BOUNDARY EXTENSION AND PERCEIVED MOTION

A Thesis
by
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Submitted to the Graduate School
at Appalachian State University
in partial fulfillment of the requirements for the degree of
MASTER OF ARTS

December 2014
Department of Psychology

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Abstract

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Boundary extension is a memory error in which a person remembers seeing beyond the boundaries of a view (Intraub & Richardson, 1989). Representational momentum is another type of memory error, in which a person remembers the last seen position of a moving object being further along its trajectory path than it actually was (Hubbard, 1995). The goal of this experiment was to assess the influence of implied motion on boundary extension. On each trial within the three experiments, participants saw a picture of a scene with an object that moved either forward or backward, in either a coherent manner or not. Memory for the views was measured with a border-adjustment task. Results revealed a significant effect of motion direction. When motion direction was forward, participants moved the approaching border significantly inward, toward the object. When motion direction was backward, participants moved the approaching border significantly outward. This implies that participants' knowledge about the type of motion depicted in a scene influences memory.

Keywords: boundary extension, representational momentum, memory

Acknowledgments

I would like to thank Dr. Chris Dickinson, Dr. Lisa Emery, and Dr. Doug Waring for their help and support.

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Boundary Extension and Perceived Motion

Our experience of what we see is a continuous, detailed, and what we believe to be an accurate view of the world. Our mental representations, however, are not nearly as continuous, detailed, or accurate as we perceive them to be (O'Regan, 1992). In reality, we are perceiving snapshots that are strung together, with gaps of missing information in between these snapshots (O'Regan, 1992).

Examples of the disconnect between how we think we perceive the world and the actual nature of our mental representations suggest that the way we see the world is as though it is continuous and highly detailed. This is based, at least partially, on the nature of the input, where each eye fixation is a snapshot that is highly detailed in the center, but whose detail drops off rapidly (Carrasco & McElree, 2001). Change blindness is a good example of the disconnect between how we think we perceive the world and how we actually perceive it (Simons, 2000). Change blindness is a phenomenon in which individuals fail to detect fairly significant changes to the visual details of the scenes and objects within the scenes (Levin, Simons, Angelone, & Chabris, 2002). Change blindness occurs when interruptions such as saccades, blinks, movie cuts, and blank screens interrupt the visual field.

Visual input itself appears to be discontinuous. An example of this is that our eyes alternate between fixations and saccades, which means we are constantly engaged in a perception-memory cycle of vision (Matin, 1974). That is, visual input is suppressed during saccades, leaving memory to take its place (Matin, 1974). This exemplifies the discontinuous nature of vision; specifically, our visual experience is knitted together from a series of snapshots we obtain from fixations. As this appears to be the true nature of the input to our visual experience, one must wonder what fills in the gaps between these snapshots. In other words, the nature of our visual experience cannot be explained by the bottom-up input we receive from the visual system alone. Something else must contribute to our experience of continuity. One type of top-down process that could possibly serve this purpose is boundary extension.

Overview of Boundary Extension

Boundary extension is a type of memory error in which a person remembers more of a view than what they actually saw (Intraub & Richardson, 1989). For example, if you were to look through a window to view the yard outside, you may only see part of the yard, but you also understand what is beyond the window's edges. Both your conceptual understanding of what you are seeing, as well as what you are actually seeing are part of your representation. This being the case, if you were to take part in a memory test for what you actually saw, you would be likely to remember having seen what appeared beyond the edges of the view, and you would have experienced boundary extension.

One of the most robust findings in the boundary extension literature is that different views elicit boundary extension to either a greater or a lesser degree. Close-up views typically elicit the most boundary extension, whereas wide-angle views elicit less (Gottesman & Intraub, 2002; Intraub & Dickinson, 2008; Intraub & Richardson, 1989). A close-up view contains a view of an object that appears larger, closer, and with less of the background showing than that of a wide-angle view, which makes the object smaller and shows much more of the background. This finding has been interpreted to suggest that because close-up views show less background, there is less context available available in the view to cue a person's memory (Intraub & Richardson, 1989).

The type of view has a large impact on the amount of boundary extension experienced, yet another well supported finding is that warning a person about boundary extension does not prevent the memory error from occurring (Gagnier, Dickinson, & Intraub, 2013; Intraub & Bodamer, 1992). Intraub and Bodamer (1992) instructed participants to draw pictures of previously viewed scenes. After the participants completed their drawings, the experimenter informed the participants that for most people, their drawings would contain more of the scene than what was actually shown in the view. The participants were then shown different views, followed by another memory test. Intraub and Bodamer (1992) found that warning a person about boundary extension did not prevent boundary extension from occurring.

Boundary extension has also been found to occur after very brief retention intervals (Intraub & Dickinson, 2008; Intraub, Hoffman, Wetherhold, & Stoehs, 2006). Intraub and Dickinson (2008) showed that boundary extension occurs with a retention interval of only 42 ms. On the other hand, Intraub, Hoffman, et al. (2006) found that boundary extension can still occur after a 2000 ms retention interval. Several other findings suggest that boundary extension is a robust phenomenon, occurring across the lifespan, and beginning in infancy (Intraub, Bender, & Mangels, 1992).

Theoretical Explanations for Boundary Extension

Intraub, Bender, and Mangels (1992) provided a framework for explaining boundary extension with the perceptual schema hypothesis. They tested three alternate explanations of boundary extension, which were the object completion hypothesis, the perceptual schema hypothesis, and the memory schema hypothesis. They discussed and tested these hypotheses in the context of how we remember pictures, as opposed to how we remember partial views of the world around us.

Object Completion Hypothesis. Intraub et al. (1992) explained that the object completion hypothesis predicts that boundary extension occurs as an attempt to complete an object being viewed when only part of the object is actually visible (e.g., a view of a trashcan where part of the trashcan is not visible because it is cut off by one of the picture's side borders). They further hypothesized that boundary extension cannot be explained by the object completion hypothesis and that boundary extension should occur with objects that are entirely visible.

Memory schema hypothesis. According to the proposal of the memory schema hypothesis by Intraub et al. (1992), the memory schema serves as a guide that integrates the successive glimpses of the visual world. It is an abstract representation that contains memory for information that was previously fixated upon, as well as the contents of future fixations. According to the memory schema hypothesis, boundary extension is caused by normalization of the scene to a mental prototype of what is typically included in that type of scene. A mental prototype would be a representation of the view that is somewhere between a close-up view and a wide-angle view. According to the memory schema hypothesis, there should be no directional distortion of prototypic pictures, and wide-angle views should elicit boundary restriction. Although the memory schema hypothesis can account for boundary extension, Intraub et al. (1992) suggested that a more comprehensive explanation is the perceptual schema hypothesis.

Perceptual schema hypothesis. The perceptual schema hypothesis is based on the assumptions that perception of the picture involves activating a mental schema for the scene that gives observers a quick understanding of what probably exists beyond the boundaries of the picture, and the information provided in the schema will most likely become combined with the person's mental representation of the picture. The perceptual schema can be described as something that allows us to perceive an object that we have never seen as a whole and extrapolate information about the world around us that we cannot perceive visually (Intraub et al., 1992). They predicted that the perceptual schema hypothesis would best explain boundary extension and that the perceptual schema hypothesis attributes boundary extension to the first understanding of the view. The first comprehension of the view includes expectations taken from the schema about what is outside of the boundaries of the view. As an explanation for boundary extension, the perceptual schema hypothesis predicts that close-up views will elicit more boundary extension, whereas wide-angle views will not elicit boundary extension at all. This is because close-up views do not contain a strong context for where the object is in the space and leave room for error by potentially incorporating other sources of input (e.g., knowledge about the view as a whole, not just what is seen), whereas wide-angle views provide a much better sense of context (Intraub et al., 1992).

Experiment 1 of Intraub et al. (1992) had four conditions: close-up version at presentation and test (CC), a medium version that was more wide-angle than the close-ups at presentation and test (MM), a close-up version at presentation and medium version at test (CM), and a medium version at presentation and close-up version at test (MC). The four test conditions allowed the researchers to assess the predictions of three different hypotheses discussed previously. Some of the pictures contained objects that were cropped, whereas other pictures contained objects that were not cropped. All stimuli were pictures of objects on natural backgrounds, such as a dust pan on the ground or a boy sitting against a wall, and each picture had a close-up and medium version.

Participants were shown 16 pictures for 15 s each. Eight were presented in their close-up version, and eight were presented in their medium version; then 48 hr later, participants returned to the lab for the recognition test. For the recognition test, the scenes were shown in the same order as in the presentation phase. The same order was used so that the participants would experience the same viewing context in order to maximize the participants' accuracy. Eight of the scenes were shown in the same version as in presentation (CC and MM conditions), and eight were shown in the other version (CM and MC conditions). Participants were instructed to decide whether the test picture was either more close-up, more wide-angle, or the same as the stimulus view. The results of Experiment 1 indicated that the close-up pictures elicited boundary extension, but the medium angle pictures did not. Unlike the close-up pictures, the medium angle pictures did not show any directional distortion. In the MC and CM conditions, an asymmetrical pattern was seen, in which the participants did recognize that the test views were different from the stimulus views. The mean ratings suggest that participants could tell that test views were different from stimulus views, but in the CM condition, mean ratings were closer to the same view than the MC condition. In other words, participants appeared to extend the picture boundaries slightly more in the CM condition than in the MC condition. The results of Experiment 1 indicate that boundary extension cannot be attributed to object completion, because boundary extension occurred despite the fact that half of the objects in the pictures were not cropped (Intraub et al., 1992).

In Experiment 2 of Intraub, et al. (1992), the predictions for the memory schema and perceptual schema hypotheses were tested for pictures rated in the typical range or as wide-angle views (e.g., prior to the start of the experiments, a separate group of participants rated all of the stimuli in terms of how close-up or wide-angle they thought they were, and that is how they operationally defined close-up, prototypic, and wide-angle views). Typical range pictures were essentially medium-angle photographs, in which the camera angle was between a wide-angle view and a close-up view. According to the memory schema hypothesis, it was predicted that participants should show no directional distortion of prototypic pictures (i.e., medium version rather than close-up or wide-angle) and should restrict the boundaries of wide-angle pictures. According to the perceptual schema hypothesis, prototypic pictures should elicit boundary extension, while wide-angle pictures should not. The retention intervals differed from Experiment 1, in that there were two different retention intervals. The intervals were immediate retention intervals where participants were tested after they were given the instructions for the memory test which took about 3 min with a 48 hr retention interval. The purpose of adding the immediate retention interval was to test for the idea that the distortion predicted by the perceptual schema hypothesis might be immediately apparent.

The results of Experiment 2 indicated that participants had better memory for the picture boundaries in the immediate retention interval compared to the delay retention interval. In support of the perceptual schema hypothesis, results revealed that picture type had a large effect on participants' memory for the picture boundaries, where boundary extension occurred for the prototypic pictures but not for the wide-angle pictures (Intraub et al., 1992).

In Experiment 3, the goal was to replicate Experiment 2 by using an independent design for the picture type where there were no distracter pictures, and all of the test pictures were identical to the stimulus pictures. All three views and both retention intervals were tested. The two conditions were picture view and retention interval. Intraub et al. (1992) predicted that boundary extension would be obtained when picture types were not mixed. Results of Experiment 3 revealed that the pattern of boundary errors was greatly influenced by picture type and time. Specifically, boundary extension occurred in all conditions except for the wide-angle condition. Instead of eliciting boundary extension, the wide-angle views elicited boundary restriction (Intraub et al., 1992).

Overall, the results of Intraub et al. (1992) indicated that close-up pictures elicit boundary extension, while wide-angle photographs do not. Their results suggest that boundary extension cannot be attributed to object completion, because half of the pictures contained main objects that were not cropped at all by the boundaries of the picture. Even though this was the case, boundary extension still occurred (Intraub et al., 1992). The results of Intraub et al. (1992) provide strong support for the perceptual schema hypothesis.

More recent evidence suggests that the perceptual schema hypothesis may not provide the most complete explanation of how boundary extension occurs. Intraub and Dickinson (2008) have argued that boundary extension is a source-monitoring error, as explained by a multisource model of scene perception (Intraub, 2010). Intraub and Dickinson (2008) looked to see if they could find some retention interval that was so brief that boundary extension would not occur. They found that their results were not entirely consistent with the predictions of the perceptual schema model. According to the perceptual schema model, boundary extension is predicted to be purely a memory based phenomenon, meaning that boundary extension happens in memory after the stimulus has been removed. Intraub and Dickinson (2008) found that boundary extension can occur with a masked retention interval as brief as 42 ms and suggested that it was too brief an interval for boundary extension to be occurring in memory after the stimulus is removed.

Intraub and Dickinson (2008) suggested that the multisource model can account for boundary extension. This multisource model assumes that we carry around with us a sense of space that we fill in with different sources of information, including vision, amodal processes, and general world knowledge (Intraub, 2010). According to this model, the filling in happens continuously during perception, meaning that while a person is seeing a partial view of the world, their mental representation of the world is being filled in with with amodal information and general world knowledge. Amodal processes refer to what is not in a sensory modality (e.g., remembering a completed object because of knowledge of what the object is, instead of remembering what you actually saw – part of the object). In the case of boundary extension, you are completing visual input at the edges of the view with information that is not in a sensory modality. This occurs when a person does not have all of the relevant visual information in a view; they fill in the gaps of missing information with top-down information (Intraub, 2010). An example of this could be looking at a view of a dog where the edge of the view ends at the dog's torso, showing only the front half of the dog. Even though the dog is not visible in its entirety, your categorical understanding of what you are looking at, or top-down processing, completes the dog in your mind with the knowledge of what the category "dog" includes, so a dog has four legs, paws, fur, etc. General world knowledge encompasses what you know, in general, about the world around you. You know that houses typically contain doors, walls, and so on. According to the multisource model, then, boundary extension is the result of a source-monitoring error, which involves attributing non-visual information to a visual source, which means that something is always being added to what we see (Dickinson & Intraub, 2008).

Dickinson and Intraub (2008) examined the early time course of boundary extension, in which they addressed how time affects boundary extension. Specifically, they examined whether, after some retention interval, boundary extension might not occur (i.e., memory for a view would be accurate). In Experiment 1 participants were presented with four different stimulus view/test view combinations, including close-up stimulus, close-up test picture (CC); wide-angle stimulus, wide-angle test picture (WW); close-up stimulus, wide-angle test picture (CW); and wide-angle stimulus, close-up test picture (WC). Masked intervals were 100, 250, 625, or 1000 ms. All four trial types were randomly intermixed in each condition. Stimuli included photographs of people doing various activities, such as kicking a ball across a field. On each trial participants saw a sequence of three pictures for 325 ms each, and their memory was tested for one of the three. The test picture appeared in the same location as the stimulus picture, to the left of the stimulus picture, or to the right of the stimulus picture. A memory test was given to participants after viewing the test picture, in which participants were asked if the view was the same as what they saw before, or if it was more close-up or more wide-angle than before. Boundary extension was shown to occur after only a 100 ms interruption as well as for all other retention intervals.

The purpose of Experiment 2 was to take a closer look at the effect of time when participants did not have to make a saccade from the location of the stimulus picture to the location of the test picture. Experiment 2 was similar to Experiment 1, except that all test pictures and stimuli were presented in the center of the computer screen. Masked intervals in

Experiment 2 were 42, 100, or 250 ms (Dickinson & Intraub, 2008). The results of Experiment 2 revealed that wide-angle views elicited less boundary extension than close-up views. Close-up views elicited boundary extension for each of the retention intervals. It was found that although observers knew what would be tested on each trial, a disruption lasting for less than 1/20th of a second was sufficient for boundary extension to occur, and results suggested that boundary extension occurs rapidly enough to play a role in view integration during visual scanning (Dickinson & Intraub, 2008).

The focus Experiments 3a and 3b were to readdress the question of whether or not boundary extension would be influenced by a shift in gaze. The masked intervals were the same duration as in Experiment 2. All stimuli in Experiment 3 were identical close-ups, all stimuli were shown on one side of the screen, and test pictures were shown either in the same location or on the other side of the screen. However, in Experiment 3b, eye-tracking was used to record participants' eye movements. Results revealed that boundary extension can be seen even after a shift in gaze (Dickinson & Intraub, 2008).

Overall, Dickinson and Intraub (2008) found that boundary extension can occur after an interruption of a view that lasts as little as 42 ms. Boundary extension was found to occur after a masked interval of 1 s, 625 ms, 250 ms, 100 ms, and 42 ms.

Representational Momentum

The theme of continuation beyond what was provided by perceptual information is common to another type of memory error. There is a body of research on a type of false memory called representational momentum (Freyd & Finke, 1984). Representational momentum is a type of memory error defined by Delucia and Maldia (2006) as a memory distortion in which individuals remember the final location of a moving object as being further along or more forward in its trajectory path than it actually was.

Freyd and Finke (1984) provided a foundation for the representational momentum literature, which consisted of three experiments that measured the changes in mental representation of a pattern that was presented visually, in which the pattern was induced through a sequence of displays that were static.

Experiment 1 involved showing participants a view of a rectangle in which three different orientations were depicted along the rectangle's possible rotation path. Each different orientation was separated by a 250 ms interstimulus interval. Participants were told to remember the third orientation for each sequence. They were then shown a rectangle at the fourth orientation after a delay of 250 ms. This was either different from, or the same as the rectangle's third orientation. A rectangle could be different in two ways. It could either be rotated slightly in the same direction, or it could be rotated slightly in the opposite direction. Participants were asked to indicate if the objects orientation was the same, or if it was different from the previous view. The results of Experiment 1 showed that participants experienced much more memory error when attempting to detect differences in the direction of the motion, meaning that participants misremembered the final position of the object as being further along in its rotational path than it actually was. This means that participants were more likely to say "same" if the rectangle was rotated slightly in the same direction than if it was rotated slightly in the opposite direction. The participant's memory for the third orientation of the rectangle was distorted in the implied direction of rotation.

The goal of Experiment 2 was to see if reversing the order of the first two object orientations (e.g., to elicit an inconsistent path of implied motion) would make the effect found in Experiment 1 disappear. They found that the effect disappeared. In Experiment 3 the authors found that implied motion of the effect can still be found up to 500 ms, and furthermore, can occur between 250 and 333 ms, or less than the blink of an eye. This means that after delaying the appearance of the test object, representational momentum still occurred. The results from these experiments were interpreted as support for a mental analogue to the momentum of a physical object in movement (Freyd & Finke, 1984).

We currently know that representational momentum is a type of memory error that appears to incorporate expectations or predictions about a moving object's position along its trajectory path (Hubbard, 1995). Hubbard (1995) described representational momentum as a phenomenon in which memory of the location of a target in motion is displaced toward the direction of the motion.

According to Hubbard (1995), representational momentum reflects properties of mental representation as well as properties of the world. Hubbard (1995) suggested that a potential functional purpose of representational momentum is that the displacement could help spatial localization, by bridging the gap between perception and action. In other words, representational momentum may help a person to process the movement of an object toward a particular direction, and incorporate this information into the memory of the scene.

Reed and Vinson (1996) gave a description of representational momentum, incorporating what we know of a scene from the standpoint of basic physics. A moving object has physical momentum that it carries with it along its trajectory path. To stop the object, an opposing force must be applied to it, but unless the force is strong enough, the object will keep moving for a certain amount of time, over a specific distance. Similar to a moving object with physical momentum, a representation of a moving object has representational momentum. Therefore, representational momentum can be thought of as the mind accounting for what it knows about the laws of the physical world, in an attempt to make a prediction dealing with time. To understand how representational momentum applies to the real world, if you were to watch a person throw a Frisbee across a field, and look away before the Frisbee hit the ground, you would probably remember the last snap shot of the Frisbees last seen location in the air, as being further along its trajectory path than what you actually saw. Furthermore, Reed and Vinson (1996) discussed how conceptual knowledge about how specific objects move or do not move, appears to affect representational momentum. In other words, a person's knowledge that a specific object appears to be moving in a scene could cause the person to remember the object being further along in its trajectory path than it actually was.

Boundary Extension and Representational Momentum

Boundary extension and representational momentum are memory errors that appear to share some surface similarities. Both concern the concept of prediction, whether it deals with predicting future events in the case of representational momentum, or with predicting what is outside of the boundaries of a view in the case of boundary extension (Munger, Owens, & Conway, 2005). Both share the idea that we anticipate what has not yet been viewed, whether the predictive factor is the scene, as in the case of boundary extension, or whether the predictive factor is time, in the case of representational momentum (Intraub, 2002). These similarities imply that boundary extension and representational momentum appear to share the same purpose of allowing someone to infer information about the visual world that is based on expectation. Both are found when memory is tested within tens of milliseconds after the offset of a stimulus disappears (Hubbard, 1995). Both boundary extension and representational momentum, therefore, appear to be quite similar phenomena. A more extensive comparison of the two memory errors, however, reveals differences that help answer the question of whether or not representational momentum and boundary extension share similar mechanisms or not.

Representational momentum happens when an individual misreports a moving object's final or last seen position as being further along its trajectory field than it really was (Intraub, 2002). In the case of boundary extension, on the other hand, the phenomena occurs when the individual misremembers the boundaries of the pictures borders and remembers seeing more of the view than they really did (Intraub, 2002). These differences imply that the predictor factor for each of the two memory errors is different. Boundary extension is a prediction about space that lies outside the edges of a view. Representational momentum, on the other hand, is concerned with predictions about time, where a prediction is made about a moving object with the expectation that the object will continue along its trajectory path.

Initially, research by Hubbard (1995) suggested that representational momentum and boundary extension may arise from similar mechanisms. In five experiments, Hubbard (1995) tested memory for stationary targets as well as moving targets that were displaced either behind the moving target in the case of the target with slower velocities, or beyond the target as in the case of the target with faster velocities. Participants were presented with computer-animated square stimuli that portrayed movement in depth. The target with slower velocities contained longer retention intervals, while the target with the faster velocities contained shorter retention intervals. Hubbard (1995) predicted that participants should be more likely to accept the object as being closer than the final stimulus view actually was. He further predicted that participants should be more likely to accept the object portrayed as farther away from the last seen stimulus view. Finally, Hubbard (1995) predicted that the magnitude of forward displacement will increase as target velocity increases. If participants experience boundary extension instead of representational momentum, they should be more likely to choose the object being portrayed as being a little bit farther away rather than the object portrayed as being a little bit closer, whether the stimuli appear to recede or to approach.

The results of Hubbard (1995) showed that representational momentum occurred for moving stimuli, and results consistent with boundary extension occurred for stationary stimuli. Hubbard (1995) suggested that boundary extension and representational momentum may arise from either different facets of the same mechanism, or similar mechanisms. Both memory errors are types of displacement, and while there are ways in which they are different, they do not seem to differ in their fundamental mechanisms. Hubbard (1995) suggested that both memory errors are evoked by schemas, where boundary extension occurs when targets evoke a scene schema, and representational momentum occurs when targets evoke a motion schema the overall magnitude of forward displacement for motion in depth was measured to be less than the magnitude of forward displacement for motion overall. Memory for the smaller stationary targets appeared to be displaced in the direction of the observer. Memory for the larger stationary targets was displaced away from the participant; finally, memory for the bottom or the top edge of the stationary target was displaced, and this displacement occurred inside the target perimeter. (Hubbard, 1995).

However, one potential shortcoming of Hubbard (1995) is that the rationales for the conclusions drawn were not sufficient as the author seemed to suggest. Specifically, the rationale for Hubbard's conclusion was that boundary extension and representational momentum both share similarities in time course, rely on internal expectations about the world, and appeal to aspects of memory that are dynamic (Hubbard, 1995; DeLucia & Maldia, 2006). Although boundary extension and representational momentum share similarities (e.g., both involve predictions about what a person should see), this does not provide strong evidence that the two memory errors arise from different facets of the same mechanism or that they arise from similar mechanisms. DeLucia and Maldia (2006) examined this issue, with results differing from those reported by Hubbard (1995).

DeLucia and Maldia (2006) examined memory for picture boundaries with the use of scenes that simulated self-motion either toward or away from the object. The stimuli used in DeLucia and Maldia (2006) are more similar to the stimuli used in typical boundary extension experiments, in that the stimuli were computer-generated pictures of real objects on natural backgrounds such as a road with a stop sign, or a fire hydrant next to a wall. Simulated self-motion is the idea that the person is simulated to move toward the object or away from the object on the screen. Self-motion was simulated by showing a video clip that depicted an object moving in depth either toward or away from the participant. An example is a computer drawn basketball goal either appearing to approach the participant or to recede from the participant. They focused on three questions: First of all, does boundary extension occur when the types of scenes used depict simulated self-motion? Second, does depicted self-motion affect a person's memory for the boundaries of a scene in a way that is comparable to representational momentum of the self? Their final question was whether or not the presence of optic-flow information has an impact on memory for the boundaries of scenes. Optic flow encompasses the visual experience of movement through a physical space.

For example, as a person walks down a hall, both the left and right peripheral sides of the visual field appear blurred as the person moves through the space, while the center of the view, where the person is fixating, remains clear. As the person moves toward the end of the hall, what they are approaching appears wider the closer they get.

Experiment 1 included three conditions in which the same scenes were used. The conditions included a continuous-motion condition, which aimed at determining whether boundary extension occurs with scenes that simulate continuous self-motion in depth, an implied motion condition, to determine whether boundary extension happens with views that depict implied self-motion, and a static condition, which was intended to be a control condition to see how much boundary extension the final stimulus views in the motion condition would elicit. The scenes simulating continuous self-motion in depth depicted a view of an object that either became larger and more close-up, or smaller, becoming more wide-angle. This created the illusion that the participant was moving either toward the object in space or away from the object. Scenes depicting implied self-motion also depicted change in depth, which were not continuous, but shown in three separate pictures rather than a video clip of the changes in depth. In the static condition, the object in the view did not get larger or smaller – it stayed the same and did not change. The static condition was the final view of the motion sequence, which was either close-up or wide-angle. Memory was tested by providing participants with a 5-point scale to rate whether the test picture was the same as the stimulus picture, more close-up or more wide-angle. There were two versions of the memory test, used in two separate experiments. In the first version, all of the stimuli were shown, and then memory was tested for the final view for each. The time between the end of stimulus presentation and the start of the memory test was approximately 4 min. In the second version, memory was tested after each stimulus presentation with a 250 ms retention interval. It was hypothesized that if moving scenes also activate the scene schema as static scenes presumably do, then the motion should not affect boundary extension. Boundary extension should not be increased or decreased by moving scenes. However, if the moving scenes activate the motion schema that underlies representational momentum, then boundary extension should not occur. Finally, it was also hypothesized that if participants take in veridical information about the environment from optic flow in the continuous-motion condition, neither representational momentum nor boundary extension should occur with the moving scenes. Furthermore, participants' memories should be more accurate in the continuous motion condition than in the implied-motion condition (DeLucia & Maldia, 2006).

The results of Experiment 1 indicated that there were no significant effects of motion on boundary extension in the 4 min retention interval condition, but boundary extension was found in all three conditions. The 250 ms condition allowed the authors to test their hypotheses about implied motion, representational momentum, and boundary extension, because memory was tested after each stimulus in the experiment, so the authors could assess memory across the same retention interval as representational momentum has been found to occur. Because of this, the results I describe are from that condition. Results revealed that there was no distortion in the static condition or the implied-motion condition. However, in the continuous-motion condition, boundary extension occurred. The results support the activation of a scene schema because motion continuity did not affect boundary ratings. However, the results also suggest that the schema activated when the test view is preceded by self-motion is not the same schema that is activated when the test view is preceded by depicted self-motion. The effect of implied self-motion was not consistent with the motion schema that was predicted to underlie representational momentum. This is because the direction of the effect of motion was opposite of what was predicted, according to the motion schema. According to the motion schema, implied self-motion that creates a close-up view should not elicit boundary extension. The results of Experiment 1 revealed that the motion sequences elicited the most boundary extension. Because the results of Experiment 1 could have been because the types of scenes that were used may not have elicited representational momentum, Experiment 2 addressed this concern.

Experiment 2 assessed memory for the position of the self with two different scenes. One scene depicted a mug, while the other scene depicted a beach ball. The mug scene started out as a wide-angle view, but ended as a medium-angle view, whereas the beach ball scene began as a medium-angle view and ended as a close-up view. Each probe could be the same as in the final stimulus image or different in terms of perceived distance from the participant, and it was displaced either farther in the direction of the implied motion trajectory or in the direction opposite of the motion. The probe was the test picture that was shown after the motion sequence. Participants were asked to report whether or not each probe picture was the same as before the final position of the object in the stimulus sequence, or different. The results of Experiment 2 indicated that the results of Experiment 1 did not occur because of the type of scene depicted (DeLucia & Maldia, 2006).

The results of DeLucia and Maldia (2006) showed that boundary extension happened with views that depict motion. The motion affected memory for the boundaries of the view, but this effect of motion was not consistent with representational momentum of the self. Boundary extension occurred for scenes that simulated self-motion, however the mean boundary scores were different for the static scenes than they were for the scenes that simulated self-motion. Boundary scores for scenes that simulated implied self-motion did not differ from scenes that simulated continuous self-motion. If the effect of motion had been consistent with representational momentum of the self, boundary restriction would have occurred. Information about the optical expansion pattern did not have the predicted effect on memory for the position of the self (Delucia & Maldia, 2006). The optical expansion pattern was predicted to give participants accurate information about object motion, which should have resulted in accurate memory for the final position of the self, relative to the object. However, boundary extension still occurred. When the views depicted self-motion in a forward direction, the participants remembered the views as being more wide-angle than they remembered the static scenes, and the authors suggest that a scene schema that was activated by the picture of a static scene was different from the scene schema that was activated by a moving scene (DeLucia & Maldia, 2006).

Based on their results, the authors concluded that the mechanisms that underlie both representational momentum and boundary extension differ, in that they each process different information. In the case of boundary extension, the underlying mechanism is the scene schema, which processes spatial and global properties of the scene. The scene schema aids in integrating successive views. In the case of representational momentum, on the other hand, the underlying mechanism is the motion schema, which processes local and global changes, as well as the details of a scene. The motion schema also incorporates optic-flow information and helps individuals to anticipate changes in the stimulus (Delucia & Maldia, 2006).

Munger et al. (2005) also examined the possible relationship between boundary extension and representational momentum. Their design was similar to DeLucia and Maldia

(2006), but they used only approach sequences for testing for boundary extension and representational momentum. In concordance with DeLucia and Maldia (2006), they hypothesized that if participants were to rate the test view as too close, that would suggest that boundary extension is occurring (Munger et al., 2005).

All participants received three blocks of trials, with the blocks in the same order, and the trial types were each presented in their own blocks. In their experiment, Munger et al. (2005) showed participants single close-up photographs with the goal of measuring baseline boundary extension, and all test pictures were identical close-ups. After viewing the test picture, participants were asked to choose whether the test picture was the same, or whether it was different from the stimulus picture, using a five-point rating scale. They then presented three-picture approach sequences, which were similar to the implied motion approach sequences presented in DeLucia and Maldia (2006). Each stimulus picture was shown for 250 ms, and a 250 ms blank inter-stimulus interval (ISI) was presented between stimulus images. This was followed by a 250 ms retention interval and the test picture, which was a close-up and identical to the last stimulus picture shown. Finally boundary extension was measured again. Representational momentum was measured in Block 3, using the same stimulus and presentation as in Block 2. The same boundary extension test that was given in Block 1 was given in Block 2. For each participant, the authors had a measure of boundary extension for static scenes, a measure of boundary extension for the approach sequence, and a separate measure of representational momentum.

Participants were divided into three groups based on whether they showed boundary extension, boundary restriction, or no directional distortion for the pictures in Block 1. The view ratings for Block 2 were analyzed separately for each group. Overall, participants who either had no distortion for the single photographs or displayed significant boundary restriction experienced more boundary extension for memory of the final view in the approach sequence, which is the opposite of what one would predict if representational momentum were affecting participants' memories of the final views of the implied motion condition (Munger et al., 2005). The group that showed no distortion in Block 1 showed significant boundary extension in Block 2, and the group that showed boundary restriction in Block 1 showed nonsignificant boundary extension in Block 2. The results indicated that how readily participants extended the boundaries on a single view had a large impact on how they responded to the approach conditions in a boundary extension task. However, this was not the case for the representational momentum task. In Block 3, they found representational momentum and they also found that participants' representational momentum scores did not correlate with their boundary extension scores in either Block 1 or Block 2. Furthermore, participants who experienced no distortion for the single views, or experienced boundary restriction, showed more boundary extension before the approach sequence, which is the opposite of representational momentum. They further concluded that the interaction between baseline boundary extension and baseline representational momentum implies that boundary extension appears to precede the inclusion of movement into the mental representation of the scene. Based on their results, they concluded that boundary extension and representational momentum are separate memory errors.

Simulated self-motion does not appear to apply to boundary extension, but that doesn't necessarily mean that boundary extension and representational momentum are not related, given that previous research has examined only one type of simulated motion.

Consequently, the current study addresses how boundary extension may be affected by perceived motion of an object, such as a person, frisbee, ball, or animal.

Previous experiments have examined simulated self-motion rather than motion of an object across a horizontal path in a scene (DeLucia & Maldia, 2006; Hubbard, 1995; Munger et al., 2005). The current experiment addresses object motion in scenes, where the direction of motion travels horizontally across the view. The type of motion being addressed in the current experiment is something that people experience on a regular basis. Understanding this type of motion is necessary to understanding how people remember scene views.

The Current Experiment

The current experiment focuses on whether or not a type of implied motion other than self-motion affects boundary extension. As described here, previous research concerning this issue has focused on representational momentum of the self. The literature is mixed concerning whether or not these two memory errors are related, with some research (DeLucia and Maldia, 2006; Munger et al., 2005) concluding that the two phenomena are not related, and other research (Hubbard, 1995) suggesting that boundary extension and representational momentum are related. However, Hubbard's conclusions may be limited because of the type of stimuli he used. The current study addressed boundary extension for objects that depict motion toward their implied trajectory path, either toward the left border of the view or the right border. This is different from depicted self-motion, which concerns the idea that the person is moving either toward or further away from a view.

To test the idea, there were four trial types. This included a forward motion depiction, a backward motion depiction, and both forward and backward conditions in an incoherent motion condition. The motion sequences consisted of an object appearing at three different positions against the same background, for example, on the left side, the middle, and the right side. The incoherent motion condition started off with the middle slide, with the sequence being either middle, first last, or middle, last, first. Each of the four conditions contained 10 pictures, with a total of 40 trials. All views were as close up as they could be to permit the depiction of motion, and the final view in each stimulus sequence was close-up with respect to the distance between the object's final position and the border closest to it. After participants viewed each stimulus sequence they were presented with a border-adjustment test, in which they were asked to adjust the borders of each test picture to match the view from the last seen picture. This allowed for assessment of the remembered distance between the object that was depicted to be moving and the border it was depicted to be moving toward.

Hubbard (1995) suggested that if representational momentum does influence boundary extension, one explanation may be that boundary extension and representational momentum are processed by the same mechanism. This is consistent with Whitney and Cavanagh (2000) as well as Freyd (1987, 1992). The basic idea behind this rationale is that boundary extension reflects dynamic properties of a mental representation, and it can be influenced by information regarding the physical principles in the scene (Courtney & Hubbard, 2008).

Reed and Vinson (1996) framed this concept from a physics perspective, in which a moving object has physical momentum that carries it along its trajectory path. To stop the moving object, an opposing force must be applied to it. However, unless the force is strong enough, the object will keep moving for a certain amount of time, over a certain distance. Similar to this, the mental representation of an object will continue to move along the implied trajectory path, even after the moving object itself has stopped. Just as a moving object has physical momentum, a mental representation has representational momentum (Reed & Vinson, 1996). Reed and Vinson (1996) tested the hypothesis that prior knowledge about an object's typical movement would affect motion representation. They compared results where representational momentum was elicited by objects with different motion trajectories. Reed and Vinson (1996) found that conceptual knowledge about an object's normal motion trajectory did affect the magnitude of representational momentum. In other words, conceptual knowledge affected participants' representation of motion.

Based on the findings of Reed and Vinson (1996), I hypothesized that there would be the following outcome: the forward-motion condition should show the least amount of boundary extension or possibly boundary restriction. This would be followed by the backward-motion condition, followed by the two incoherent-motion conditions. The goal of my hypothesis was not to assess overall boundary extension; it was to assess memory for the border closest to the end of the object's trajectory. My hypothesis was based on boundary extension and representational momentum sharing a common mechanism.

Experiment 1a

Method

Participants. A total of 64 undergraduates who were registered with the psychology department subject pool participated in the experiment. This sample size was based on previous boundary extension research that has used a border-adjustment test (Gagnier et al., 2013). Participants were recruited through the Psychology Subject Pool by registering on software called SONA. After registering students could elect to sign up for the experiment listed in SONA. IRB approval for the experiment was obtained on December 9, 2013, as can be seen in Appendix A. All participants were treated in accordance with appropriate ethical guidelines. The consent form given to all participants can be seen in Appendix B.

Apparatus and stimuli. Stimuli were presented, and participants' responses were recorded with a Dell Optiplex 755 computer with 4 mb of RAM and a video card with 512 mb of video RAM. Stimuli were displayed on a Dell P-1130 CRT monitor was used, with the refresh rate set at 120 Hz. Images were shown at a resolution of 1024 x 768 pixels in 32-bit color. The full screen subtended 28° x 22° of visual angle at a viewing distance of 80 cm. The display program was based on a template program provided by SR Research Inc., written in C, which was used to display the stimuli and record participants' responses

Stimuli consisted of 12 background/object pairs, using both indoor and outdoor scenes. Appendix C lists a description of each background and its object. The backgrounds included scenes of a kitchen, a backyard with a pool, a field, and other common scenes. Each background had one object added to it, although different backgrounds contained different numbers of other objects. Examples of the added objects include a person jogging or a running horse. Each stimulus image had three versions, each using the same background but with the object in three in three separate positions on each trial: the left side, the center, and the right side of the image. Objects were added to the backgrounds using Adobe PhotoShop CS5. Ten of the background/object pairs were used for the experimental trials, and two were used for the practice trials. The stimulus and initial test views subtended approximately 15° x 10° of visual angle, with each view shown on a black background.

Procedure and design. In this experiment, participants saw a total of 40 trials, with an additional eight practice trials. There was a forward-coherent condition, in which the picture sequence showed a motion progression in a forward direction (e.g., the object appeared on the left side, then in the center, then on the right side); a backward-coherent condition, in which the picture sequence showed a motion progression in a backward direction; and both of those conditions in an incoherent-motion condition, in which both started off with the middle slide, with the object locations being middle, first, last, or middle, last, first.

Each trial started with a central fixation cross, and the participants started each trial by pressing the space bar. Each picture was shown once for 250 ms. Between each image with an object, the background without the object was shown for 250 ms. Immediately after this, a 250 ms mask appeared, separating the final stimulus picture from the test picture. The test picture appeared immediately after the mask and was always identical to the final image in the stimulus sequence. Participants were instructed to maintain central fixation until the test picture appeared. The border-adjustment test allowed the participant to move the four borders of the picture either out or in, allowing the view to be adjusted to be either more close-up or wide-angle. The borders were always be in the same position as they were in the stimulus views when the test picture appeared after the mask, and participants were be told that the borders may or may not need to be adjusted. After the border-adjustment test, participants rated their confidence in the accuracy of their border adjustments on a four-point scale. The four labels on the scale were *sure, pretty sure*, *not sure*, and *DRP*, which stands for do not remember picture. The four practice trials consisted of the two practice scenes being shown in all four conditions, and during the experiment, participants saw the 10 experimental images four times – once in each condition – yielding a total of 40 experimental trials. The backgrounds were always shown in the same sequence across participants, and the actual sequence of conditions was counterbalanced. For example, the picture for Trial 1 was the same for all of the participants, but some participants saw the forward-coherent condition (FC), while others saw the backward-coherent condition (BC), or the forward-incoherent condition (FI), or the backward-incoherent condition (BI). For half of the participants, the images were mirror reversed, so that all participants saw each of the image/background pairs showing motion in the direction of the right border, and the left border.

Results

I excluded trials from analysis on which participants made a DRP response. For the four conditions, the percentage of DRP trials was as follows: FC: 0.63%; FI: 1.43%; BC: 0.48%; BI: 0.79%. I excluded a participant's data from analysis if the mean change in area was 3 *SD*s or greater than the overall mean of all participants for at least two of the four conditions (Gagnier et al., 2013). Based on this criterion, one participant's data was excluded from all analyses.

To test the hypothesis that there would be an effect of motion condition, I ran a one-way ANOVA to see if the means for motion condition in the four conditions differed from one another. I also ran a contrast test to find out if the differences were in the order that I predicted. All hypotheses were tested using the distance from the border closest to the object (i.e., either the left or right border) to the part of the object that was closest to the border. Results of the ANOVA showed that motion condition affected memory for the position of the front border (i.e., the border that the object appears to be approaching) relative to the object, $F(1.04, 64.48) = 20.99$, $p < .001$. Because Mauchly's test for sphericity was significant, I am reporting the Greenhouse-Geisser corrected degrees of freedom and p value. To determine whether the differences between means were in the order I predicted (FC, BC, FI, BI), I conducted a set of repeated contrasts. These contrasts revealed that as I predicted, the mean for the FC conditions was significantly smaller than the mean for the BC condition, $F(1, 62) = 20.00$, $p < .001$. Contrary to my prediction, the mean for the BC condition was significantly greater than the mean for the FI condition, $F(1, 62) = 20.00$, $p < .001$. Finally, the mean for the FI conditions was significantly smaller than the mean for the BI condition, $F(1, 62) = 24.36$, $p < .001$. Results showed the following order, from the border that was moved the farthest inward to the border that was moved the farthest outward: FC (M = -15.35, SD = 29.50), FI (M = -10.24, SD = 18.85), BI (M = 8.39, SD = 13.04), BC (M = 11.96, SD = 20.02).

Because the data did not support my hypothesis, I conducted a 2 x 2 (Motion direction [forward, backward] x Motion coherence [coherent, incoherent]) analysis of variance (ANOVA) to determine the effects of motion direction and coherence on memory for border position. There was no main effect for coherence, $F(1, 62) = 2.01$, $p = .162$, but there was a main effect of motion direction, $F(1, 62) = 21.91$, $p < .001$. When motion direction was forward, participants moved the border significantly inward, toward the object. When motion was backward, participants moved the border significantly outward, away from the object. In other words, when motion was forward, participants got boundary restriction for that border, but when the motion was backward, participants got boundary extension for that border. The results also revealed that there was an interaction $F(1, 62) = 11.24$, $p = .001$. The interaction reflects that when motion was coherent, participants moved the approaching border closer to the object for the forward condition, but in the backward condition, participants moved the approaching border further away from the object. The results of 2 x 2 ANOVA suggest that the direction of motion had a clear but unexpected effect on participants' memory for the location of the border closest to the end of the object's motion path.

To assess if boundary extension occurred, I looked at the overall change in area for each condition. Results revealed that boundary extension did not occur in any of the four conditions: FC (M = -1.15, SD = 7.52), FI (M = -0.30, SD = 6.79), BC (M = -0.34, SD = 8.18), BI (M = -0.11, SD = 7.99).

Experiment 1b

After being informed that some participants may have been confused about the instructions in Experiment 1a, specifically, that they were supposed to pay attention to just the object's location instead of trying to remember the overall view of each scene, I decided to replicate Experiment 1a. The only difference between the two experiments was that Experiment 1b had slightly modified instructions. In Experiment 1b, the wording of the instructions was changed to make it clear that participants should try to remember the overall view of the scenes and not focus on the object's location.

Method

Participants. Participants were 63 undergraduates who signed up to participate in the experiment for one ELC credit. None of the participants in Experiment 1b participated in Experiment 1a.

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

Procedure and design. The procedure and design were the same as in Experiment 1a, with the exception that the instructions were changed to specify that participants were to pay attention to the overall view of each scene, rather than the object's location.

Results

I excluded trials from analysis on which participants made a DRP response. For the four conditions, the percentage of DRP trials was as follows: FC: 0.34%; FI: 0.51%; BC: 0.34%; BI: 0.68%. I excluded a participant's data from analysis if the mean change in area was 3 *SD*s or greater than the overall mean of all participants for at least two of the four conditions. Based on this criterion, four participants' data were excluded from all analyses.

As in the first experiment, I tested the hypothesis that there would be an effect of motion condition. I ran a one-way ANOVA to see if the means in the four conditions differed from one another. The results of the ANOVA showed that there was a significant effect of condition, $F(2.03, 117.59) = 8.94$, $p < .001$. Because Mauchly's test for sphericity was significant, I am reporting the Greenhouse-Geisser corrected degrees of freedom and *p-value*. To determine whether the differences between means were in the order I predicted, I conducted a set of repeated contrasts. These contrasts revealed that the mean for the FC conditions was significantly smaller than the mean for the BC condition, $F(1, 58) = 9.18$, $p = .004$. However, contrary to my prediction, the mean for the BC condition was significantly greater than the mean for the FI condition, $F(1, 58) = 10.53$, $p = .002$. Finally, the mean for the FI conditions was significantly smaller than the mean for the BI condition, $F(1, 58) = 12.99$, $p = .001$. Results showed the following order, from the border that was moved the farthest inward to the border that was moved the farthest outward: FI ($M = -0.26$, $SD = 4.27$), FC ($M = -0.07$, $SD = 3.70$), BI ($M = 1.90$, $SD = 3.70$), BC ($M = 1.83$, $SD = 4.25$).

Because the data did not support my hypothesis, I conducted a 2 x 2 (Motion direction [forward, backward] x Motion coherence [coherent, incoherent]) ANOVA to determine the effects of motion direction and coherence on memory for border position. The results revealed that there was no main effect for coherence $F(1, 58) = 0.04$, $p = .850$, but there was a main effect of motion direction $F(1, 58) = 13.53$, $p = .001$. There was no interaction between motion direction and coherence, $F(1, 58) = 0.24$, $p = .629$. The lack of interaction may have been the result of the instruction change. The results of the 2 x 2 ANOVA suggest that motion direction affected participant's memories for border position relative to the object, and coherence did not.

To assess if boundary extension occurred, I looked at the overall change in area for each condition. Results revealed that boundary extension occurred in all of the four conditions: FC ($M = 1.16$, $SD = 4.36$), FI ($M = 1.45$, $SD = 5.11$), BC ($M = 1.38$, $SD = 5.19$), BI($M = 1.49$, $SD = 5.36$). Again, the instruction change may have caused the different results in Experiment 1b, compared to the results of Experiment 1a.

Experiment 1c

The goal of Experiment 1c was to address potential issues from Experiment 1a and Experiment 1b. Because of the nature of the task, participants could have been adjusting the border closest to the object's ending position based on memory for the view or memory for the object's location. Because the data do not allow me to determine which of these possibilities may have been occurring, I chose to make this experiment more similar to a representational momentum experiment and changed the instructions to indicate that participants should try to remember the object's exact final location as well as the overall view to see if I would still get the same pattern of results.

Method

Participants. Participants were 64 undergraduates who signed up to participate in the experiment for one ELC credit. None of the participants in Experiment 1c participated in Experiment 1a or 1b.

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

Procedure and design. The procedure and design were the same as in Experiment 1a, with the exception that the instructions were changed to indicate that the participants should pay attention to the object's location in addition to trying to remember the overall view of each scene.

Results

I excluded trials from analysis on which participants made a DRP response. For the four conditions, the percentage of DRP trials was as follows: FC: 0.79%; FI: 1.27%; BC: 1.27%; BI: 0.63%. I excluded a participant's data from analysis if the mean change in area was 3 *SD*s or greater than the overall mean of all participants for at least two of the four conditions. Based on this criterion, one participant's data was excluded from all analyses.

To test the hypothesis that there would be an effect of motion condition, I ran a one-way ANOVA to see if the means in the four conditions differed from one another. The results of the ANOVA showed that motion condition affected memory for the position of the front border (i.e., the border that the object appears to be approaching) relative to the object, $F(1.06, 65.73) = 8.534$, $p = .004$. To determine whether the differences between means were in the order I predicted FC (Forward Coherent), BC (Backward Coherent), FI (Forward Incoherent), BI (Backward Incoherent), I conducted a set of repeated contrasts. These contrasts revealed that the mean for the FC conditions was significantly smaller than the mean for the BC condition, $F(1, 62) = 8.10$, $p = .006$. Contrary to my prediction, the mean for the BC condition was significantly greater than the mean for the FI condition, $F(1, 62) = 20.00$, $p < .001$. Finally, the mean for the FI conditions was significantly smaller than the mean for the BI condition, $F(1, 62) = 8.82$, $p = .003$. The results showed the following order, from the border that was moved the farthest inward to the border that was moved the farthest outward: FC (M= -4.21, SD=14.11), FI (M= -2.13, SD=7.99), BI (M=4.71, SD=10.74), BC (M=5.32, SD=13.59).

Because the data did not support my hypothesis, I conducted a 2 x 2 (Motion direction [forward, backward] x Motion coherence [coherent, incoherent]) ANOVA to determine the effects of motion direction and coherence on memory for border position. There was no main effect for coherence, $F(1, 62) = 3.92$, $p = .052$, but there was a main effect of motion direction, $F(1, 62) = 8.93$, $p = .004$. When motion direction was forward, participants moved the border significantly inward, toward the object. When motion was backward, participants moved the border significantly outward, away from the object. In other words, when motion was forward, participants got boundary restriction for that border, but when the motion was backward, participants got boundary extension for that border. Results also revealed that there was no interaction $F(1, 62) = 3.68$, $p = .060$. The results of 2 x 2 ANOVA revealed the same effect of motion that I found in Experiment 1a and an effect similar to what I found in Experiment 1b. The only difference was that in Experiment 1b, the change in border position for the forward-motion conditions was not significant.

To assess if boundary extension occurred, I looked at the overall change in area for each condition: FC (M = 0.97, SD = 5.51), FI (M = 1.94, SD = 5.77), BC (M = 1.21, SD =

5.26), BI(*M* = 1.82, *SD* = 6.59). I found significant boundary extension in the FI (*M* = 1.94, *SD* = 5.77) and BI (*M* = 1.82, *SD* = 6.59) conditions. However, I did not find boundary extension in the FC (*M* = 0.97, *SD* = 5.51) or the BC (*M* = 1.21, *SD* = 5.26) conditions.

Discussion

How does implied motion of an object affect a person's representations of the spatial expanse of scene views? In the initial investigation of this question, I tested participants' memories for the view of the border closest to the end of the object's motion path, and I asked whether object motion would affect that memory. This included a forward-motion condition, a backward-motion condition, and both incoherent versions of the forward and backward conditions. Across all three versions of my experiment, I found a fairly consistent pattern of results. Specifically, I found a significant effect of motion, but the effect of motion was not what I predicted. The results of the 2 x 2 ANOVA revealed that motion direction had an effect on memory, but the effect of motion coherence was not consistent.

The results of Experiment 1a showed an effect that was different from what I predicted, based on the results of the contrast test. The results revealed that there was an effect of motion condition, in which the four conditions fell in the following order from closest to the object, to furthest from the object: FC, FI, BI, BC. The direction of motion did have an effect on participants' memory for the border position relative to the object. In the forward-motion condition, participants remembered the border to be closer to the object's final position than it actually was. In the backward-motion condition, participants remembered the approaching border to be further outward from the object than it actually was. Even though the effect of motion coherence was not significant, there was a slight trend toward more memory distortion for the coherent conditions. I did not find significant boundary extension.

The results of Experiment 1b again showed an effect that was different from what I predicted, based on the results of the contrast test. The results revealed that there was an effect of motion condition in which the four conditions fell in the following order from closest to the object, to farthest from the object: FI, FC, BI, BC. The direction of motion did have an effect on participants' memory for the border position relative to the object. In the forward-motion condition, participants remembered the border to be closer to the object's final position than it actually was, although results were not significantly different from no change in position. In the backward-motion condition, participants remembered the approaching border to be farther away from the object than it actually was. The effect of motion coherence was not significant, which may have been because the mean changes in border position were much smaller than they were in Experiment 1a. However, significant boundary extension was found in all four conditions.

The results of Experiment 1c revealed that there was an effect of motion condition in which the four conditions fell in the following order from closest to the object, to farthest from the object: FI, FC, BI, BC. The direction of motion did have an effect on participants' memory for the border position relative to the object. In the forward-motion condition, participants remembered the border as closer to the object's final position than it actually was. In the backward-motion condition, participants remembered the approaching border as farther away from the object than it actually was. Even though the effect of motion coherence was not significant, there was a trend toward more memory distortion for the coherent conditions. Significant boundary extension was found in the FI and BI conditions.

Regardless of the change in instructions across all three experiments, participants moved the approaching border inward in the forward condition but moved the border outward in the backward condition. In other words, the forward condition always showed boundary restriction, and the backward condition always showed boundary extension. There was a nonsignificant trend of coherent motion strengthening the effect of motion direction in Experiments 1a and 1c. This suggests that coherence may have had some part to play in the overall scheme of things, although its effect was inconsistent.

Interpretation of Results

Overall, the results suggest that people appear to be influenced by conceptual understanding of what is going on or should be occurring (Courtney & Hubbard, 2008; Reed & Vinson, 1996). When an object appeared to be moving in a forward direction, participants seemed to anticipate the continuation of motion and remembered the border as being closer to the object. The results of Experiments 1a, 1b, and 1c, were not consistent with standard representational momentum research, such as Experiment 3 of Hubbard (1995). On the other hand, the results were consistent with the results of Reed and Vinson (1996), because the pattern of border adjustments was consistent with participants remembering the direction of motion being the direction the object was facing instead of the direction it actually moved. This may suggest that conceptual knowledge of how the objects moved more than general knowledge of the principles of physics was affecting participants' memories in the present experiment. According to this possibility, when participants moved the border farther inward in the forward conditions, they did so because of their conceptual understanding of the type of motion they were viewing. Likewise, in the backward condition, participants moved the border farther outward. These border adjustments are consistent with participants' conceptual knowledge of how these objects moved.

A common concern between the three different experiments was how participants were interpreting the instructions. In Experiment 1a, it came to my attention that some of the participants may have been confused about the instructions; specifically that they were supposed to pay attention to only the object's location instead of to the view. Because I was concerned that the participants may have been trying to remember the object's location, I decided to replicate Experiment 1a, with slightly modified instructions. In Experiment 1b, the wording was altered to make it clear to participants that they should attempt to remember the overall view of the scenes and not focus solely on the location of the object. In Experiment 1c, I instructed participants to remember both the object's final location and the location of the four borders and found the same effect of motion direction. The pattern of results in Experiment 1a was consistent with the other two experiments, which suggests that the wording in Experiment 1a may not have been an issue.

Integration with Previous Research

The results of the current set of experiments do not fit with DeLucia and Maldia (2006) or Munger et al. (2005), who examined the relationship between boundary extension and representational momentum. DeLucia and Maldia (2006) found greater boundary extension in the implied-motion condition than in the static-scene condition. It should be noted that in their implied-motion condition, there were differences between their static condition and their motion conditions. This could have had something to do with why participants experienced greater boundary extension in the implied-motion condition. Furthermore, if conceptual knowledge of motion had been affecting boundary extension, there would have been less boundary extension in their motion conditions than in the static condition. In other words, results of DeLucia and Maldia (2006) were not consistent with conceptual knowledge of motion affecting boundary extension, whereas the results of my experiment suggest that representational momentum, conceptual knowledge of objects' motion, or both, could affect boundary extension.

In Munger et al. (2005), similar differences between the implied-motion condition and the static condition were present. Munger et al. (2005) found that how readily participants extended the boundaries of a single view whether they experienced boundary extension, boundary restriction, or no directional distortion, had a large impact on how they responded to the approach conditions in a boundary-extension task in the implied-motion condition. Munger et al. (2005) found a main effect of motion when they looked at all of their participants. There was more boundary extension for the motion condition than for the static condition. Again, the effect of motion that they found was not consistent with the results of the present experiment or with representational momentum affecting boundary extension.

One issue to be taken into consideration is whether or not the different types of motion (i.e., implied self-motion, object motion) might have something to do with the different effects of motion, as well as potential conceptual effects with the stimuli of the present experiment. DeLucia and Maldia (2006) addressed simulated self-motion, which is distinctly different from perceived motion of an object traveling along a horizontal path. In other words, DeLucia and Maldia (2006) assessed implied self-motion using objects that would not be expected to move themselves, based on conceptual knowledge about the objects, whereas the current experiment assessed object motion, such as a person skating in a horizontal direction.

Whether or not the current set of experiments fits as a whole into the representational momentum literature, it certainly fits into the conceptual framework discussed by Reed and Vinson (1996). Reed and Vinson (1996) described representational momentum as the mind accounting for what it knows about the laws of the physical world, as well as what it knows about how specific objects move or do not move, in an attempt to make a prediction dealing with time. This account helps to make sense of the overall results of the current set of experiments, in which participants seemed to be making inferences about what they saw, or should have seen.

Limitations

There are several limitations of the current set of experiments. First of all, the instructions across the three experiments were slightly different from one another. My initial concern was that the differences in the wording of the instructions across the three experiments might interfere with what I was actually measuring. However, the results across all three experiments showed a similar pattern, so it seems unlikely that participants in the different experiments were adjusting the borders based on different information (i.e., memory for the view vs. memory for object location).

Another limitation to consider is the backgrounds used in the current experiment. The backgrounds depicted in DeLucia and Maldia (2006) and in almost every other representational momentum experiment except for Munger et al. (2005) were very simple. Objects were displayed on very simple backgrounds that were not actual photographs but were created by a computer. It is possible that the complexity of my backgrounds might have had an impact on the effect of motion. My rationale for this possibility is that for my stimuli, there was much more information available in the background of each of the scenes. In other words, the backgrounds in my experiment were much more similar to real-life scenes, compared to those used by DeLucia and Maldia (2006), which may have given participants too much visual information to pay attention to during the stimulus presentation. In other words, the views in my experiment contained full scenes similar to what a person would view in real life, whereas previous experiments have depicted simple objects on a nearly blank background. This could explain why the effect of motion direction would be consistent with participants not encoding the full motion sequence, but rather just the last position of the object, and then inferred its direction of motion from the direction the object was facing.

Another potential limitation is the fact that the stimuli did not consistently elicit overall boundary extension. The only exception was Experiment 1b, and even then the amount of boundary extension was very small. This limited my ability to see if there was an effect of motion on overall memory for spatial expanse. Boundary extension was found across all three experiments in the backward-motion conditions but only for the border that the object appeared to be approaching. The fact that overall boundary extension was not found in Experiment 1a and Experiment 1c limits my ability to draw conclusions about how object motion affects boundary extension for overall views of scenes, as opposed to boundary extension for part of the view.

Conclusions

Results of Experiments 1a, 1b, and 1c revealed that motion did have an effect on participants' memories of the scenes boundaries. While it is difficult to tease apart the effects of boundary extension and representational momentum in this context, some type of anticipatory prediction may have been occurring when participants were presented with scenes that depicted some type of motion. There appeared to be a strong effect of conceptual knowledge of how the objects in the scenes moved. This suggests that participants may have been incorporating knowledge about the motion occurring in the scene, as well as knowledge about how specific objects move into their memory of the view.

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Appendix A

From: IRB Administration

Date: 12/09/2013

RE: Notice of IRB Exemption

Study #: 14-0121

Study Title: Boundary-Extension and Perceived Motion

Exemption Category: (2) Anonymous Educational Tests; Surveys, Interviews or Observations This study involves minimal risk and meets the exemption category cited above. In accordance with 45 CFR 46.101(b) and University policy and procedures, the research activities described in the study materials are exempt from further IRB review.

Study Change: Proposed changes to the study require further IRB review when the change involves:

- an external funding source,
- the potential for a conflict of interest,
- a change in location of the research (i.e., country, school system, off site location)
- the contact information for the Principal Investigator,
- the addition of non-Appalachian State University faculty, staff, or students to the research team, or
- the basis for the determination of exemption. Standard Operating Procedure #9 cites examples of changes which affect the basis of the determination of exemption on page 3.

Investigator Responsibilities: All individuals engaged in research with human participants are responsible for compliance with University policies and procedures, and IRB determinations. The Principal Investigator (PI), or Faculty Advisor if the PI is a student, is ultimately responsible for ensuring the protection of research participants; conducting sound ethical research that complies with federal regulations, University policy and procedures; and maintaining study records. The PI should review the IRB's list of PI responsibilities.

To Close the Study: When research procedures with human participants are completed, please send the Request for Closure of IRB Review form to irb@appstate.edu.

If you have any questions, please contact the Research Protections Office at (828) 262-7981 (Julie) or (828) 262-2692 (Robin).

Appendix B

Consent to Participate in Research

Information to Consider About this Research

Quantifying Boundary Extension and Examining Scene Viewing Patterns

Principal Investigator: Sarah G. Hinnant
Department: Psychology
Contact Information: sh74810@appstate.edu; Dr. Chris Dickinson: 203 Smith-Wright Hall, (828) 262-2272, x415, dickinsonca@appstate.edu

What is the purpose of this research?

You are invited to take part in a research study about movement and memory. If you take part in this study you will be one of about 240 to do so. By doing this study, we hope to learn about how people perceive motion and remember every day scenes.

Why am I being invited to take part in this research?

You are being invited to participate because you a healthy volunteer at least 18 years old. If you volunteer to take part in this study, you will be one of about 240 people to do so.

What will I be asked to do?

The research procedures will be conducted at Smith-Wright Hall in room 216. You will need to come here 1 time during the study. Each of those visits will take about 30 minutes. The total amount of time you will be asked to volunteer for this study is 30 minutes over the next 1 day. If you agree to be part of the research study, you will be asked to view multiple series of photographs of natural scenes, with each series followed by a memory test for each picture in the series. Each picture will be shown for about 250 ms.

If you have any uncorrected vision problems, or attention deficits that might affect performance in this experiment, you must inform the experimenter that you may not be eligible to participate. You are not required to disclose the actual reason, however.

What are possible harms or discomforts that I might experience during the research?

To the best of our knowledge, the risk of harm for participating in this research study is no more than you would experience in everyday life.

What are possible benefits of this research?

There may be no personal benefit from your participation but the information gained by doing this research may help others in the future. This study should be beneficial by adding knowledge about the way in which people remember moving scenes, as a result of studying two types of common memory errors that people encounter in every-day life. In addition, your participation may contribute to overall knowledge about how people study and remember scenes.

Will I be paid for taking part in the research?

We will not pay you for the time you volunteer while being in this study. You will receive 1 Experiential Learning Credit (ELC) toward your General Psychology research participation requirement for today's experiment (if you are participating for credit in another class, you will receive 1 ELC for that class). The requirements and options for research participation have been outlined in the syllabus for your General Psychology class. Your course instructor can also provide you non-research alternatives to obtain ELCs.

How will you keep my private information confidential?

This study is anonymous. That means that no one, not even members of the research team, will know that the information you gave came from you. Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about the combined information. You will not be identified in any published or presented materials.

Whom can I contact if I have a question?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at sh74810@appsate.edu, or Dr. Chris Dickinson at 262-2272, x415. If you have questions about your rights as someone taking part in research, contact the Appalachian Institutional Review Board Administrator at 828-262-2130 (days), through email at irb@appstate.edu or at Appalachian State University, Office of Research and Sponsored Programs, IRB Administrator, Boone, NC 28608.

Do I have to participate?

Your participation in this research is completely voluntary. If you choose not to volunteer, there is no penalty or consequence. If you decide to take part in the study you can still decide at any time that you no longer want to participate. You will not lose any benefits or rights you would normally have if you do not participate in the study.

I have decided I want to take part in this research. What should I do now?

If you have read this form, had the opportunity to ask questions about the research and received satisfactory answers, and want to participate, then sign the consent form and keep a copy for your records.

By proceeding with the activities described above, you acknowledge that you have read and agreed to the descriptions and terms outlined in this consent form, and voluntarily agree to participate in this research.

Appendix C

List of Backgrounds with the Object that was Depicted in Motion

Background	Object
Courtyard with fountain	Man rollerblading
Desert road with mountain in background	Camel walking
Outdoor pool at night with house in background	Beach ball in the air
Grassy field with trees in the background	Horse galloping
A forest with snow on the ground	Deer running
An outdoor fountain with a house in the background	Boy riding a skateboard
Outdoor brick barbeque	Basketball in the air
Outdoor pool in the daytime	Bird flying
Outdoor deck railing	Butterfly flying
Living room	Man walking

Vita

Sarah Grace Hinnant was born in High Point, North Carolina, to Greg and Susan Hinnant. She graduated from Appalachian State University in 2011 with a Bachelor of Science degree in Psychology and a Bachelor of Science in Communication Studies. Immediately afterwards, she attended Appalachian State University where she was awarded a Master of Arts degree in General Experimental Psychology.