004). Through attention we are able to select portions of a visual scene for further processing.

Visual attention was originally thought to enhance processing for a specific area of the visual field. Analogous to a spotlight in a dark room, attention increases processing of a portion of a scene, and visual information outside of this "spotlight" receives less processing. It was later discovered that there is an additional attentional mechanism that allocates attention to the perceptual groups we call "objects." In addition to being able to attend to a particular location in the visual field, we also have a mechanism that selectively enhances processing of certain things or shapes within the visual field. Object-based attention describes the phenomenon that attending to a region within an object facilitates processing of other locations within that object relative to external components of the visual field (Chen, 2012). The spread of the object-based attentional enhancement effect is thought to be constrained by the boundary of the object (Malcolm & Shomstein, 2015). Although the object-based attention effect is a highly accepted phenomenon, the process that determines which aspects of the visual field become perceived as objects remains a very enigmatic topic. Researchers have taken great interest into identifying what, why, and how features are collectively formed into perceived objects.

Feature integration theory is one popular theory of how features are combined into the perception of objects. According to Feature Integration Theory, features such as color, orientation, and direction of movement are processed in parallel (Treisman & Gelade, 1980). When attention is directed to a particular location containing a full set of features, these features are perceived to be a part of an object. For example, the motion, surface color, and depth of an object can be examined and integrated into a whole. The process in which stimulus properties are formed into an object is known as feature binding. It was previously proposed that the mechanisms of inhibition and top-down feedback are sufficient to explain the process of object perception (Wyatte et al., 2012). Inhibition suppresses irrelevant information by creating competition amongst neural populations that code different features, while top-down feedback reinforces relevant features (Wyatte et al., 2012). Together, these mechanisms result in a collection of features that are uniquely benefitted by enhanced processing and ultimately result in the perception of an object, which stands out from other information in the visual field.

The enhanced processing from object-based attention was traditionally thought to be independent of both higher level characteristics, such as semantic meaning, and lower level characteristics, such as feature similarity or contrast (Malcolm & Shomstein, 2015). The enhanced processing from object-based attention was thought to be constrained solely by the global properties of the object, and the enhanced attention to features within an object was thought to be free of influence by any qualities of the features themselves. An important finding on how we process features prior to and during the process of binding is that computation of features is itself a multistep process, rather than an instantaneous event (Herzog, Otto, and Ogmen, 2012). Through attentional mechanisms, the flow of information between different levels of processing is modified such that the perception of an object is continuously updating. The stimuli selected by attention are accessed by higher levels of processing such as recognition, awareness, and memory (Lee, Koch, & Braun, 1999). A consequence of the fact that our object perception is continuously updating is that perceptual groupings can persist even if some of those features were to change. For example, if a box with one of its faces directed toward the viewer were rotated such that an edge of the box was directed toward the viewer, we would still perceive it as the same box, and the features belonging to the box would still be perceived as separate from background stimuli. In other words, features of an object remain grouped together even when certain features of an object change while the object is in motion. Although this implies that individual features of an object should not impact the processing of the object once the perceptual grouping is formed, this line of research is limited in its focus on the binding of features into an object. It is possible that other means of segmenting components of an object may be important in the formation of object percepts. In fact, there are several theories of object perception that suggest that the ability to process components of an object, and consequently the segmentation of objects into parts, is an important part of the process of object recognition.

Recognition by Components Theory suggests that object representations are formed from a sort of visual vocabulary. This vocabulary is composed of combinations of a limited preexisting set of simple shape representations such as cylinders or geons. These geons consist of 37 components that differ in their curvature, collinearity, symmetry, parallelism, and cotermination (Biederman, 1987). Particularly important in the process of recognition by components is the detection of edges. These edges are parsed at curvatures, particularly at concavities. The parsed components are then matched with their corresponding geons. These geons are summarily viewed as an object, the product of the unique organization of its geons.

Another group of theories posits that there are geometric rules by which an object's boundary determines both the segmentation of the object from background and the segmentation of an object into constituent parts. According to this group of theories, objects are defined by their part boundaries, rather than consisting of part shapes (Hoffman & Richards, 1984). The border of the object determines its shape as a whole, and the unique properties of the border define the object.

Past studies of part based attention

Given the apparent significance of object part perception, a growing body of literature began to investigate the possibility of a part based attention sensitive to distinctions between parts of an object. Reppa & Leek (2003) investigated this part based attention by testing whether specific manipulations of object internal components could influence the spread of attention across an object, using inhibition of return (IOR) as an implicit measure of the spread of attention through an object. Inhibition of return refers to the observation that attention to an area is inhibited for a brief period of time after being cued (Klein, 2000). After an initial experiment confirming that object-based IOR can spread across the surface of an object, a second experiment investigated the impact of internal structural discontinuities upon the spread of object-based IOR by comparing IOR for an object with an internal line segment bisecting the object with IOR for an object without an internal line segment (Reppa & Leek, 2003). The researchers found that IOR was significantly greater when cues and targets within an object were separated by an internal structural discontinuity than when they appeared on the same part of the object, thus indicating that the flow of attention can be modulated by features within an object (Reppa & Leek, 2003).

Reppa & Leek (2003) suggest that internal components of an object are capable of influencing object-based IOR. The study therefore suggests that an object's global boundary is not the sole determinant of the spread of object-based attentional enhancement within an object. Though this may be correct, the use of a line segment to separate one part of the object from the other may have led to the perception of two separate but adjoining objects rather than two components of a single object.

Other studies have attempted to demonstrate a part-based attentional effect without creating boundaries between parts. After determining an appropriate threshold for exposure duration, participants from Vecera, Behrmann, and Filapek (2000) were briefly presented a multipart object and instructed to report attributes from the objects. Two colored arrows signified whether participants should report a part's length or its orientation. If both arrows pointed to the same part of the object, the participant reported both the length and direction of that part. Participants' reports were significantly more accurate when discerning two attributes belonging to the same part than when discerning attributes of two separate parts. The finding that performance in the task was poorer when attention was divided across parts of an object than when attention was committed to a single part of the object is similar to the object-superiority effect, wherein a whole object more easily recognizable than its constituent parts.

The strong resemblance of the part-based attention effect with the object-based attention effect led Vecera et al. (2000) to attempt to discern whether the part-based attention effect is a unique process of attentional selection, or merely a remapping of the part-object hierarchy, where the parts would merely be viewed as whole objects. In a second experiment, participants were briefly presented with multipart objects and reported features belonging either to the same part or to two different parts. Rather than varying part distance, two multipart objects were presented simultaneously. In this experiment participants reported features from the same part of the same object, features from different parts of the same object, features from congruent parts of the different objects, or features from nonmatching parts of the different objects. Subjects were more accurate in the same-part condition than in the different-parts condition and more accurate in the same-object condition than in the different-objects condition. This experiment indicates that the part-based attentional effect occurs simultaneously with the object-based attentional effect. The findings therefore support the notion that part-based attention effect is a unique process of attentional selection.

Vecera et al. (2000) demonstrated that the part-based attention effect occurs simultaneously with the object-based attention effect. This finding negates the possibility that the observed part-based effect is due to participant's decomposing stimuli such that their components are viewed as whole objects, thereby creating a difference in feature discrimination accuracy via the object-based attention effect. In Vecera et al. (2001), the experimenters also manipulated the distance between parts in order to determine whether the part-based attentional effect was merely due to spatial attention processes. Their results indicated that accuracy was significantly greater when parts were close to one another than when parts were further away from one another. However, accuracy for feature discrimination in a single part was greater than accuracy for discriminations across two parts both when parts were near one another and when parts were further away from one another. In other words, location-based attentional effects did not significantly influence the cost of dividing attention across multiple parts of an object.

A potential issue with Vecera et al. (2000; 2001) is that judgments considered to be between parts involved comparisons along a contour with high curvature (Barenholtz & Feldman, 2003). According to the minima rule, only concave curvatures are perceived as a part boundary. Convex curvature would indicate an exterior boundary point within the object part. Barenholtz & Feldman (2003) therefore ran several experiments testing performance in a perceptual comparison task for features separated by concave and convex curvatures along the boundary of the object. Barenholtz and Feldman (2003) found that perceptual comparisons were faster for features separated by convex curvature extrema than by concave curvature extrema. This finding is consistent with the theory that perceptual comparisons are easier within an object part than between two object parts, but also reveals a confound in Vecera et al.'s (2000; 2001) experiments. Interestingly, the effect of curvature on the feature discrimination task was not found when the curvature minima were a part of a global configuration that wasn't conducive to the interpretation of a concavity as a part boundary (Barenholtz & Feldman, 2003). In this experiment, a section of an object would be conducive to perception as a part boundary when two concave curvature extrema were closer in proximity than two convex curvature extrema. They concluded that local shape curvature influences perception in a manner that can disrupt the spread of attention through an object, provided that the global factors are conducive to the perception of concave curvature as a part boundary.

Motion

Recent research suggests that motion may be an important feature in the perception of parts. Higgins and Stringer (2011) used Visnet, a biologically plausible computational model of the ventral visual stream, to investigate how the visual pathway processes visual stimuli. A previous study using Visnet was able to simulate a ventral pathway that could develop view-invariant representations of objects when multiple objects were present. In this simulation, statistical properties of the stimuli were the key to the network's development of view-invariant representations: features within the individual objects occurred more frequently together than features between different objects. Higgins and Stringer (2011) tested whether a similar mechanism could lead to separate representations of an object's parts via independent motion. The simulation involved training on an object with two "arms" that either moved congruently or independently of one another. In the independent movement condition each transform of an arm was seen with all possible transforms of the other arm, allowing the features within one transform of an arm to be seen together more often than features between arms. When the arms moved together, they were seen as a single object, but independent movement led the visual system to form separate representations of the arms while still able to form a representation of the whole object.

The simulations by Higgins & Stringer (2011) indicate that the perception of both an object and its parts can occur if parts move independently. The simulations also indicate that this process can consist of purely feedforward mechanisms in a hierarchical network model of the ventral visual pathway in the absence of any attentional feedback mechanisms. If so, then it is possible that independent motion should be capable of invoking separate representations of object parts, thereby modulating the spread of attention between objects just as curvature minima do. Barenholtz and Feldman (2003) suggest that curvature minima may be fed as candidate part boundaries to some complex global mechanism that determines part boundaries. If independent motion is another such factor, then the relative motion of parts could modulate the impact of curvature minima on the spread of attention between parts of an object even in circumstances where global factors are not conducive to the interpretation of concave curvature extrema as part boundaries.

Present study

The present study aims to contribute to the growing body of literature on attention by investigating the impact of object-internal features on the spread of attention within an object. In particular, this study investigated the effect that distinct local motion of object parts may have upon attentional spread between parts of an object. Participants viewed either an object whose components exhibit independent movement or an object whose parts exhibit movements in lock-step. Performance was measured on a Posner cueing task with cues appearing on the left and right arms of an object whose parts exhibit congruent motion or independent motion. There was additionally be a two object condition in which two objects will exhibit independent motion. If motion is a contributing mechanism to the process of part boundary determination, then the cost for invalid cues will be greater for participants tested while viewing objects with independently moving parts than for objects with parts exhibiting the same pattern of motion, but similar to or less than for the two object condition.

Reaction time for validly cued targets should be equal for both congruent and incongruent motion conditions. We hypothesize that, if object part boundaries inhibit the spread of attention across parts of an object, reaction time will be significantly greater for validly cued targets than for invalidly cued targets. Furthermore if incongruent motion inhibits the spread of attention across parts of an object, reaction time for invalidly cued targets will be significantly greater for participants in the independent motion condition than for the congruent motion condition. Reaction time for the two object condition should be greater than the congruent motion condition, but similar to reaction time of the incongruent condition.

METHOD

Participants

Participants (*N* = 85) will be undergraduate students recruited from Florida Atlantic University. Selection criteria will include participants self-reporting that they have normal or corrected vision. Participants will receive course credit in participating psychology courses as compensation for their participation.

Stimuli

Participants will view single objects consisting of two arms represented as two rounded black rectangles. These arms will rotate around the central fixed hinge point in 37 equal steps on a grey background as shown in Figure 1 and Figure 2. In order to examine the effect of congruent motion in visual comparison between parts of an object, the arms of the object will rotate with either congruent or independent movement.

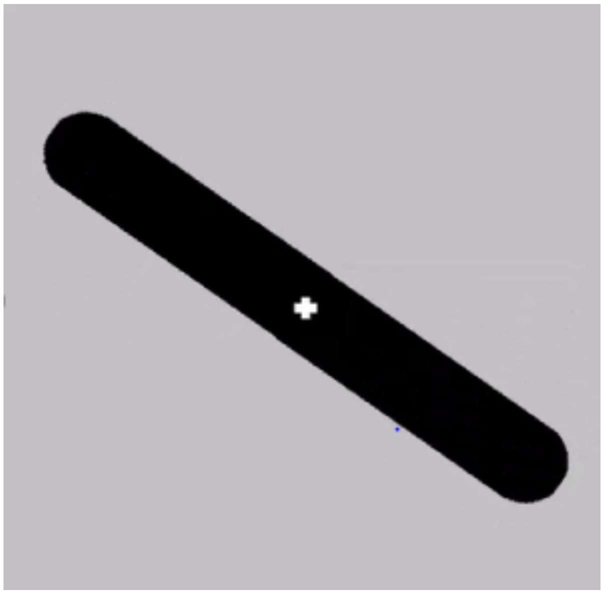

Figure 1. Congruent motion. The arms will rotate 45 degrees upward and 45 degrees downward in 5 degree intervals.

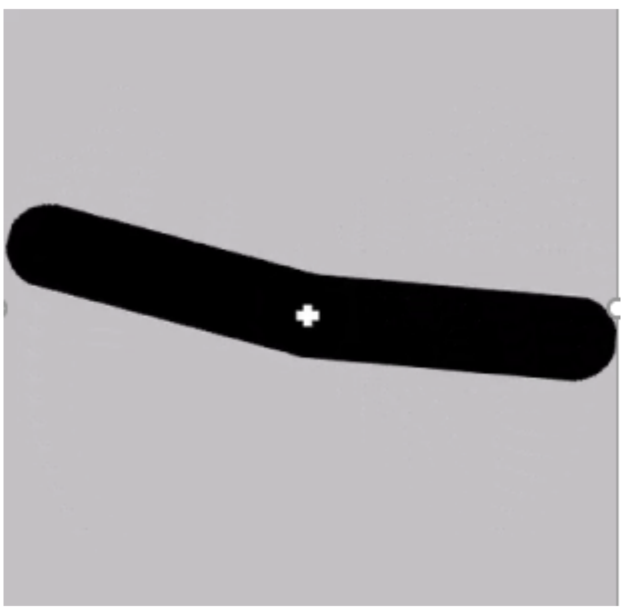

Figure 2. Incongruent motion. The arms will rotate 45 degrees upward and 45 degrees downward in 5-degree intervals. One arm is offset by 15 degrees from the other arm.

For the congruent movement condition, the arms will be animated to rotate simultaneously in lock-step (figure 1). This will ensure that each view of one arm will always be seen with the same view of the other arm during rotation. Each animation begins with two full rotations lasting a total of 2300 ms. The arms will begin at 0 degrees and 180 degrees, rotating at 5-degree intervals clockwise for 9 steps and then counterclockwise, returning in 5-degree intervals towards their original position, proceeding in 5-degree intervals in the opposite direction, and finally returning to their original position over the course of 1000 ms.

For the independent movement condition, the left arm will begin at 180 degrees and begin moving upward at 5-degree intervals for a total of 9 steps, returning in five degree steps towards its original position, and repeat the movement in the opposite direction (Figure 2). The right arm will begin at 15 degrees, move downward in 5-degree intervals for 9 steps, move in 5-degree intervals towards its original position, and perform the same movement in the opposite direction over the course of 1000 ms. The animation will complete the full movement twice over the course of 2300 ms per trial for both the congruent and incongruent motion types.

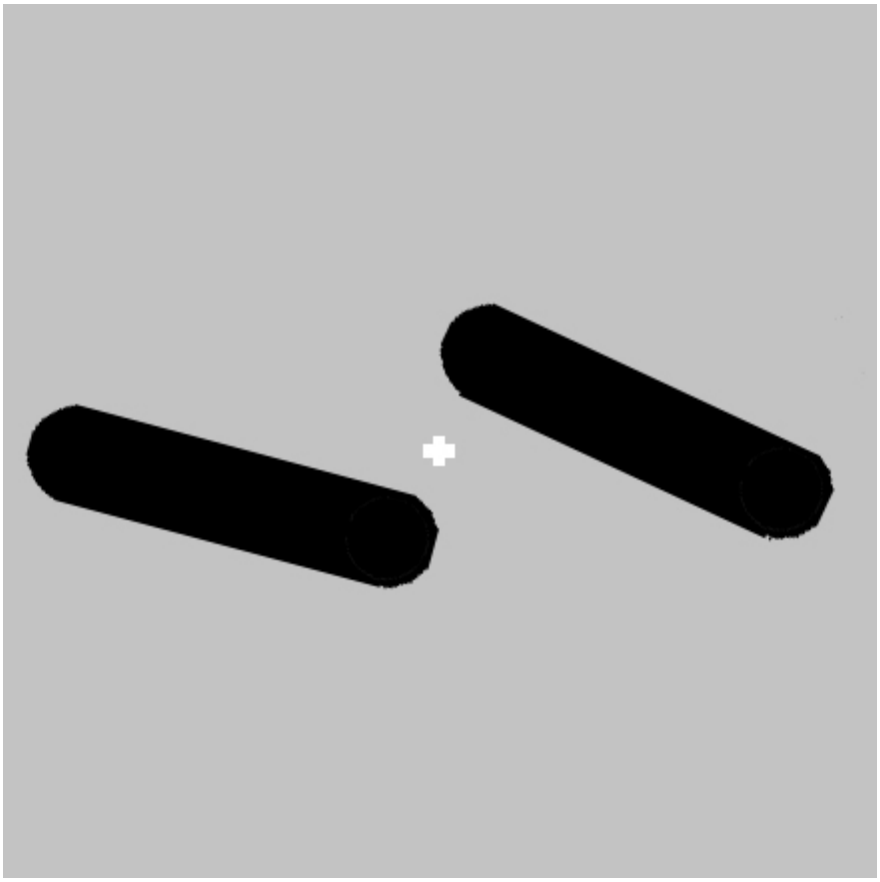

Figure 3. Two object condition. The arms will rotate 45 degrees upward and 45 degrees downward in 5-degree intervals. One arm is offset by 15 degrees from the other arm.

In the third condition, the center of the object will be omitted, and the right arm will be positioned slightly lower than the left arm, thus separating the stimuli into two separate moving objects (Figure 3). The left arm will begin at 180 degrees and begin moving upward at 5-degree intervals for a total of 9 steps, returning in five degree steps towards its original position, and repeat the movement in the opposite direction. The right arm will begin at 15 degrees, move downward in 5-degree intervals for 9 steps, move in 5-degree intervals towards its original position, and perform the same movement in the opposite direction over the course of 1000 ms. The animation will complete the full movement twice over the course of 2300 ms per trial.

The cue and target stimuli will generate after the first 1000 ms of the animations, the arms will rotate for 1000 ms and afterwards, one of the two arms will be cued via a white outline appearing for 100 ms on one of the two arms. The rotation will then continue without cue for 200ms, followed by a 1000 ms rotation in which a target consisting of a white sphere on the end of either arm will be present during rotation. The stimuli described above will be created using Adobe Photoshop CS11 and animated using Adobe Animate.

Task

The task will be for the participants to decide whether the target appears on the left or right arm of the object. Responses will be indicated by pressing the “p” or “q” key with either the left or right index finger. Reaction times (RTs) to make the decision will be recorded in milliseconds. Accuracy will also be recorded.

Procedure

The procedure involves two stages: a learning stage and a testing stage. In each trial, a fixation cross will appear with its midpoint at the center of the screen. Participants will be instructed to keep their eyes focused on the position where the fixation point had been after it becomes replaced by the cue stimulus.

Participants will be randomly assigned to the congruent movement condition (e.g., participants will be exclusively presented with objects with arms demonstrating congruent movement), to the independent movement condition (i.e., participants will be exclusively presented with objects with independently moving arms), or the two object condition. Each trial consists of two full rotations lasting a total of 2300 ms.

After an interval of 1000 ms the cue will appear. The cue will randomly occur on either the right or left arm for 100 ms. Following the cue, the arms will rotate for another 200 ms. Next, the target stimulus will appear for 1000 ms. For 75% of trials, the target will appear on the same arm of the object that the cue had previously appeared on. For the remaining 25% of trials, the target will appear on the arm opposite of that on which the cue had previously appeared. This is to measure the effect that cueing one arm of the object will have upon allocation of attention to the opposite arm. The participants will have until the end of the target animation to indicate whether the target appears upon the left or right arm of the object. The arms of the object will continuously rotate throughout the trial. Once the animation is complete, the next trial will begin.

Participants will be asked to indicate whether the target appears on the left or right arm as quickly as possible, and respond by pressing a key on the computer keyboard. The computer will record the response and response time (RT) for each trial. The next trial will begin after a 500 ms interval in which a blank background will be present upon the screen.

Design

The independent variables will be the type of motion exhibited during the testing stage and whether the targeted arm was validly cued or invalidly cued. The dependent variables will be the participant's ability to accurately determine whether the target appeared on the right or left arm of the object, and the reaction time, in milliseconds, in which participants indicate their judgment for the task.

RESULTS

An ANOVA was used to determine whether motion type and cue validity influenced the reaction time of participants correct responses (Figure 4). There was no significant main effect of motion type $F(2,162) = .386$ $p=.680$, MSE=79961.There no significant effect of cue validity $F(1,162)=.948$, $p=.630$, MSE= 48146.There was also no significant interaction $F(2,162)= .577$, $p= .909$, MSE= 19824.

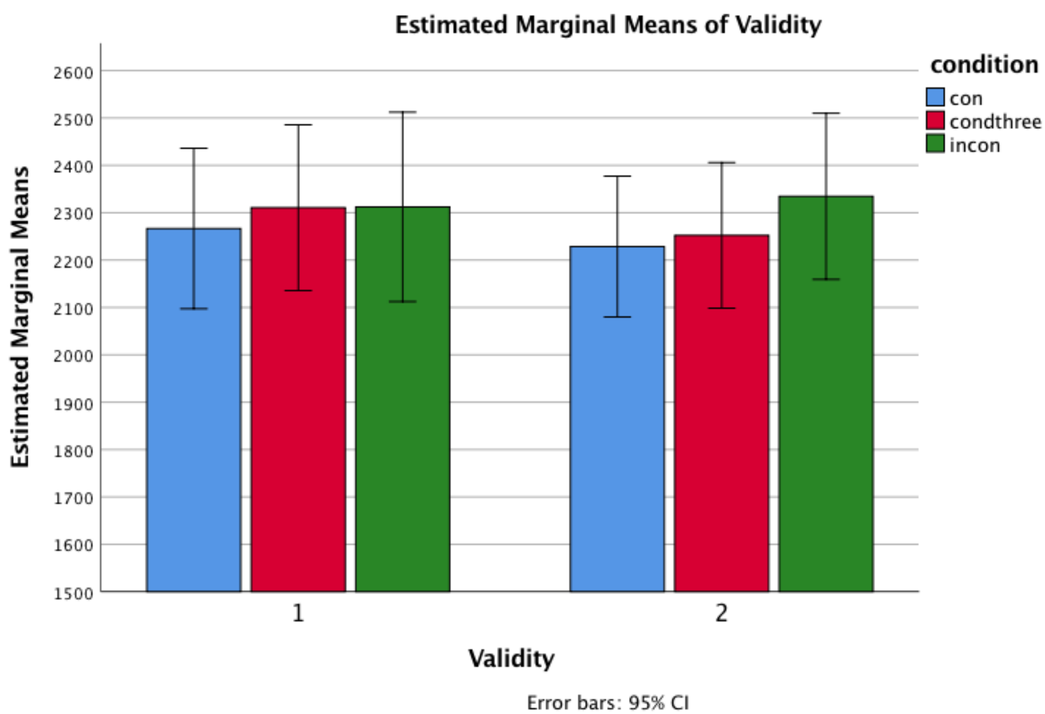

Figure 4. Bar graph for ANOVA 1. There were no significant main effects or interaction.

An ANOVA was used to determine whether motion type and cue validity influenced the error percentages of participants (Figure 5). The main effect of motion type approached significance $F(2,162)=2.460$ $p= .089$, MSE = .012, with the two object condition exhibiting greater error rate than the other two conditions. There was a significant effect of validity $F(1,162)=21.191$ $p<.001$, MSE= .096, with invalid cues leading to greater error rate than valid cues . There was no significant interaction $F(2,162)= .932$ $p=.396$, MSE=.004.

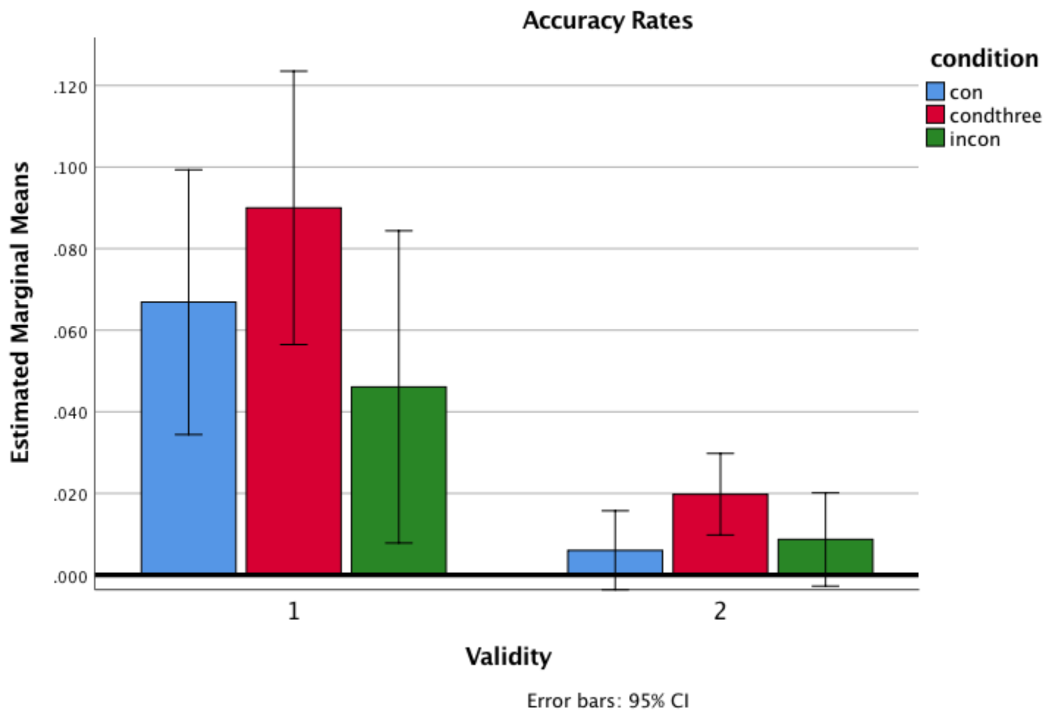

Figure 5. Bar graph for ANOVA 2. Invalid cues led to significantly higher error rates than did valid cues.

DISCUSSION

This study sought to investigate whether differential motion could influence the spread of attention across an object. We did not find a significant effect of motion type or validity upon reaction time. The results of our ANOVA may have been due to the low power of the study. Future studies may benefit from the inclusion of a greater number of participants in their study.

We also investigated whether error rates were effected by motion type and validity. As expected, invalid cues led to greater occurrence of error than did valid cues. The effect of motion type also approached significance, with the two object condition leading to higher error rates than congruent motion and incongruent motion.

Unlike Reppa & Leek (2003), we found no significant impact of an objects internal features upon the spread of attention through an object. In our study, the type of motion exhibited by an object did not significantly impact reaction time. Our study also found no significant impact of the number of objects. Given that previous research has shown repeatedly that the spread of attention across two objects is slower than the spread of attention within an object, we believe that our study may have had different results if a greater number of participants were included in the study.

The present study does corroborate the findings of Higgins and Stringer (2011). They found that a simulated ventral visual pathway would make separate representations for each part of an object when it exhibits incongruent motion. Accordingly, the incongruent motion condition should have led to similar or lesser reaction time compared to the two object condition. We found no significant differences in reaction time between these conditions.

The present study is also in agreement with the findings of Barenholtz and Feldman (2003) in terms of stimuli. Our study did not demonstrate a disruption in the spread of attention in a shape that was found to be not conducive to interpretation of an object as multipart according to Barenholtz and Feldman (2003). This may suggest that global configuration is the sole determinant of the spread of attention across an object.

In addition to a greater number of participants, this study would have also benefitted from a fourth condition in which two objects exhibit congruent motion. This would clarify whether motion of an object in general would promote a same object cost, or if incongruent motion alone influences the spread of attention across an object.

Future studies may also benefit from use of other stimuli. The stimuli in this study are more similar to that used in Davis and Holmes (2015), which were designed to avoid commonalities between stimuli used in studies of object based attentional enhancement. For example, the same object benefits may have been greater with the use of object stimuli primarily consisting of outlines (Davis and Holmes, 2015).

A problem with the present study may have been the large amount of inter-subject variation in reaction times. The present study may have benefitted from a within-subjects design where each subject was subjected to all three motion conditions. Future studies may benefit from this manipulation to the present study.

In conclusion, the study did not demonstrate that the type of motion exhibited by an object can influence the spread of attention across an object. It may be the case that the global configuration of an object is the sole determinant of the spread of attention across an object. It may also be the case that such effects require a study with greater power to detect differences in the spread of attention across an object. While this study did not find interesting results, it remains a novel approach to the study of object based attention and a font of information for future studies on the subject.

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