EXAMINING MEMORY FOR AREA AND DISTANCE:

UNTANGLING THE RELATIONSHIP BETWEEN MEMORY PSYCHOPHYSICS AND BOUNDARY EXTENSION.

by

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TABLE OF CONTENTS

Acknowledgments ... ii

List of Figures ... v

List of Tables ... vi

Introduction ... 1

Boundary Extension ... 1

Boundary Extension Methodologies ... 3

Boundary Extension Theory ... 6

Extension-Normalization Model ... 6

Perceptual Schema ... 7

Memory Psychophysics ... 10

Motivation 1 ... 14

Motivation 2 ... 18

Questions ... 20

Experiment 1 ... 20

Method ... 21

Results ... 23

Discussion ... 25

Experiment 2 ... 27

Method ... 28

Results ... 28

Discussion ... 29

Experiment 3 ... 30

Method ... 31

Results 33

Discussion 34

Experiment 4 35

Method 37

Results 40

Discussion 42

General Discussion 43

Answering Questions 43

Question One 43

Question Two 45

Question Three 47

Anticipatory Schema and Response Type 48

Limitations and Final Thoughts 51

References 55

Appendix A 59

Appendix B 61

Appendix C 64

Appendix D 67

Appendix E 76

Appendix F 78

LIST OF FIGURES

1. Sample materials from a boundary extension experiment using recall judgments.........2

2. Photographs of scenes used in Experiments 1-3..22

3. Example rating judgment scale used in Experiments 3 and 4 32

4. Photographs used in Experiment 4 38

5. The perceptual cycle 49

LIST OF TABLES

1. Means and standard deviations from stepping response used in Experiment 1............24

2. Means and standard deviations from stepping response used in Experiment 2............28

3. Means and standard deviations from verbal distance ratings used in Experiment 3 33

4. Means and standard deviations for height, width, and area from recall judgments used in Experiment 4...41

5. Means and standard deviations from recognition analysis in Experiment 4 42

Examining Memory for Area and Distance:

Untangling the Relationship between Memory Psychophysics and Boundary Extension

In everyday life, people interact with objects in their surrounding environment. Interaction with and navigation through the environment is influenced by a person's perception and memory of his or her location in space and by the perception and memory of the locations of objects. People are generally accurate in their perception and memory and, subsequently, accurate in the judgments that they make regarding spatial positions. However, there are numerous instances of inaccuracies in visual perception and memory. An instance of an inaccuracy or bias in memory for stimuli in a person's environment is often evident in spatial memory for scenes. More specifically, there seems to be an asymmetry in a person's spatial memory for a close-up view of an object such that the object is remembered as being smaller (taking up less visual area) than when the object was first perceived.

Boundary Extension

When observers view a picture of a scene, their memory for that scene often includes details that were not present in the picture, but that might have been present just outside the boundaries, this is an effect referred to as *boundary extension* (Intraub & Richardson, 1989, Intraub, 2004). As depicted in Figure 1, the remembered visual angle of objects within a scene that are viewed close-up (and that subsume a relatively large area of the picture space) are reproduced (in drawings) as being smaller than the remembered visual angle the objects subsume during perception. Boundary extension has been suggested to show that people remember seeing a greater expanse of a scene than was originally perceived (Intraub & Richardson, 1989) and to illustrate the anticipatory dynamic nature of mental representations (Intraub, 2002).

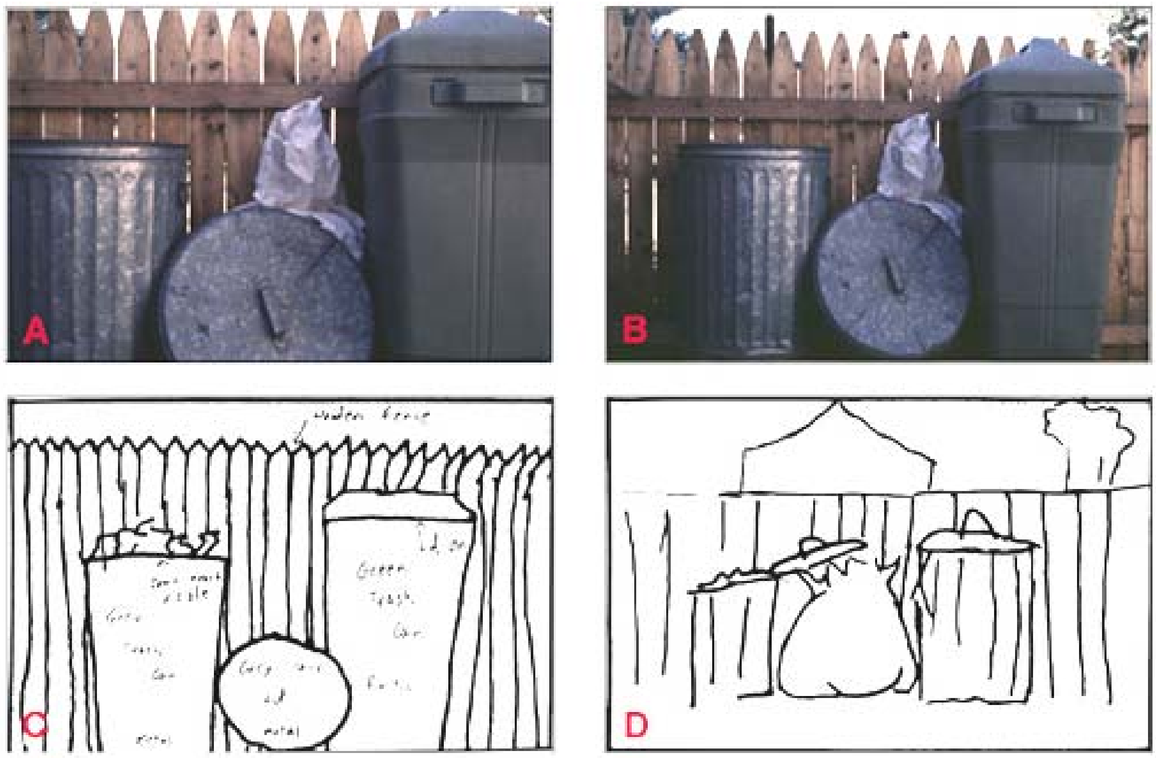

Figure 1. Participants remember an object in a scene taking up a smaller visual area than was shown in a photograph. When drawing panel A from memory participants tended to draw the main objects as smaller as shown in a representative example from participants drawings in panel C. When the main objects were completely shown as in panel B, participants still remember the objects as taking up a smaller visual area as shown in a representative example from participant's drawings in panel D (adapted from Intraub & Richardson, 1989).

The existence of boundary extension has implications for how perceptual information is encoded. Traditional information processing views characterize the encoding of information in data arrays. When an observer perceives stimuli in the environment, light strikes the photoreceptors and the stimuli are mapped onto specific locations on the observer's retina. Such retinal information can be conceived of as a data array or an internal (mental) representation of the external world. This data array transfers throughout the system from structure to structure (retina to the lateral geniculate nucleus to the visual cortex and so on). These representations are then stored and can be retrieved as a mental image. The traditional view within cognitive science was to treat mental representations as static matrices; for example, keeping the data arrays from retinotopic mapping consistent as they move through the nervous system. However, effects such as boundary extension have given reason to consider representations as being dynamic (for a comparison of dynamic and static representations, see Mitchell, 1998).

The description of representations as dynamic is due to the fact that the representation of a previously examined view changes as a function of time and as a function of the characteristics of a scene (Intraub, 2002). As a consequence of these dynamic representations, memories of views and objects within views are not static, and judgments based on memory of objects are often not accurate. Memories for close-up scenes are instead extrapolated outward, and this is thought reflect an anticipatory process within the observer which prepares the observer to interact with objects and parts of the scene that exist just beyond a current view (Intraub, 2002). Consistent with this, Intraub (2004) characterizes displacements found in boundary extension to reflect anticipatory projections of observers. In other words, boundary extension reflects observers having "remembered" a portion of space that was not present at the initial fixation, but expected to be seen perhaps with the next eye fixation.

Boundary Extension Methodologies

Experiments examining boundary extension use one of two basic methodologies to search for biases in memories: recognition or recall of stimuli (Intraub & Richardson, 1989). Experiments examining memory via recognition typically involve the successive presentation of several pictures in a slide show. The presentation of the pictures is immediately followed by a comparison task between the presentation of the previously perceived scenes and the observer's memory for those scenes. Recognition tasks that consist of the same pictures (or sometimes similar pictures with different views) as those that were initially shown have also been used as a test for boundary extension. Upon a subsequent view of pictures participants are instructed to judge if they think that the view they are now examining is the same as the one they first perceived.

Recognition judgments of subsequently shown pictures have most often been collected using a 5-point scale rating regarding camera position (distance). The 5-point scale gives participants the option of responding that a subsequent view of a scene is: much too far away (2), slightly farther away (1), same (0), slightly closer (-1), much too close (-2) in relation to their memory of the original view. In such experiments, participants tend to remember the camera as being closer to the stimulus than it was in the initial scene. This results in a negative score, and indicates an extension of boundaries (Intraub & Richardson, 1989). Recognition tasks have also used same/different probes in which participants tend to respond *same* to a picture that shows a more wide-angle view (thus reflecting a memory for a smaller object area, Intraub & Richardson, 1989). Using such recognition judgments, Intraub, Gottesman, Willey, and Zuk (1996) found that boundary extension is present after a one-second interval, and Hubbard (1996) found boundary extension occurring after retention intervals as short as 250 ms.

A recognition task typically immediately follows the completion of the recall task. The recall task most often involves participants drawing a previously viewed scene within a specified frame on an otherwise blank sheet of paper, and the scene to be drawn is named or described by a one-word description at the top of the paper. The relative area taken up by the main object in the participant's drawing is then compared to the relative area taken up by the object in the original picture. Typically, the area of an object that is drawn by participants in the recall task is smaller than the area of the object that was shown. A few variations of a recall task have been used to examine boundary extension. The recall task has also involved participants producing boundaries to match previously viewed scenes (it might be argued that the recall task is also a production task). In one such study, Nystrom (1992) presented participants with a photograph, and when the photograph was subsequently viewed, participants were asked to physically move boundaries to match their recollection of the first view. Nystrom (1992) found that participants extended boundaries for the subsequently presented photograph. However, in Nystrom's (1992) study, only one picture was used under this methodology and there were a small number of participants, thus the results were of questionable generalizability.

Intraub (2004) conducted an experiment using a recall task in which participants kneeled and moved boundaries of a small 3-D scene created on a floor. The scenes were perceived visually (that is, participants were able to examine the scene visually during first examination and a later judgment) or haptically (that is, participants were able to examine the scene haptically during first examination and a later boundary production period). Participants were allowed to move the boundaries of the scene; however, the objects in the scene were fixed to the floor. Intraub (2004) found that participants would extend the boundaries outward, creating a larger space in the scene than was first perceived. In another recall study, Gottesman and Intraub (2003) had participants view computer-printed photographs of objects and then instructed participants to reconstruct the previously viewed scenes from memory by placing objects that varied in size on a photograph of the background alone. Boundary size was kept constant, and participants chose smaller objects, which was also interpreted as a boundary extension effect.

Boundary Extension Theory

Some of the first photographs used in studying boundary extension included objects that were cropped or cut off (e.g. Figure 1, panel A), and so an initial hypothesis was that boundary extension simply involved completion of an incomplete figure (as might be the case in Figure 1, panel B). Although such amodal completion might be one possible contributing factor to boundary extension (e.g. Intraub, 2004), when stimuli include complete figures (e.g. Figure 1, panel B) objects are still remembered as being smaller (e.g. Figure 1, panel D). Therefore, it should be noted that an object in a scene need not be cut off for the object to be remembered as being smaller, as evident from full object views in recall tasks, and converging evidence provided by recognition methods. It seems that amodal object completion can then be ruled out as the sole explanation for the occurrence of boundary extension (Intraub & Richardson, 1989). The explanation most often cited for the occurrence of boundary extension is framed within the Extension-Normalization model.

Extension-Normalization Model

Intraub, Bender, and Mangels (1992) explain boundary extension in terms of a two-component Extension-Normalization model. The first component of the model, “extension”, involves a perceptual schema mechanism defined as a representation of space that contains the anticipated layout of the close-view or a truncated view of a scene. This perceptual schema mechanism gives an observer a representation of what might come into view with the next eye fixation, and facilitates a filling in of parts of the scene that might subsequently come into view (Intraub, 1992). Such an extension of the space in a scene is reflected by tests of memory via a recall or recognition task after relatively short delays (Intraub, et al. 1992). The second component of the model, “normalization”, reflects memories being closer to the average of a stimulus set after a certain period of time. Normalization is reflected by a regression in memory to the average of stimulus sets after a delay of several days in testing. That is, after a delay of several days of testing, memories for all objects in scenes seem to reflect the average area subsumed by the stimulus set. Thus, the regression to the average of the stimulus set acts as a function of time and is not immediately evident (Intraub et al. 1992).

Perceptual Schema

The extension portion of the Extension-Normalization model is further elaborated by the perceptual schema hypothesis, which posits that boundary extension is due to the activation of a scene schema that represents parts of the scene that are anticipated to come into view (Intraub, 1992; Intraub et al. 1992; Intraub & Richardson, 1989). The activation of this schema allows the viewer to fit the current view into a larger context. This schema is closely related to the idea of spatial representation proposed by Hochberg (1978), in which an abstract mental schema provides a context for the interpretation of partial views. For example, presentations in video displays often include fast shifts in camera view, but the observer easily integrates these discontinuous shifts as being a part of a continuous scene. The “extension” portion of the Extension-Normalization model is of particular interest, because the action of the perceptual schema mechanism of representation is implicated as a cause for the memory error seen in studies of boundary extension (Intraub, 1992).

Intraub (1997) proposed that the activation of a perceptual schema results in extrapolation beyond the borders of a current view. Along these lines, Intraub, Gottesman, and Bills (1998) predicted that boundary extension should occur only for pictures that activate a perceptual schema. Pictures that activate a perceptual schema are described as being "scenes", that is, pictures of naturalistic real world surfaces depicting a truncated view of a continuous world (Gottesman & Intraub, 2002). One implication of Intraub et al.'s (1998) prediction is that pictures of "non-scenes" (i.e. line-drawn objects on blank backgrounds) would not activate the perceptual schema, and so no representation of an anticipated part of the scene would be available, and thus no boundary extension should be evident in participant's responses. Consistent with this, Legault and Standing (1992) found boundary extension for photographs but not for line drawings of the same pictures, and Intraub et al. (1998) found that boundary extension occurred for scenes and that neither extension nor restriction occurred with non-scenes in the absence of any other instructions. However, participants that were shown non-scenes and instructed to imagine the view with rich detail (hypothesized to invoke similar conditions in viewing a scene) also showed boundary extension, and this suggested that the perception of scenes and imagination of scenes activate the same perceptual schema (Intraub et al., 1998).[1]

[1] In the study by Intraub et al. (1998) for the group that was imagining a scene the experimenter gave a description of the scene to be imagined during the 15 s intervals that the picture was being viewed whereas the non-scene group had no additional task during the 15 s intervals that they were encoding the pictures. Although the results of this experiment might reflect greater activation of the perceptual schema in the

Although boundary extension might result from the perceived or imaged presence of a scene context, an argument has also been made to attribute the compression of an object's remembered area in boundary extension to a displacement in depth (Hubbard, 1996). In Hubbard's (1996; Experiment 4) study, participants were shown stimuli consistent with non-scenes in which a solid black square was presented on a blank white background. Participants' memory for the square was tested using brief retention intervals (250 ms or 750 ms). For the shorter retention interval, participants remembered the square as being smaller, and this is geometrically consistent with the square being displaced away from the observer. The key difference in Hubbard's (1996) study from other recognition tasks that are typically used to study boundary extension might be that the retention intervals leading up to the recognition probes were very brief (< 1 second), whereas in previous research on boundary extension the retention intervals are on the scale of several minutes, as the recognition test typically follows the recall test. Although boundary extension has been found following test intervals as brief as 1 second by Intraub (2002), Intraub's experiment did not examine retention intervals shorter than a second and also did not examine 1 second retention intervals for non-scenes.

Hubbard's (1996) results are in direct contrast to a prediction based on Intraub's (2002) two-component Extension-Normalization model describing perceptual schema, in that pictures that do not consist of partial views (non-scenes) should not result in boundary extension. Hubbard (1996) offered the possibility that boundary extension is due to a displacement in depth of the stimuli being observed. Such a displacement in

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imagine condition by the creation of a scene from imagery, an alternative explanation is that attention was divided or diminished in the imagery condition because there were two tasks (description and viewing) rather than one, leading to greater boundary extension. Such a finding would be consistent with Courtney and Hubbard (2006), who found that divided attention increased the amount of boundary extension.

depth would result in a change in remembered distance from actual distance and this displacement would be away from the observer resulting in the smaller remembered object area. Intraub and Richardson (1989) recognized the possibility that boundary extension might reflect changes in remembered distance. However, Intraub (2002) and Gottesman and Intraub (2002) dismissed the possibility of boundary extension being due to a more general mechanism such as a change in remembered area or a displacement in depth.

Memory Psychophysics

In boundary extension experiments, the remembered size of or distance to an object are typically measured. Perception and memory for area and distance have also been examined using a variety of psychophysical methods. Psychophysical methods have been used for decades to examine relationships between stimulus intensity and perceived magnitude of stimuli (e.g. Stevens, 1975). In memory psychophysics, researchers have adapted such methods to examine relationships between stimulus intensity, perceived magnitude, and also memory magnitude. Such studies have consistently found that people generally perceive and remember areas of and distances to objects as being smaller than they actually are in the physical world (for a review of memory psychophysics, see Algom, 1992; Hubbard, 1994).

Studies using memory psychophysics have consistently shown that when perceived magnitude of visual area is compared with physical visual area for the same objects, a compressive power function emerges. That is, participants perceive the area of an object as being smaller (taking up less area) than it actually does (in physical space). Similarly when remembered visual area is compared with physical visual area, a compressive power function emerges, and this finding of smaller remembered object area is consistent with findings from studies on boundary extension. Typically, the memory function is more compressive than the perceived function for object area; that is, the represented visual area subsumed by an object is typically smaller in memory than in perception, and typically smaller in perception than the physical referent object (e.g. Kemp, 1988; Moyer, Bradley, Sorensen, Whiting, & Mansfield, 1978)[2].

Memory reflecting a smaller area for an object than is actually present in the physical stimulus (consistent with experiments examining boundary extension) has been reliably demonstrated in studies employing memory psychophysics. Although at first glance the memory psychophysics literature seems to be consistent with studies on boundary extension, upon further consideration, a puzzle emerges. The smaller visual angle of a remembered object in boundary extension (and often in memory psychophysics examining area) suggests the object is remembered as being more distant, and this is consistent with boundary extension. However, it seems that if there is any consistent bias in memory for distances as examined by memory psychophysics studies, it is that people actually remember objects being closer than they were upon first perception reflecting a larger remembered object size, which is inconsistent with boundary extension.

One example of distances to objects being remembered as closer up can be seen in Bradley and Vido (1984), who had two groups of participants make magnitude estimations of the distances of objects that were viewed from a mountaintop. The day after these initial distance judgments were made, participants were either instructed to

[2] The perceived area subsumed by an object is also smaller than the area that is actually shown in a stimulus in such experiments. However, perceptual judgments are typically more accurate than are memory judgments (Kerst, Howard, & Gugerty, 1987).

return to the mountaintop (perception group) or to simply imagine the objects in their mind's eye as those objects had appeared from the mountaintop and judge the distance to the various objects judged on the first day. Data from both groups showed that participants reported a shorter distance to the object, and that the participants in the imagery group remembered being closer to the objects than did participants in the perception group. That is, participants remembered the objects as closer than they actually were. In fact, this finding is quite common in literature examining memory psychophysics for distance (Hubbard, 1994), and seems inconsistent with findings that object area is generally remembered as being smaller than it actually is. A consistent finding in distance memory would be remembering an object as further away than it actually is, as a smaller object area would be indicative of an object being a further distance away.

Remembering objects to be closer than the objects were during previous perception also seems inconsistent with findings of smaller remembered area (as area should change as a function of distance). One possible explanation for this finding is that observations generally made in experiments examining remembered or perceived distance are of objects that take up a relatively small visual angle, (e.g. Bradley & Vido, 1984, had participants observing objects from a mountaintop), whereas the types of stimuli that usually bring about a smaller remembered area for an object are close-up views of an object that take up a relatively large visual angle (cf. Intraub, 2002). Along these lines, views of objects used in experiments on remembered or perceived area are similar to close-up views used in boundary extension, whereas objects in experiments on memory for distance are more similar to wide-angle views used in boundary extension.

People most often remember area of objects in wide-angle views accurately; however, when examining memory for distance sometimes they remember them as being closer than objects were when first perceived (e.g. Safer, Chistianson, Autry, & Osterlund, 1998), resulting in a boundary restriction (Intraub 2002). Such a boundary restriction effect is consistent with distant objects being remembered as closer as in Bradley and Vido (1984). However, studies examining distance memory have not explicitly tested close-up views of objects to see if distances to those objects are remembered, as being closer or further away than when first perceived.

Intraub and colleagues have continually dismissed the possibility that boundary extension is due to a change in remembered distance of an object in a scene (e.g. Gottesman & Intraub, 2002; Gottesman & Intraub, 2003; Intraub, 2002). In fact, Intraub et al. (1998) dismissed findings from memory psychophysics as relating to boundary extension because studies from memory psychophysics were not designed to test memory for boundaries. However, as previously indicated by Hubbard (1996), a simple black square presented in the context of a blank background or a "non-scene" will be remembered as smaller, consistent with findings in boundary extension. Indeed, the argument that boundary extension might be due to a displacement in depth is strengthened by the previously described verbal distance rating dependent measure typically used by Intraub (e.g., 2002) and colleagues in their recognition task. The recognition task typically used instructs participants to decide if a subsequently presented probe picture of a previously viewed scene is the same, too close (bigger), or too far away (smaller), and this measure clearly involves a verbal estimate of distance. Use of such a measure suggests that a dismissal of an explanation of boundary extension based on changes in distance memory might be premature.

The dismissal of a distance mechanism in boundary extension tends to rely on two main arguments (Intraub, 2002): First, remembering objects as varying in distance (e.g. closer up) could be maladaptive. Although Intraub (2002) has suggested that anticipating layout just outside of a current view is adaptive, the status of boundary extension as an evolutionary trait has not yet been established. However, it might be argued that remembering objects as being further away (as in boundary extension) does indeed have an adaptive value: Remembering objects as being further away would encourage one to move toward neutral or appealing objects whereas remembering objects as being closer than they actually are (as might be the case in studies of emotional pictures which yield a increased remembered area for an object, or boundary restriction, Mathews & Mackintosh, 2004; Safer, et al., 1998) would encourage one to move away from threatening or non-appealing objects. Second, in studies looking at boundary extension in 3-D environments, viewers did not step back from scenes, which would have indicated a displacement in depth. It is not clear if stepping back was a dependent variable of the studies or was simply an observation, as no data regarding stepping forward or backward from scenes was reported (Intraub, 2004).

Motivation 1: Resolving Findings From Boundary Extension and Memory Psychophysics

Motivation 1 for the studies conducted in this dissertation was to resolve conflicting findings from boundary extension and memory psychophysics. These conflicting findings are two-fold.

1) Studies on memory psychophysics for distance show that people remember being closer to objects, whereas studies for boundary extension show that people remember being further away from objects. However, it is possible that boundary extension reflects changes in remembered distance rather than changes in remembered area. It is also possible that effects of boundary extension do not translate to realistic 3-D displays of scenes. Therefore Experiments 1-3 were designed to examine if boundary extension reflects a displacement in depth (Experiments 1-2), and if effects consistent with boundary extension could be attained with truncated close-up views of 3-D scenes (Experiment 3).

2) Studies on memory psychophysics for area show that people remember an object's area as being smaller. Likewise, studies on boundary extension also show that people remember an object's area as being smaller, and thus studies on memory psychophysics and boundary extension seem consistent. However, few studies examining boundary extension have looked at memory for the entire scene including the boundaries; instead, most studies have kept boundary size constant and only looked at memory for the object(s) within the scene. One possibility that might invalidate recall judgments made in boundary extension experiments, yet still be consistent with experiments on memory psychophysics, is that memory for the entire scene (objects and boundaries) is smaller than the remembered size at first perception. One method to examine this possibility is to test memory for the boundaries of a scene rather than for the objects within the scene. Specifically, if memory for the boundaries of the scene is tested, then it is possible that the area of the objects within the scene, along with the boundaries surrounding that scene, will be remembered as smaller. This would be

consistent with findings of memory psychophysics but not boundary extension. Therefore, Experiment 4 was designed to examine if recall studies on boundary extension reflect changes in remembered area of an object or an extension of boundaries. Furthermore, if object area is held constant in a recall judgment and memory for the area that the boundaries take up is measured, and boundary extension is found, this would lend further support to the idea that boundary extension results because people remember having seen a greater expanse than was actually present, and that boundary extension does not reflect a displacement in depth.

Although there does not yet seem to be strong evidence for a change in remembered distance being responsible for boundary extension, there does seem to be some evidence that a person's perceived distance to close-up views shows a bias similar to what might be occurring in boundary extension. Evidence for a bias in distance perception comes from an experiment by Kraft and Green (1989), in which they showed participants photographs of scenes with different focal lengths ranging from very wide-angle views to close-up views. Participants were asked to judge the distance to the object depicted in the picture as if they were the person taking the photograph. For more wide-angle views, participants perceived that the object was closer than it actually was, and this is consistent with prior research on distance memory. However, as the view got progressively closer, participants perceived that they were farther away from the object than the camera actually was. This judgment was made while the photograph was still being shown; therefore, it was a test of perception and not memory. However, this study does show a possible relationship of close-up views and a displacement in depth away from the observer. As previously stated, studies examining remembered area in memory psychophysics often show an even smaller remembered area for objects than is found for perceived area.

A change in memory for the distance to an object that is consistent with the perceived displacement away from an observer found by Kraft and Green (1989) would have implications for boundary extension. In fact, the reason that one might see a smaller object area represented in memory in studies on boundary extension might involve a displacement in depth away from the observer. Furthermore, the dependent measure often used in recognition tests of boundary extension asks participants to make a verbal estimate of distance of their current view of a scene, compared to their initial view of a scene.

It is not clear why arguments of “the view is farther away” and “I saw more of the scene” should be competing or mutually exclusive explanations of boundary extension. It seems that the two views might be necessarily complimentary, as a displacement in depth or an object being remembered as further away would allow for a more expansive view of a scene. However, it might also be possible that boundary extension reflects a change in memory for area and not for distance. The purpose of this study is to determine whether results such as those found in studies on boundary extension involve a displacement in depth, and if so, perhaps an additional component should be added to the extension component of the Extension-Normalization model. It might be the case that results found in experiments on boundary extension are due to a more general mechanism (a displacement in depth) rather than or in addition to an extension of boundaries per se. However, it is also possible that people respond differently for memory regarding area and distance, and that boundary extension reflects the former rather than the latter.

Motivation 2: Validating Anticipatory Processes

Boundary Extension in 3-D Scenes and Ecological Validity

Intraub (2004) found boundary extension for haptic and visual examinations of 3-D scenes, and before the 3-D studies were published, Intraub (2001) referred to those studies as "normal viewing conditions in the three-dimensional (3-D) world" (p.678). In Intraub's (2004) experiments examining memory for 3-D scenes, objects were placed on the floor or on a tabletop and partial views of the floor or the tabletop were presented by using either a 3" tall wooden frame (in the haptic condition) or by surrounding the objects with black cloth (in the visual condition) to create a window around the objects. Participants reconstructed the scenes in the same modality in which they first observed the scenes by recreating the window that was surrounding the objects. Intraub found significant effects of boundary extension for both haptic and visual observers. Intraub also found that visual exploration of 3-D scenes led to greater boundary extension than did haptic exploration of the same scenes.

Bertamini, Jones, Spooner, and Hecht (2005) also found boundary extension for 3-D stimuli. In Bertamini et al's. (2005) examination of memory for area of objects, boundary extension was found using stereograms, and the authors concluded that boundary extension is not a mere picture perception phenomenon because boundary extension was present for these 3-D stimuli. However, it should be noted that although stereograms provide more depth information than do 2-D photographs of scenes, they are also lacking in certain binocular information about depth such as motion parallax. Results of Intraub (2004) and of Bertamini et al. (2005) might lend support to the idea that mental representation includes anticipatory projections about future views and that boundary extension might reflect internalization of spatial continuity, a proposed regularity of our environment (Intraub, 2001).

In fact, Intraub (2004) concluded that these studies proved that boundary extension is not limited to picture memory and that it might be a fundamental component of spatial cognition. However, the ecological validity of studies such as Intraub's (2004) study is not clear. For example, the participant's field of vision for the object was occluded far away from the participant as the objects were covered up as opposed to an occlusion of the participant's view. Occluding the area surrounding the object instead of the field of vision might be somewhat unnatural, especially when one compares truncated views of scenes to what might be available to the perceiver during a single-eye fixation. A more natural occlusion of vision corresponding to a limited view of a scene, as might be occurring in a single eye fixation, would occlude the vision of the observer nearer to the retina. Furthermore, such scenes might be best characterized as a more ecologically valid 3-D version of a partial view rather than "normal viewing conditions in the three-dimensional world" as they were described by Intraub (2001). Although previous studies on boundary extension and 3-D scenes are encouraging, their results do not provide conclusive evidence that such processes are adaptive or ecologically valid, and so theories derived from such experiments should not yet be treated as such. Therefore, an additional motivation behind Experiments 1-3 was to attempt to find effects consistent with boundary extension for 3-D stimuli that people viewed while standing, and that were located in the picture plane in front of them instead of below them (as on a table).

Questions

Based on the arguments given in Motivations 1 and 2, three main questions arose from previous studies examining memory for area and distance in boundary extension and memory psychophysics. Question 1: Is boundary extension reflective of a displacement in depth or a change in the remembered expansiveness of a scene? Experiments 1-3 (and to a degree Experiment 4) address Question 1. Question 2: Are theories derived from research on boundary extension applicable to ecologically valid 3-D stimuli? Experiments 1-3 address Question 2. Finally, Question 3: Are results from previous studies examining recall and boundary extension due to changes in remembered area or remembered expansiveness? Experiment 4 addresses Question 3.

Experiment 1

The purpose of Experiment 1 was to examine the argument against attributing boundary extension to a displacement in depth and to examine spatial memory for a partial view of a 3-D scene. The argument against attributing boundary extension to a displacement in depth relies on the observation of Intraub (2002, 2004) that participants did not step back from a 3-D scene. However, participants could have used reaching distance as an explicit cue for measuring their distance to the object being judged. Therefore the purpose of Experiment 1 is to determine if memory for distance is distorted for close-up views of objects in a real world setting, thus further supporting the ecological validity of previous findings (Intraub, 2004), and to determine if participants allowed to step backward or forward will in fact do so, and by their movements indicate a judgment that differs from the initial viewpoint. If participants presented with a 3-D scene step back from the scene upon a subsequent presentation of the scene, this would be consistent with a displacement in depth, and would also challenge the criticism that boundary extension should not be attributed to a remembered displacement in depth. However, if participants step forward into the scene upon a subsequent presentation of the scene, this would be consistent with results from studies on memory psychophysics, and would lend evidence to the idea that boundary extension results from a change in remembered area rather than a change in remembered distance, and that the two might be separable.

Method

Participants. Fifty-nine undergraduates (twenty-eight in the 90 cm condition and thirty-one in the 45 cm condition) naïve to the hypothesis were recruited from the participant pool in the Department of Psychology at Texas Christian University and received partial course credit in return for participating.

Materials. Each participant wore a set of goggles during the experiment, and vision was occluded with tape with the exception of a 25 mm X 17 mm viewing window for each eye in the front of the goggles. Participants viewed four scenes (see Figure 2): North (a computer monitor on a cart), East (a large stuffed animal on a desk), South (a set of books on a bookshelf), and West (a pine cone and a candle on a bookshelf). Scenes were located in various locations in the Dynamics Laboratory at Texas Christian University. The North and South scenes were located at opposite ends of a hallway and the distance between the scenes measured approximately 10 m. The East and West Scenes were located against the wall of a hallway and against the wall of an adjoining room and the distance between the scenes was approximately 4 m. The axis of the East and West scenes was approximately 2 meters from the North Scene. A Black & Decker

Auto Tape with measurements for cm was used for taking measurements of participant judgments.

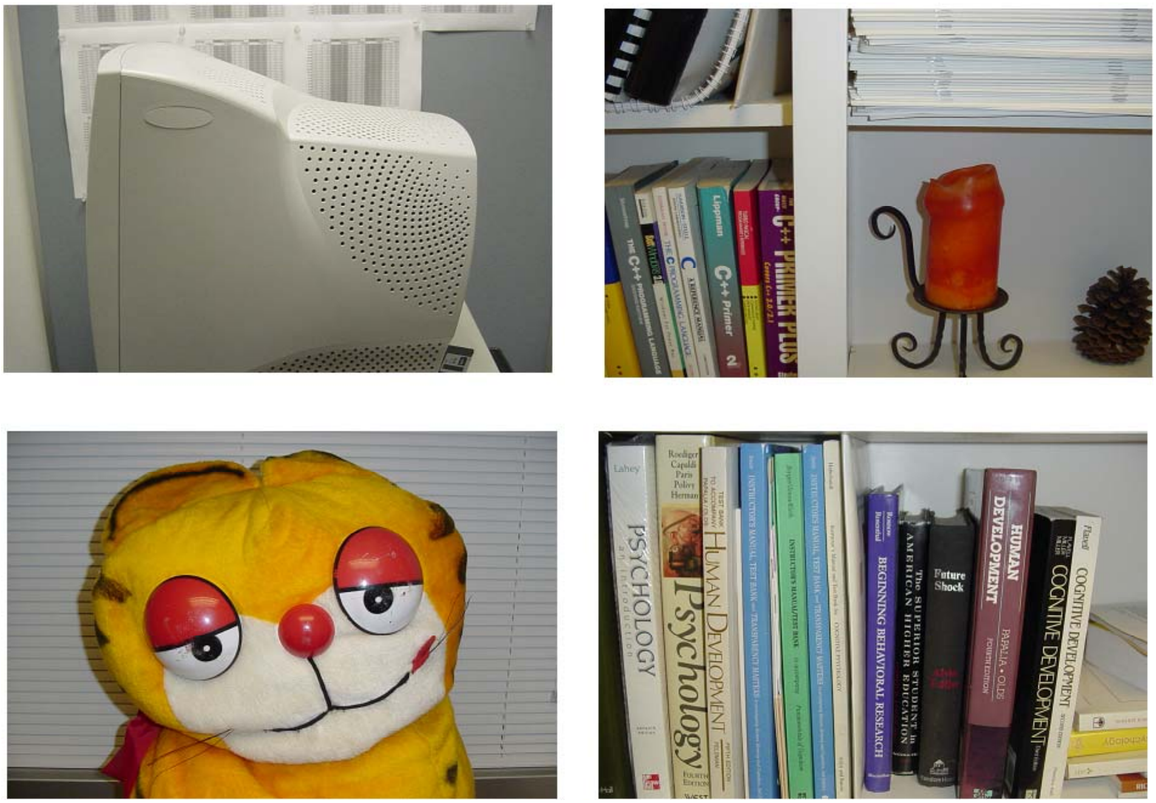

Figure 2. Photographs of scenes used in Experiments 1-3 depicting a computer monitor with a bulletin board in the background; a series of shelves with paper, books, a candle, and a pine cone; a stuffed animal with window blinds in the background; and a shelf of books. Views depicted in this figure are at 45 cm from the main object(s) in the scene.

Procedure. Participants were randomly assigned to one of two groups (90 cm or 45 cm from the front of the focal object(s)). Participants read and completed informed consent (Appendix A) and were given instructions (Appendix B) and were then brought to a central location in the laboratory. All participants viewed 4 scenes in a different random order. These scenes were viewed through a set of goggles that had a 25 mm X 17 mm (width X height) viewing window for each eye, the same 3:2 ratio typically used in boundary extension experiments. At the beginning of each trial, a cardboard flap on the window of the goggles occluded the participant's views. The participant was led to a predetermined position in front of the object to be observed. Positions from the objects were marked with tape on the floor and the front of the toe of the participant's foot was lined up on the tape. The experimenter then removed the cardboard flap and asked the participant to look straight ahead at the object, and to try to remember the characteristics of the scene they observed in great detail.

After viewing the scene for 15 seconds (a time typically used in recognition studies examining boundary extension), the experimenter lowered the cardboard flap, once again occluding vision, and led the participant to the next scene. After viewing all 4 scenes, the participant was led back to the scenes in the order in which they were presented. At each scene, the participant was positioned at the same distance at which he or she had initially viewed the scene. The experimenter then raised the occluding flap and the participant was instructed to adjust his or her position by moving forward or backward only (not sideways), to indicate the original position from which he or she first viewed the scene. After the participant made his or her judgment by stepping forward or backward, the judged position was measured in reference to the original starting position. At the conclusion of the session, the participant was debriefed and the rationale of the experiment was explained.

Results

Means and standard deviations for each scene are reported in Table 1. Data were analyzed using the mean produced position across participants for each object in cm: If a participants underestimated the distance to the object, then a positive number was assigned to his or her adjusted position; if a participant overestimated the distance to the object, then a negative number was assigned to his or her adjusted position. Thus, a mean positive score would indicate a result consistent with memory psychophysics in which participants generally remember being closer to the object, whereas a mean negative score would indicate a result consistent with boundary extension in which participants generally remember being further away from the object. These scores were

Table 1: Means (in cm) and standard deviations for each scene (North, South, East, and West) in Experiment 1.

Distance (N) and Data Type	North	South	East	West
45 cm (N=31)				
Mean	10.5*	5.7*	9.9*	5.5*
SD	12.1	12.3	15.3	9.7
90 cm (N=28)				
Mean	10.0*	3.8*	9.4*	9.6*
SD	15.7	13.8	17.8	14.4

Note. An asterisk indicates a significant mean difference from zero via t-test ($p < .05$).

compared against 0 via a t-test where a significant positive score indicates underestimation of the distance to the target and a significant negative score indicates overestimation of the distance to the target. When data were collapsed across scenes, participants remembered being closer to the scene than they actually were at initial viewing $t(58) = 5.9$, $p < .001$. Significant displacements were also found in for each scene: north $t(58) = 5.7$, $p < .001$, south $t(58) = 2.8$, $p < .01$, east $t(58) = 4.5$, $p < .001$, west $t(58) = 4.7$, $p < .001$. Additionally, a one-way analysis of variance (ANOVA) was performed on distance (90 cm and 45 cm). There was no significant effect of viewing distance $F(1, 57) = .01$, $MS\ E = 112.4$, $p < .919$.

Discussion

Experiment 1 was designed to find out if a truncated view of a close-up 3-D scene resulted in participants stepping back, which would have been consistent with boundary extension and indicated that boundary extension is most likely due to a displacement in depth rather than to a change in remembered area. However, participants in all scenes remembered being closer to the object than they were when they first viewed the scene regardless of distance to the object. This result is consistent with previous studies examining memory for distance in 3-D scenes in memory psychophysics (e.g. Algom, 1992), but not with previous studies of close-up views of 3-D scenes and boundary extension (Intraub, 2004). The stepping forward of participants seems to indicate that they remembered the area being larger than it was when they first viewed the scene, and this appears to be inconsistent with studies of memory for area (but not distance) in memory psychophysics and boundary extension which implies that objects are remembered as being further away.

Several factors might have contributed to participants' judgments and resulted in participants stepping forward rather than backward. One possibility is that participants stepped forward rather than backward because they remembered distances to objects differently than they remembered areas for objects, and although these two dimensions seem that they should result in consistent memories, perhaps they are separable in participants' memories. This is consistent with the idea that boundary extension does not result from a displacement in depth, but rather results from a change in remembered area in which the boundaries of a scene are extrapolated outward and the area for an object is remembered as being smaller. A second possibility is that the scenes used would not typically exhibit boundary extension. However, a subsequent study that examined boundary extension for photographs of the scenes used in Experiment 1 showed that participants do exhibit boundary extension for 2-D pictorial representations of the objects that take up approximately the same visual angle and have the same boundary sizes, $t(22) = -3.45$, $p < .01$. A third possibility is based on the previously described function of misremembering distances being adaptive. This notion would predict that a participant in an aroused state would feel threatened and therefore remember an object as being closer, and this would in turn encourage a person to move away from that object. It is quite possible that participants were in a heightened state of arousal during the experiment given that they were led around an unfamiliar environment with no visual input (flap down on goggles) and they viewed previously unknown scenes through a small opening.

Finally, it is possible that the representations of the scenes did not activate the perceptual schema because the scenes were relatively rich in detail. Courtney and Hubbard (2006) found that when participant's attention was divided (which would lead to less encoding of a scene), then the activity of the perceptual schema (described in the extension component of the extension-normalization model) was higher and boundary extension became more pronounced. Therefore, it might be the case that a relatively richer 3-D scene (as compared to a 2-D scene) would decrease activity of the perceptual schema as there would be fewer gaps to fill in as compared to a 2-D scene of the same stimuli. Along these lines, a reduction in peripheral information might increase activation of a perceptual schema. Although experiments on boundary extension have not found that too much peripheral information results in remembering the scene as being too close (exemplifying boundary restriction), and 2-D scenes of the stimuli in Experiment 1 yielded boundary extension, it has been found that tight close-ups most often lead to the greatest amount of boundary extension (Intraub et al., 1992). Therefore, it could follow that reducing the available visual field while viewing a scene might lead to an effect consistent with boundary extension (stepping back) rather than an effect consistent with previous research on memory psychophysics (stepping forward).

Experiment 2

Boundary extension is strongest for tight close-ups in which little background surrounds the object(s) being observed, and declines as more of the scene is made available (Intraub et al., 1992). The purpose of Experiment 2 was to examine the possibility that smaller binocular windows might be necessary for a displacement in depth to be backward. A smaller window would allow less peripheral information for the participant, perhaps resulting in greater activation of the perceptual schema, and thus result in a displacement backward because a component of close-up views is that very little of the periphery is available to the participant. Therefore, participants in Experiment 2 used binocular windows that were approximately 46% smaller in area than the windows that were used in Experiment 1. It is possible that reducing the available visual field would cause an effect consistent with boundary extension.

Method

Participants. Thirty-two undergraduates naïve to the hypothesis were recruited from the participant pool in the Department of Psychology at Texas Christian University and received partial course credit in return for participating. None of the participants in Experiment 2 had participated in the previous experiment.

Materials. Materials were identical to Experiment 1 with the exception that the window in the center of the goggles was reduced to 18.75 mm X 12.5 mm for each eye.

Procedure. The procedure for Experiment 2 was identical to that of Experiment 1, with the exception that all participants viewed scenes from 45 cm.

Results

Means and standard deviations for each scene are reported in Table 2. Data were analyzed as in Experiment 1. As in Experiment 1, when data were collapsed across scene, participants remembered being closer to the scene than they actually were at first viewing $t(31)=1.91$, $p < .06$, and this effect was marginally significant. Only one of the

Table 2: Means (in cm) and standard deviations for each scene (North, South, East, and West) in Experiment 2 (distance of 45 cm, N=32).

Data Type	North	South	East	West
Mean	2.6	8.1*	2.8	3.1
SD	19.9	17.0	13.6	13.6

Note. An asterisk indicates a significant mean difference from zero via t-test (p < .05).

four scenes reached significance (south): north $t(31) = .75$, $p < .461$, south $t(31) = 2.7$ $p < .01$, east $t(31) = 1.14$, $p < .261$, west $t(31) = 1.3$, $p < .207$. However, the main effect was marginally significant, and an ANOVA comparing the results from the 45 cm viewing distance judgments of Experiment 1 to the distance judgments made in Experiment 2 was not significant, $F(1, 61) = 1.68$, $MSE = 128.00$, $p < .199$.

Discussion

Experiment 2 examined the possibility that stepping forward in Experiment 1 was a result of the expansiveness of the scenes. More specifically, the possibility that stepping forward occurred due to the presence of a large background was examined. It is possible that the windows that participants viewed scenes through in Experiment 1 were too large to represent a truncated view of a 3-D scene. As in Experiment 1, observers stepped forward, that is, scenes were remembered as being closer. However, the results of Experiment 2 seem to be weaker than those of Experiment 1, as only one of the four scenes reached significance and the t-test for means across scenes was marginally significant. To further examine the possibility that a more truncated view such as that used in Experiment 2 significantly effected observers judgments, a one-way ANOVA comparing results from the 45 cm viewing distance in Experiment 1 with the results from Experiment 2 was performed. The effect of effect of experiment (i.e. of window size) was not significant, and shrinking the window for viewing the close-up scene still did not result in a displacement in depth backward, as a distance explanation of boundary extension might have predicted.

Although stepping did not show an effect on memory consistent with research on boundary extension, the previously described rating system used in recognition experiments for boundary extension used a distance description to assess memory. However, such a rating system has not previously been used to uncover differences in distance for 3-D scenes. One possibility is that Experiments 1 and 2 failed to find effects consistent with boundary extension because boundary extension does not reflect a displacement in depth. Although the rating system typically used in experiments examining boundary extension for 2-D photographs explicitly asked participants to make judgments about distance of the view depicted in a probe photograph, it is possible that participants draw on memory for area (i.e. the remembered visual angle) rather than on memory for distances when making such a judgment because they do not typically have to interact (in terms of distance, e.g., stepping forward or backward) with the stimuli being judged.

Experiment 3

Intraub (2004) suggests boundary extension reflects changes in remembered expansiveness rather than changes in remembered distance. One possible reason that an effect consistent with memory psychophysics rather than an effect consistent with boundary extension was found in Experiment 1 is that the dependent measure of stepping is an explicit measure of distance rather than a verbal rating measure of distance such as that used in boundary extension experiments. It is possible that verbal ratings previously used in boundary extension experiments might tap memory for area rather than memory for distance (even though distance is mentioned in the verbal judgments). Studies on memory for close-up views have successfully found that participants remember a photograph of a scene as being closer up (exhibiting boundary extension) compared to the same photograph showing the same view only once (Courtney & Hubbard, 2006).

Therefore, the purpose of Experiment 3 was to examine memory for close-up views of 3-D scenes with a ratings task that has previously been shown to be successful in attaining effects of boundary extension in 2-D scenes by having participants make distance ratings of a subsequent (same) view as compared to the first time they viewed the scene. It is possible that when views are occluded for 3-D scenes that distance ratings will correspond with memory psychophysics studies (and Experiments 1 and 2) and objects will be remembered as closer up. However, it is also possible that using the same ratings task that is used in experiments on boundary extension will result in an effect of boundary extension or a no change in memory. The prediction for an effect of boundary extension follows that boundary extension was found for the same scenes represented in photographs using ratings judgments. The prediction for no change in memory to be evident comes from the finding that wide-angle views or views with a lot of information fail to activate the perceptual schema resulting in neither boundary extension or boundary restriction (Intraub & Berkowits, 1996).

Method.

Participants. Twenty-eight undergraduates naïve to the hypothesis were recruited from the participant pool in the Department of Psychology at Texas Christian University and received partial course credit in return for participating. None of the participants in Experiment 3 had participated in previous experiments.

Materials. Materials were identical to those used in Experiment 1 with two exceptions: Participants only viewed scenes from the 45 cm distance, and participants were shown a 2-D example of ratings judgments with corresponding photographs (Figure 3).

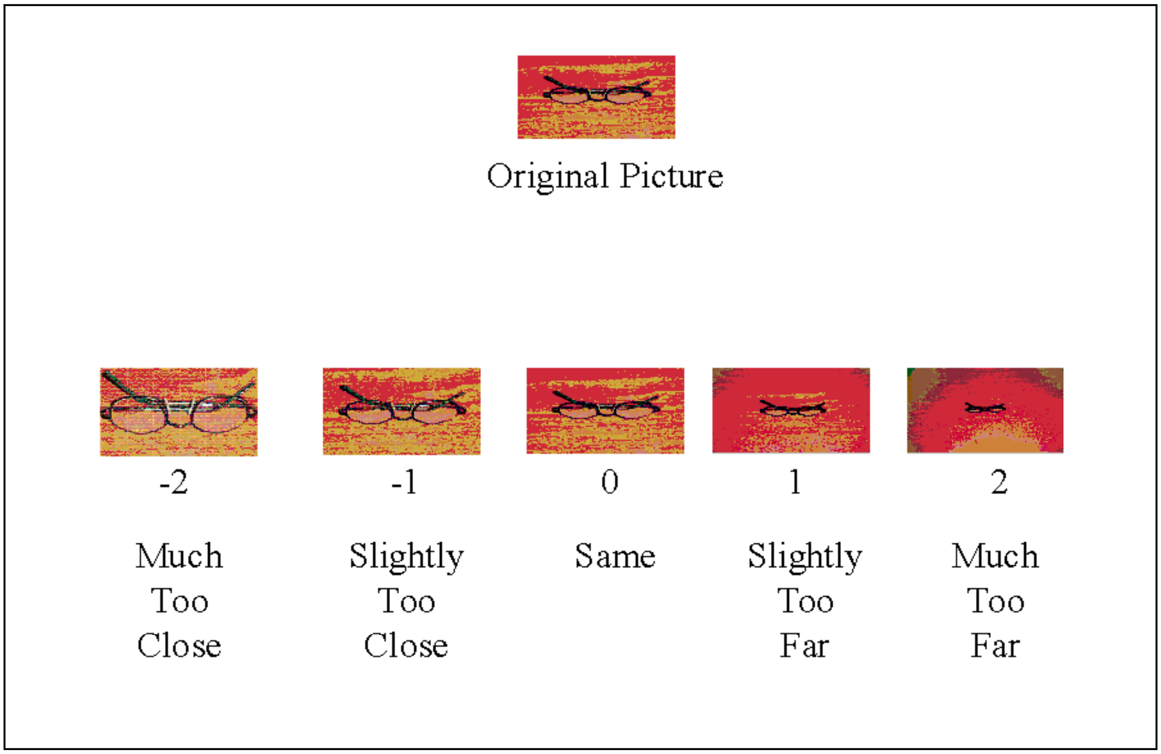

Figure 3. Figure 3 shows an example ratings judgment scale given to participants in Experiments 3 and 4 regarding distance ratings for a subsequently presented view of the original picture. A pair of glasses on a desk is shown in the original picture, and a series of different views of the glasses are shown below in the ratings scale. The view of glasses corresponds to a negative rating when a subsequent view is perceived as being closer in comparison to memory of the original picture and a positive rating when a subsequent view is perceived as being further away in comparison to memory of the original picture.

Procedure. The procedure used in Experiment 3 was identical to that used in Experiment 1 with the following exceptions (see Appendix A for informed consent and Appendix C for instructions used in Experiment 3): All participants sequentially viewed a set of 4 objects from a distance of 45 cm. After viewing all 4 scenes, participants were led back to each of the 4 scenes in the order that the scenes were initially viewed, and then positioned at the same distance of the initial viewing. They then made a rating of each scene on a 5-point scale as to whether their view of each scene was exactly the same or slightly different than the one they saw during the first presentation of that scene (-2 =

"much too close", -1 = "slightly too close", 0 = "same", +1 = "slightly too far", +2 = "much too far"), and this scale was modeled on those used by Intraub and colleagues. Participants were presented with a laminated copy of Figure 3 to aid their understanding. The rating procedure was repeated for the scenes in the order of initial viewing. At the conclusion of the session, participants were debriefed, and the rationale of the experiment was explained.

Results

Means and standard deviations for each scene are reported in Table 3. Data were analyzed using the mean distance rating across participants for each object. These scores were compared against 0 via a t-test where a significant positive t-test indicates overestimation of the distance to the target and a significant negative number indicates underestimation of the distance to the target. Participants showed no significant differences for ratings for the scenes when data were collapsed across scene $t(27) = 1.02$, $p < .318$, and none of the four scenes reached significance: north $t(27) = 0.00$, $p < 1.00$, south $t(27) = .420$, $p < .678$, east $t(27) = 1.03$, $p < .312$, west $t(27) = .682$, $p < .501$.

Table 3: Mean ratings and standard deviations for each scene (North, South, East, and West) in Experiment 3 (distance of 45 cm, N=28).

Data Type	North	South	East	West
Mean	0.0	0.1	0.2	0.1
SD	1.0	0.9	1.1	0.8

Discussion

Experiment 3 examined distance ratings using the same visual angle for the goggles and the same views from the 45 cm distance condition of Experiment 1. Such a distance rating has been successful in attaining boundary extension for 2-D scenes (e.g. Courtney & Hubbard, 2006); however, no effect of rating was found for any of the 3-D scenes presented in Experiment 3. One potentially important distinction between the results found in Experiments 1 and 2 and the results found in Experiment 3 is that a displacement in depth toward the stimuli was found in Experiments 1 and 2 but was not found in Experiment 3. Finding no boundary restriction in Experiment 3 suggests the lack of backward displacement in Experiments 1 and 2 was not due to participants being in an aroused state or feeling threatened (and therefore remembering an object as being closer due to the fact that they were led around an unfamiliar environment with no visual input [flap down on goggles]).

The results of Experiment 3 are consistent with the idea that the ratings judgment of distance tested memory for area, because recognition tests examining boundary extension do not yield boundary restriction (consistent with remembering being closer to an object as in Experiments 1 and 2). It seems that rating distance provides a different result than does actually stepping forward or backward toward or away from the object(s) in the scene. If verbal ratings judgments tap memory for area rather than memory for distance, then the results of Experiment 3 also lend support to the idea that boundary extension is not due to a displacement in depth.

This leaves the question of why boundary extension did not occur for any of the scenes in Experiment 3. However, it is puzzling that boundary extension was found for photographs of scenes used in Experiment 3, and this might speak to the issue of the ecological validity of boundary extension and spatial continuity. According to the perceptual schema hypothesis in which boundary extension is often framed, a primary function of perceptual schemata is to “fill in the gaps” in perception (e.g., see Hochberg, 1978, Intraub, 2002). It might be possible that the rich viewing conditions of a 3-D scene would not result in activation of a perceptual schema, as with more detail in a 3-D scene there would be fewer gaps to fill and subsequently less activation of the perceptual schema. It seems that the perceptual schema hypothesis might be further supported, as this hypothesis predicts that the perceptual schema is not highly activated and boundary extension does not occur for scenes in which much information regarding the scene is available as in wide-angle views (Intraub & Berkowits, 1996). Such a relationship between reduced schema activity and decreased boundary extension is further supported by data showing that when the perceptual schema is more highly activated, more boundary extension is found (Courtney & Hubbard, 2006). Regardless, the memory psychophysics consistent effects of Experiments 1 and 2 and the lack of boundary extension consistent effects of Experiment 3 (see Intraub & Berkowits, 1996) support the idea that boundary extension is not due to a displacement in depth.

Experiment 4

Experiment 4 further examined the possibility that distance information is not explicitly used in tests of remembered area, and examined if boundaries are in fact extrapolated outward or if boundary extension instead reflects changes in remembered area of an object. Along these lines, Experiment 4 investigated whether a recall test of boundaries in a 2-D setting would lead to boundary extension. Previous research on memory psychophysics for area (e.g. Algom, 1992) has consistently shown that objects are remembered as smaller than they actually are (i.e. subsuming a smaller visual angle than the visual angle subsumed during perception). Consistent with this finding, results from previous studies examining boundary extension in 2-D settings have suggested that an object is remembered as subsuming a slightly smaller visual angle, as compared to when it was first perceived.

However, previous studies examining recall for scenes and boundary extension for 2-D scenes have most often kept the boundaries constant (e.g. Intraub & Richardson, 1989) and asked participants to draw objects in the boundaries of a blank rectangle. Even studies using methodologies such as cutouts of objects have varied object size and kept boundary size consistent (Gottesman & Intraub, 2003). This might not reflect boundary extension, but instead reflect object reduction and a change in remembered distance for a 2-D object rather than an outward extrapolation of the boundaries. This is based on the fact that size and distance are closely related in real world perception, and a smaller remembered object would seem to reflect a change in remembered distance or area (or both). Do results of recall experiments that find boundary extension reflect a displacement in memory for the target per se, or is the smaller remembered visual angle a consequence of extending the boundaries? In other words, does boundary extension result from a distortion in memory for the boundaries of the scene, or from a distortion in memory for the object?

As noted earlier, Intraub (2002) suggests boundaries of the scene are extended and additional information is incorporated into the memory of the scene. In this case, the remembered smaller size is a consequence of the incorporation of this additional information because the original scene and rectangles in which participants drew their memory of scenes often had the same relative perimeter size. It could be argued that if boundary extension really resulted from an extension of the boundaries, and perimeter size was free to vary, the object should not be remembered as subsuming a smaller visual angle, but the boundaries of the perimeter of the scene would be increased. Alternatively, if results found in experiments on boundary extension resulted from an object area being remembered as smaller (consistent with memory psychophysics studies examining object area), then the entire scene, including the borders surrounding the object might be remembered as being smaller than they were when first perceived.

Method.

Participants. Thirty-four undergraduates naïve to the hypothesis were recruited from the participant pool in the Department of Psychology at Texas Christian University and received partial course credit in return for participating. None of the participants had participated in previous experiments.

Materials. Pictures were displayed in a classroom setting using a IBM laptop computer connected to a ceiling mounted computer video projector (NEC Model NT 1050), and were projected on a screen measuring 82” x 32”. Scene stimuli consisted of 4 pictures previously found to exhibit boundary extension in tests of recognition and recall (Courtney & Hubbard, 2006), and each picture consisted of a single central figural object that subsumed approximately 80% of the area of the picture (see Figure 4). The central object in each picture was a close-up view of a lamp, a basketball, a horse, or a cup, and the aspect ratio of each picture (horizontal: vertical) was 3:2. Pictures were taken with a Sony Cyber-shot 2.0 mega-pixel digital still camera (Model DSC-P51).

Figure 4. Scenes used in Experiment 4 depicting a lamp on a desk, a basketball on the floor, a horse running in a field, and a cup with a chalkboard in the background.

Test booklets consisted of nine pages (see Appendix D). Page 1 was an otherwise blank page that advised observers to wait for further instructions. Pages 2-5 each contained cutouts of each of the four objects (one object per page) and the objects were in the same order as they were previously presented, each page was blank except for the cut out of each object. Page 6 was an otherwise blank page that advised observers to wait for further instructions. Page 7 contained four rating scales with the name of each picture located above each scale, and one scale for each picture. Each rating scale was a five point scale (-2 = "much too close", -1 = "slightly too close", 0 = "same", +1 = "slightly too far", +2 = "much too far"), and this scale was modeled on those used by Intraub and colleagues. Page 8 was an otherwise blank page that advised observers to wait for further instructions. Page 9 was a brief post-experiment questionnaire which asked observers what they thought the purpose of the experiment was, if they had a phobia or other strong association to any of the pictured objects, what strategy they had used, and if they had ever participated in a similar study.

Procedure. Participants sat near the center of each of the first three rows directly in front of the screen on which the pictures were projected (see Appendix E for informed consent and Appendix F for instructions used in Experiment 4). Participants were told to pay attention to each picture and to remember the main object and the background including layout, size and location of everything in the picture space. The pictures were presented sequentially; each picture was visible for 15 seconds, and there was no pause between successive pictures.   Immediately following the presentation of the last picture, observers completed a recall task. Instructions for the recall task closely mirrored methodology used in previous studies on boundary extension (Intraub & Richardson, 1989). Participants were told to complete the scene for the cutout object and to draw the boundaries that surrounded the object using as much detail as possible. Immediately following the recall task, observers completed a recognition task in which they saw the same scenes again. The test slides were then presented in the same order and duration as they had been at the beginning of the experiment. Observers rated each picture on a 5-point scale signifying camera distance. Finally, observers filled out the post-experimental questionnaire.

Results

Means and standard deviations of each condition are reported in Table 4 (recall) and Table 5 (recognition).

Recall. Height and width measurements for the background scene drawn for each cut out were measured in cm and multiplied to calculate area. The height, width, and area in the drawings were then compared, via t-test, to the measurements of the height, width, and area that the boundaries would have taken up relative to object size on the pages that participants drew on. Participants' responses exhibited boundary extension in all cases. Remembered height collapsed across objects was significantly larger compared to actual height for the drawings, $t(33) = 8.59$, $p < .001$, and each drawing height was significantly larger compared to actual height for the pictures of the lamp, $t(33) = 7.15$, $p < .001$, basketball, $t(33) = 7.32$, $p < .001$, horse, $t(33) = 10.16$, $p < .001$, and cup, $t(33) = 6.10$, $p < .001$. Remembered width collapsed across objects was significantly larger compared to actual width for the drawings, $t(33) = 5.76$, $p < .001$, and each drawing width was significantly bigger compared to actual width for the pictures of the lamp, $t(33) = 3.97$, $p < .001$, basketball, $t(33) = 5.31$, $p < .001$, horse, $t(33) = 7.98$, $p < .001$, and cup, $t(33) = 4.18$, $p < .001$. Also, remembered area collapsed across objects was significantly larger compared to actual area for the drawings, $t(33) = 6.71$, $p < .001$, and each drawing for area was significantly bigger compared to actual area for the pictures of the lamp, $t(33) = 5.27$, $p < .001$, basketball, $t(33) = 6.06$, $p < .001$, horse, $t(33) = 8.09$, $p < .001$, and cup, $t(33) = 5.63$, $p < .001$.

Table 4. Means (in cm) and standard deviations for recall judgments made on each scene (Lamp, Basketball, Horse, and Cup) in Experiment 4 (N=34).

Measure and Data Type	Lamp	Basketball	Horse	Cup
Height				
Mean	15.3*	15.9*	16.8*	15.5*
SD	4.3	4.7	3.9	5.3
Width				
Mean	19.4*	20.5*	21.9*	19.9*
SD	6.5	6.0	5.1	6.8
Area				
Mean	319.5*	353.1*	385.7*	339.7*
SD	187.5	195.5	170.0	196.6

Note. An asterisk indicates a significant mean difference from zero via t-test ($p < .05$).

Recognition. Recognition scores were recorded and analyzed to ensure that the pictures yielded boundary extension after a different type of recall task was given. To determine boundary extension for the recognition task a t-test was performed on ratings of the pictures. The mean rating (M = -.50) across objects was significantly different from zero, $t(33) = -6.63$, $p < .001$. Each picture showed a significant effect of boundary extension, lamp, $t(33) = 5.27$, $p < .001$, basketball, $t(33) = 6.06$, $p < .001$, horse, $t(33) = 8.09$, $p < .001$, and cup, $t(33) = 5.63$, $p < .001$.

Table 5. Mean ratings and standard deviations for recognition judgments made on each scene (Lamp, Basketball, Horse, and Cup) in Experiment 4 (N=34).

Data Type	Lamp	Basketball	Horse	Cup
Mean	-.38*	-.38*	-.94*	-.29*
SD	.55	.65	.69	.80

Note. An asterisk indicates a significant mean difference from zero via t-test ($p < .05$).

Discussion

Experiment 4 was designed to determine if findings from previous studies using recall to examine boundary extension were due to an object being remembered as smaller or due to an outward extrapolation of boundaries reflecting additional elements of a scene being present in memory. Results from Experiment 4 are consistent with explanations for results from previous experiments examining boundary extension, as boundaries were extended in a recall judgment. Consistent with recall scores from Experiment 4, distance ratings of participants resulted in significant effects of boundary extension for the set of pictures.

A possible reason for previous experiments examining boundary extension finding a smaller remembered area for recall drawings of pictures was that boundary size was kept constant. Therefore, the recall task in Experiment 4 kept object size constant and allowed for recall of boundaries. When object size was kept constant, instead of boundaries being remembered as smaller (consistent with smaller remembered area seen in memory psychophysics), the area of remembered boundaries were extended. The findings from Experiment 4 are consistent with the idea that boundary extension is due to an extension of the boundaries rather than to the object being remembered as being a smaller size or as displaced in depth away from the observer.

General Discussion

The four experiments described here were an effort to (a) find if results such as those found in boundary extension and elsewhere are due to changes in remembered distances of objects, (b) apply theories drawn from boundary extension to ecologically rich stimuli, and (c) resolve inconsistencies between research on boundary extension and memory psychophysics. The data from the four experiments address the questions raised earlier, and provide answers to these questions.

Answering Questions:

Question One: Is Boundary Extension Reflective of a Displacement in Depth or a Change in the Remembered Expansiveness of a Scene?

Previous research on boundary extension and memory psychophysics has shown that people generally remember an object's visual area as being smaller than when that object was first perceived. Specifically, in boundary extension, memory for a scene tends to include an area outside of the boundaries of the actual scene, and this reflects a smaller remembered area for a particular object in a scene. This result has been attributed to a perceptual schema allowing an observer to remember seeing more of the scene (e.g. Intraub, 2002). Hubbard (1996) offered the possibility that boundary extension results from a displacement in depth of the stimuli being observed which would result in a change in remembered distance from actual distance. This claim is further supported by the fact that recognition experiments using remembered depth as a dependent measure (e.g. Courtney & Hubbard, 2006). Intraub and Richardson (1989) recognized the possibility that boundary extension might reflect changes in remembered distance; however, Intraub (2002) and Gottesman and Intraub (2002) dismissed the possibility of boundary extension being a displacement in depth.

Experiments 1 and 2 were designed to look for displacements in depth by a consideration of the remembered distances to objects. In Experiment 1, truncated close-up views of 4 scenes were presented to participants. Upon seeing the views again from the same distance, participants remembered being closer up at first perception than they actually were. Such a result is consistent with previous findings regarding distance and memory psychophysics, but is not consistent with previous findings regarding boundary extension (or area and memory psychophysics). It was hypothesized that perhaps if the size of the viewing windows were reduced, then a different effect would be found; however, the use of a reduced viewing window in Experiment 2 did not significantly reduce the magnitude of the effect from that observed in Experiment 1. In Experiments 1 and 2, no effects of boundary extension were found, which suggests that a close-up object is remembered as being smaller due to the extension of boundaries and not because of a displacement in depth away from the observer.

In Experiment 3, participants viewed the same four scenes as in Experiments 1 and 2, but instead of stepping forward or backward, participants rated whether the same view of a scene appeared closer or further away. This rating method had previously revealed either no effect only for wide-angle views, or boundary extension for close-up views (Courtney & Hubbard, 2006; Intraub & Berkowitz, 1996) including for photographs of scenes presented in Experiments 1-3. No effect of boundary extension or restriction was found. The lack of boundary extension in Experiment 3 is inconsistent with a separate study in which boundary extension was attained for the scenes used in Experiment 3 when participants viewed pictures of the scenes rather than the actual 3-D scenes. Such an inconsistency might be of further research interest if one is to determine the ecological validity of boundary extension, and whether or not such effects occur in normal 3-D viewing conditions.

What is the answer to the question “is boundary extension reflective of a displacement in depth or a change in the remembered expansiveness of a scene?” It is possible that the rating judgments used in Experiment 3 and the stepping judgments used in Experiments 1 and 2 draw on memory for area and distance, respectively, which is consistent with previous memory psychophysics research (e.g. reviewed in Algom, 1992). Furthermore, Experiment 4 showed that boundaries are in fact extended outward, thus indicating that previous studies on recall judgments for boundary extension finding smaller remembered areas for objects (which is consistent with a displacement in depth) are most likely due to changes in remembered expansiveness of a scene rather than a change in remembered area of or distance to an object. Experiments 1-4 are consistent with the idea that boundary extension is indicative of a more expansive view being remembered rather than a displacement in depth (Intraub, 2002).

Question Two: Are theories derived from research in boundary extension is applicable to ecologically valid 3-D stimuli?

Given that an additional goal of the studies reported here was to examine the role of memory for distance and area in boundary extension, the methodology for this dissertation was, to a degree, inspired by Neisser’s (1976) outlook on the future of cognitive psychology. In 1976 Neisser offered a warning that if cognitive psychology commits itself too thoroughly to a model of methodology that relies on using computer-generated stimuli for examining questions, then any explanations based on those data would eventually lack in ecological validity. The studies using 3-D scenes have not ultimately disproved any theories that were developed based on digitally or computer-generated stimuli (or based on people wearing vision-occluding goggles while walking about interacting with the environment), but the methodology used here has perhaps added another piece to the puzzle of scene perception and made an effort to understand how cognition might occur in a more natural environment.

Although there seems to be some evidence that boundary extension results from a displacement in depth based on 2-D recognition probe judgments (Hubbard 1996), ratings of remembered distance for 2-D pictures (Intraub & Richardson, 1989), and recall of 3-D objects located in a window on a floor or tabletop, boundary extension was not found for 3-D scenes in Experiment 3. This is particularly surprising because boundary extension was found for 2-D pictures of the scenes used in Experiment 3 that were taken from the same distance and used the same boundary measurements (see Figure 2). It is possible that viewing conditions in previous studies examining boundary extension with 3-D stimuli might have limited use of distance cues such as accommodation. It seemed that if boundary extension was an anticipatory process that functioned in the 3-D world, then such displacements in depth should be found for truncated close-up views of 3-D scene; however, no such displacements were evident.

It is possible that the views of these objects used by Intraub (2004) might not have as strongly tapped 3-D vision cues (e.g. motion, stereopsis, accommodation, convergence, binocular disparity, etc.) of the scenes as did Experiments 1-3 reported here and that increasing such cues reduce or eliminate effects of boundary extension. However, there is also evidence that increasing depth information does not necessarily reduce the effect of boundary extension (Bertamini et al., 2005). Furthermore, it possible that displacements such as those typically found in studies on boundary extension are limited to picture memory. However, such a claim makes an assumption that previous studies examining boundary extension for 3-D scenes draw on pictorial memory and scenes used in the current study do not draw on pictorial memory. What is the answer to the question "are theories derived from research in boundary extension is applicable to ecologically valid 3-D stimuli?" It is possible that anticipating spatial layout applies to 3-D scenes, but these effects were not observed with the methodology reported here.

Question Three: Are Results From Previous Studies Examining Recall and Boundary Extension Due to Changes in Remembered Area or Remembered Expansiveness?

Experiment 4 was designed to examine the conflict between previous recall studies on boundary extension and previous studies examining memory for area in memory psychophysics, and to determine if recall studies examining boundary extension reflect a smaller remembered area (or further remembered distance) or an extension of boundaries. Boundary extension was found for recognition judgments, but more importantly, when object size was held constant and participants represented their recall judgments by drawing boundaries around these objects, the boundaries were larger than those present in the originally perceived photograph. What is the answer to the question "are results from previous studies examining recall and boundary extension due to changes in remembered area or remembered expansiveness?" Recall for pictures in this instance displayed an extension of boundaries rather than a change in remembered area of the main object(s) and further supports the claim that boundary extension reflects participants remembering seeing more of a scene (expansiveness) rather than a remembering a change in remembered area or a displacement in depth.

Anticipatory Schema and Response Type

Another possible reason that participants remembered being closer up to the stimuli in Experiment 1 (which used the same stimulus parameters except for response type) relative to with Experiment 3 has to do with differences between verbal responses (used in Experiment 3) and motor responses (used in Experiment 1). Milner and Goodale (1995) have discussed the possibility of the existence of separate pathways for identification and action. These separate pathways might be available to observation via different response modes (e.g. identification pathways from verbal responses and action pathways from motor responses). Perhaps when one is anticipating judging distances with motor responses a different schema and/or action plan is used than when one is anticipating judging area with verbal responses. Such a speculation might be consistent with proposed function of anticipatory schema in general.

Neisser (1976) describes anticipatory schemata as cognitive structures that prepare a perceiver to accept certain kinds of information and control the activity of looking. These anticipatory schemata are framed in a perceptual cycle by Neisser (see Figure 5) in which the observer actively explores his or her environment, and these explorations are directed by anticipatory schemata (consisting of plans for action and readiness for certain types of information). The observer perceives the outcomes of the explorations, remembered salient events, and the original schemata are further modified. Thus modified, the schema subsequently directs further exploration and becomes ready for more information. This dynamic model operates as a function of time, allowing for changes to occur in perception and memory and allowing observers to adapt to their environment.

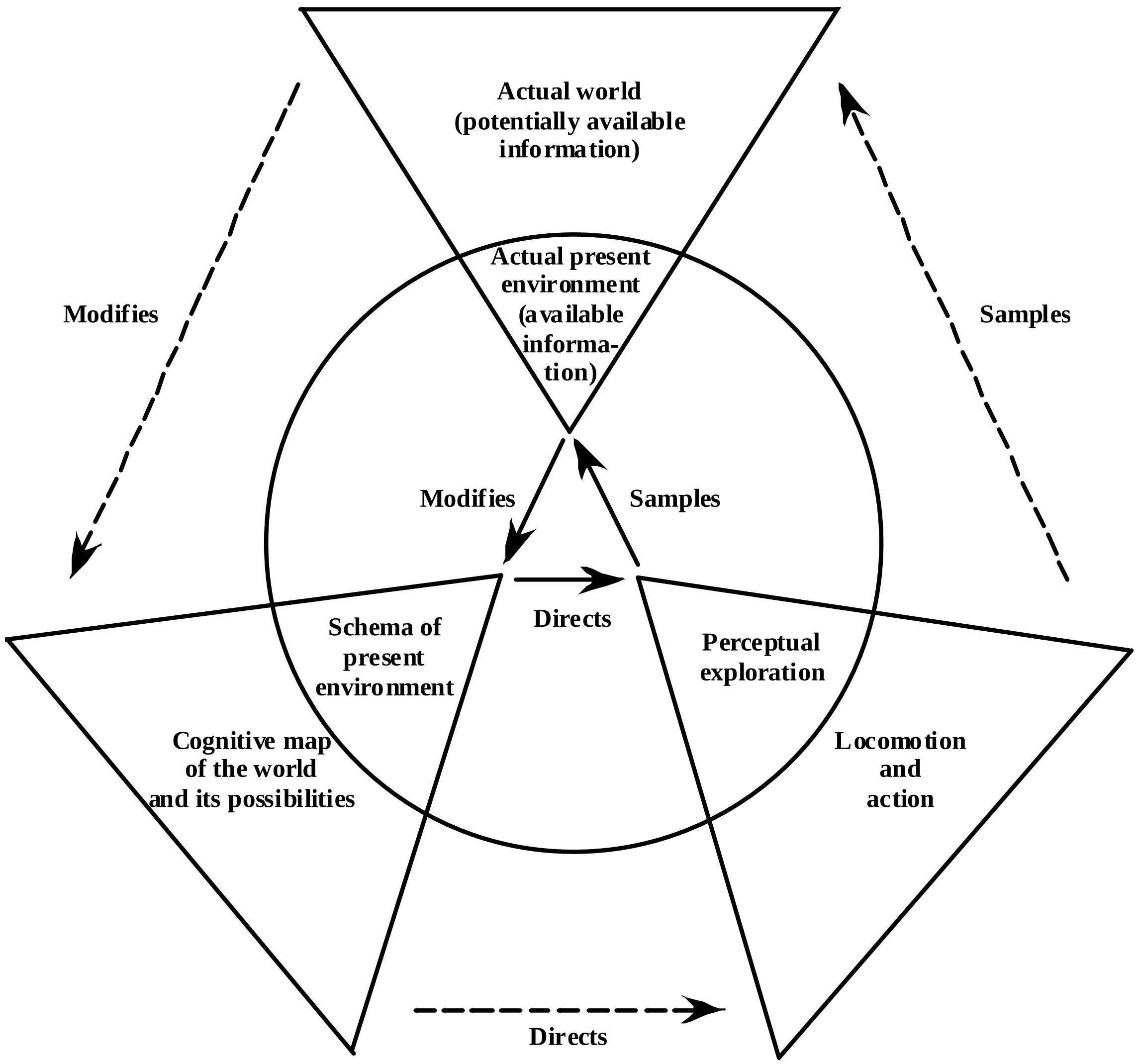

Figure 5. The perceptual cycle, adapted from Neisser (1976). This version of Neisser's perceptual cycle shows cyclic processes embedded within one another within the conceptual framework of cognitive maps.

It is possible that separate schemata for area and distance exist, or perhaps these schemata activate different perceptual expectancies and explorations. This is analogous to the idea that successive stages or levels of processing seem to exist. However, Neisser (1976) proposes that such relationships are embedded rather than strictly successive. For example, a schema might be activated for the room that you are reading this paper in and the paper itself. The ideas of paper and the room exist together, and one includes the other within it and this relationship is not easily separable. However, if you are asked about the room or about the paper you will give different responses based on which part of the embedded cognitive map schema is activated. Analogously it is possible that a schema that draws primarily on previous interactions with distances would encourage an interaction on an axis in which an observer approaches or recedes from an object (a z-axis in 3-D space), and a schema that draws primarily on previous interactions with areas would encourage an interaction on an axis in which an observer is orthogonal to the axis of distance (an x-axis or y-axis in 3-D space).

Even though schemata for area and for distance might each be embedded within the other, the relationship between perceptual exploration and response could still be influenced by response type. Such a possibility is reflected by the differences in spatial memory that are attained when different response methodologies or modalities are used to examine dynamic representation. There does seem to be evidence that distance and area are treated differently by the perceptual/memorial system, and this possibility is supported by Marr’s (1982) view that depth could be represented explicitly (perhaps even from area). Accordingly, it seems evident that boundary extension is most likely due to an expansion of the boundaries instead of a displacement in depth. Additionally, it might be possible that a motor action schema was created during the experiment as participants moved from scene to scene which lead to a forward bias with the motor judgment of Experiment 1 but not with the verbal judgment of Experiment 3.

Regardless, Neisser's (1976) model allows for the existence of schemata for area and depth within a flexible framework that allows for learning. Such frameworks are also quite valuable in explaining why people exposed to different environments perceive and remember the world uniquely. For example, people who have never observed stimuli over great distances seem to have problems with correctly identifying both distances and object sizes. Turnbull (1961) observed a group of Pygmies who were not accustomed to views of great distance. During these observations Turnbull noted that a specific member of the tribe (Kenge) believed that a group of buffalo seen at a great distance were in fact insects seen at a closer distance. Likewise, others have observed that some observers not accustomed to viewing 2-D pictures have trouble identifying objects and seeing pictorial depth (e.g. Deregowski, 1980). If anticipation of depth or area is an adaptive process, such a process will necessarily depend on both the context of the observer and that observer's previous experience in that context. Effects such as boundary extension (and anticipatory processes more generally) might be evidence of such adaptive constructs; however, the appropriate contexts might be needed to observe such effects.

Limitations and Final Thoughts

It is interesting that no boundary extension consistent effect was observed in the distance ratings in Experiment 3. It is possible that a more sensitive measure would be needed to find effects of boundary extension in such a 3-D environment. A precedent for needing such additional sensitivity for more ecologically valid stimuli can be found from research on a related anticipatory phenomenon representational momentum, an effect in which an object portraying motion is remembered as being further along in the path of motion than it actually was when it disappeared (for review see, Hubbard, 2005). If representational momentum is examined using very artificial stimuli (a black square moving against a blank white background) participants will most often (incorrectly) judge true same probe positions as being further along the path of motion. However, in a study examining representational momentum with very rich stimuli, a video display of many moving objects in a scene are presented and true same probe positions are accurately remembered (see Thornton & Hayes, 2004).

Along these lines, it is possible that presenting participants with the same view is sufficient for finding effects of boundary extension when participants are observing photographs (e.g., Courtney & Hubbard, 2006), but not in more ecologically valid scenes such as those used in Experiments 1-3. It might be possible that when a view is very rich, effects such as boundary extension are still present, but are harder to examine due to the added biases and variables that are present. Nevertheless, future studies using similar methodologies should use a number of probe positions. However, the researcher would either have to treat probe position as a between subject variable or conduct a series of studies specifically examining exposure to different views of the same scene. Such control would need to be implemented due to the fact that learning effects (e.g. previous experience with multiple views of the same scene) on boundary extension have not been well examined. It is possible that pre-exposure to such scenes would change anticipatory schemata for those scenes and subsequent memories and interactions regarding different views of such scenes.

Some of the greatest potential limitations in studies on vision are created when experiments are conducted in more ecologically valid environments compared with experiments run on computers. Implementation of experiments such as those examining cases of memory psychophysics and those used here in Experiments 1-3 might also be more challenging than computer-generated experiments for a several reasons. The most outstanding limitations perhaps being that in a more ecological context stimulus presentations might contain more variability than stimulus presentation in computer-generated experiments (e.g. lack of millisecond precision timing) and that experiments not run on computers might not seem as economical in setup or participant use. However, it can be argued that the challenges of experiments carried out with 3-D stimuli (and all real world stimuli for that matter) are offset by the gain in ecological validity, along with the testing and development theories that might apply to our interaction with stimuli in a real world setting instead of simply applying to interactions with artificial computer generated stimuli.

Overall, the experiments reported here are generally consistent with previous studies examining memory psychophysics, and are consistent with the idea that boundary extension reflects more of the scene being remembered rather than simply a change in remembered distance or area for objects. Furthermore, it seems that boundary extension is likely not due to a displacement in depth as close-up truncated views of 3-D scenes result in motor responses consistent with memory psychophysics and not boundary extension. It seems that the four experiments reported here support the idea that boundary extension reflects changes in remembered expansiveness. It might be of value to begin to characterize and test displacements such as boundary extension in a framework of anticipatory schema such as that introduced by Neisser (1976). Such a framework might aid in explaining how different effects can be attained with similar stimuli, and what mechanisms are responsible for these effects. Finally, hopefully a growing number of researchers will examine theories and ideas derived from computer-generated stimuli in more ecologically rich settings, so that theories regarding anticipation, reflection, and interaction regarding computer-generated stimuli can be applied to real world settings.

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Appendix A

STATEMENT OF CONSENT

I, the undersigned, do hereby give my informed consent to my participation in the ___Moon_______ Study. I have been informed about each of the following:

- The purposes of the study- The purpose of this experiment is to study visual perception and memory. In studying these issues, the investigators hope to extend our understanding of how visual and auditory perception operates and what factors influence visual perception and memory.
- The procedures – During the experiment you be observing a number of objects (e.g. buildings, toy cars, etc.). You will be asked to wear a blindfold or other vision occluder (blacked out goggles). You will be asked to make various judgments about these visual (e.g., distance to an object), and you will indicate the nature of your judgments by verbal response, pen and paper, and positioning yourself. Any objects that you might lift and place are very small and should cause you no discomfort.
- The benefits – Participation in this experiment satisfies part of the research participation requirement of General Psychology (10213) or another psychology class. Understand that you may also satisfy a research participation requirement by taking part in other experiments or by completing an alternative activity designated by your professor. This is solely a research project, and you will receive no psychological, medical, or other personal benefits from your participation other than the partial satisfaction of the research participation requirement in your psychology class.
- The risks- Understand that participation in this project involves no risks to you. Neither the visual and/or auditory stimuli should cause you any discomfort, but if discomfort occurs notify the experimenter immediately and he or she will take steps to eliminate discomfort. The tasks will not be physically exerting.

I understand that I may withdraw at any time before or during the experiment at my option.
Recognizing the importance of avoiding bias in the results of this experiment, I agree not to discuss any of the details of the procedure with other participants. I understand that all of the research and evaluation materials will be confidentially maintained. The means used to maintain confidentiality are:

- My data will be given a code number for research identification, and my name will be kept anonymous.
- Data, along with consent forms, will be kept in a locked file cabinet.
- Only the investigators will have access to my identification data.

I understand that if I have questions concerning the research, I can call the following persons:

Jon R. Courtney, Principal Investigator
Department of Psychology
257-7410

Timothy L. Hubbard,
Co-Principal Investigator
Department of Psychology
Chair, TCU Committee on
Safeguards of Human
Subjects
257-7413

Dr. Donald Dansereau
Chair, Department of Psychology
Human Subjects Committee
257-7410

Jan Fox, TCU Coordinator
Research and Sponsored
Projects
257-7515

____

Participant's Name (PLEASE PRINT) Date

____

Participant's Signature Phone Number

____

TCU ID# Professor Course #

Appendix B

The Moon Study

Greet participants outside the lab door, explain the informed consent, and measure participant's height. Have them fill out informed consent and wait for the experiment to begin.

IMPORTANT: Make sure participants are blindfolded before they come into the lab so they do not have any priming of scenes or distance cues.

After viewing four scenes for 15 seconds each, you have two tasks to perform for this experiment.

The first task is to pay close attention to each scene and try to remember the main objects and the background in as much detail as possible. Try to remember everything in the scene, including its layout-that is the size and location of everything with in the allowed viewing. In other words, try to retain an exact copy of each scene in memory. After you have viewed all of the scenes

When you are taken back though the scenes you will complete a second task. The second task will be for you to adjust yourself to your original position at each scene. After the assistant has lead you to an approximate distance, adjust your position by moving you will be taken back though the scenes in the same order you originally saw them in. backward or forward such that you are viewing the scene exactly as you viewed it the first time.

The conditions under which you will perform during this experiment are as follows.

- **Your peripheral and at times full vision will be blocked by means of goggles, blindfold, masks, eye shields, or a combination of more than one.**

- **You will be lead by an assistant to specific locations while blindfolded.**
- **When you are asked to remove your blind to view the scene, it is imperative that you do not look in any direction except straight forward.**
- **You will be given minor directions, during the original viewing, such as "forward until you feel your toes at the block." or "Move left/right two inches…", to ensure you are with in a standard space for the experiment to begin.**
- **Minimal communication during experiment, especially if other participants are present.**
- **Your height will be measured prior to the experiment, to obtain an average height. In the event you are too far outside the average range, you might be excluded from the experiment.**

Do you have any questions?

Take participants though a practice trail and make sure they don't have any questions.

Debriefing

Previous research has shown that people generally remember objects being smaller than they actually were when first perceived. In a related phenomenon, boundary extension (BE), memory for a scene tends to include an area outside of the boundaries of the actual scene reflecting a smaller remembered area for a particular object in a scene (e.g. Intraub, 2002). Hubbard (1996) offered the possibility that boundary extension is in fact due to a displacement in depth of the stimuli being observed which would result in a change in remembered distance from actual distance. Intraub and Richardson (1989) recognized the possibility that boundary extension might reflect changes in remembered distance. However, Intraub (2002) along with Gottesman and Intruab (2002) have dismissed the possibility of boundary extension being a displacement in depth. The purpose of this research is to resolve the question; "Is boundary extension due to changes in remembered distances of objects?"

Thank you for participating and please do not discuss this experiment with other potential participants.

Appendix C

The Moon Study

Greet participants outside the lab door, explain the informed consent, and measure participant's height. Have them fill out informed consent and wait for the experiment to begin.

IMPORTANT: Make sure participants are blindfolded before they come into the lab so they do not have any priming of scenes or distance cues.

You will be viewing four scenes for 15 seconds each.

Pay close attention to each scene and try to remember the main objects and the background in as much detail as possible. Try to remember everything in the scene, including its layout-that is the size and location of everything with in the allowed viewing. In other words, try to retain an exact copy of each scene in memory. After you have viewed all of the scenes you will be taken back though the scenes in the same order you originally saw them in.

The conditions under which you will perform during this experiment are as follows.

- **Your peripheral and at times full vision will be blocked by means of goggles, blindfold, masks, eye shields, or a combination of more than one.**
- **You will be lead by an assistant to specific locations while blindfolded.**
- **When you are asked to remove your blind to view the scene, it is imperative that you do not look in any direction except straight forward.**
- **You will be given minor directions, during the original viewing, such as "forward until you feel your toes at the block." or "Move left/right two inches…", to ensure you are with in a standard space for the experiment to begin.**

- **Minimal communication during experiment, especially if other participants are present.**
- **Your height will be measured prior to the experiment, to obtain an average height. In the event you are too far outside the average range, you might be excluded from the experiment.**

After they view the four scenes give them this instruction…

You will be seeing the same scenes again, but this time your task is to rate each scene on a 5-point scale as to whether your view is exactly the same or slightly different than the one you saw during the first presentation. As in this example (show the laminated example), you see ranges from close-up to wide angle. When you're your view is closer, less of the scene is visible, when your view is further away, more of the scene is available. Tell me the number that corresponds with your judgment on the scale ranging from (2) much too far to (-2) much too close. Any questions?

Remind them not to move their head, and take them back through the scenes.

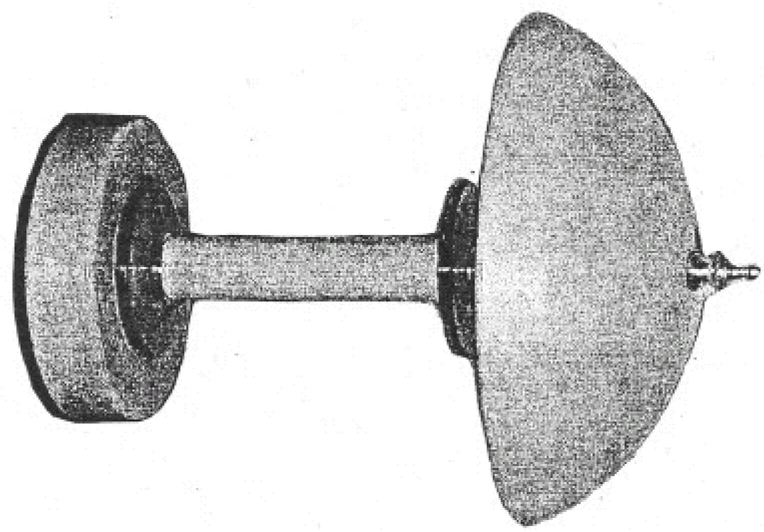
Debriefing

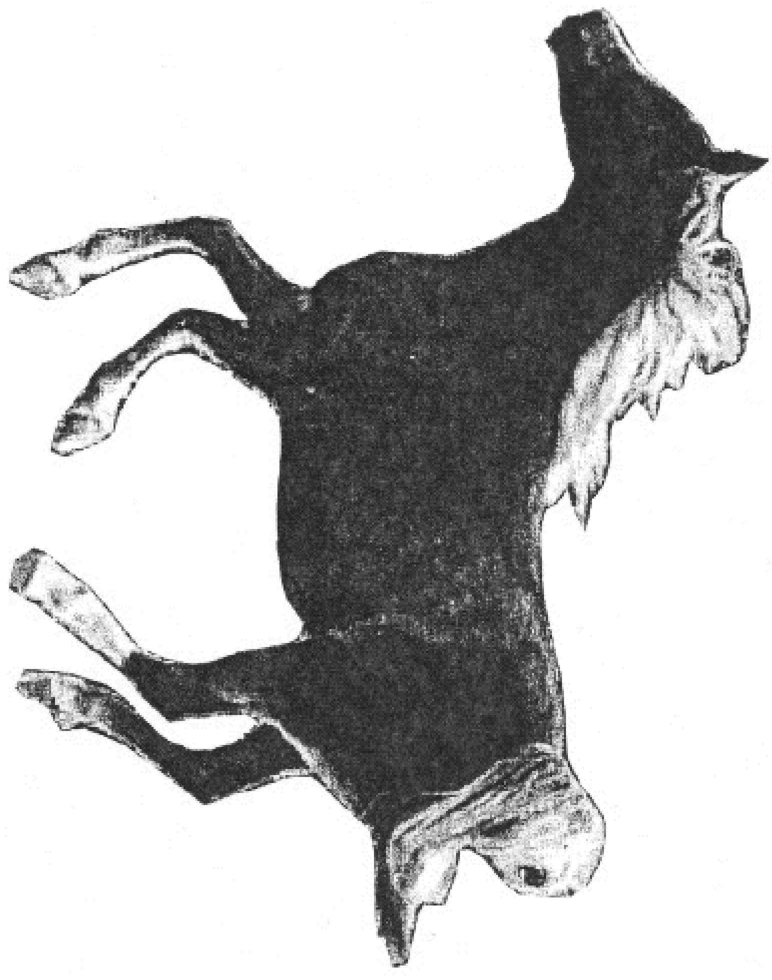
Previous research has shown that people generally remember objects being smaller than they actually were when first perceived. In a related phenomenon, boundary extension (BE), memory for a scene tends to include an area outside of the boundaries of the actual scene reflecting a smaller remembered area for a particular object in a scene (e.g. Intraub, 2002). Hubbard (1996) offered the possibility that boundary extension is in fact due to a displacement in depth of the stimuli being observed which would result in a change in remembered distance from actual distance. Intraub and Richardson (1989) recognized the possibility that boundary extension might reflect changes in remembered distance. However, Intraub (2002) along with Gottesman and Intruab (2002) have dismissed the possibility of boundary extension being a displacement in depth. The purpose of this research is to resolve the question; "Is boundary extension due to changes in remembered distances of objects?"

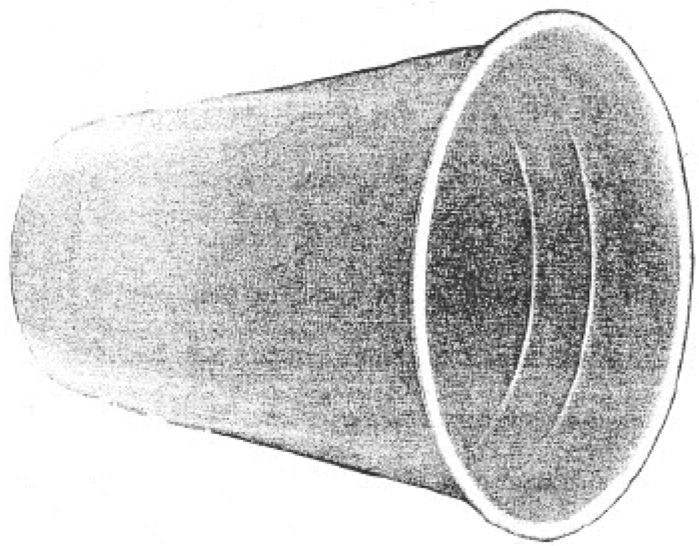
Thank you for participating and please do not discuss this experiment with other potential participants.

Appendix D

Please do not turn the page!
Wait for further instructions.







Please do not turn the page!
Wait for further instructions.

Please circle the number that corresponds to your feelings toward the pictures.

The picture is now…

Lamp
Camera Distance

-2	-1	0	1	2
Much Too Close	Slightly Too Close	Same	Slightly Too Far	Much Too Far

Basketball
Camera Distance

-2	-1	0	1	2
Much Too Close	Slightly Too Close	Same	Slightly Too Far	Much Too Far

Horse
Camera Distance

-2	-1	0	1	2
Much Too Close	Slightly Too Close	Same	Slightly Too Far	Much Too Far

Cup
Camera Distance

-2	-1	0	1	2
Much Too Close	Slightly Too Close	Same	Slightly Too Far	Much Too Far

Please do not turn the page!
Wait for further instructions.

Questionnaire

Sex (Circle one) Male Female

1. What do you think was the purpose of the experiment? Please explain.

2. Did you ever perceive that the type of object you saw had an effect on your memory for where that object was located? (Also please mention if you had any phobias to the stimuli you saw.) Please explain.

3. What strategy, if any, did you use for judging the placement of the visual stimuli?

4. Have you ever participated in a study similar to the current study? If so please describe the study.

5. Do you have any suggestions on how this experiment could be improved, or suggestions for future studies?

Appendix E

STATEMENT OF CONSENT

I, the undersigned, do hereby give my informed consent to my participation in the ___Gold_______ Study. I have been informed about each of the following:

- The purposes of the study- The purpose of this experiment is to study visual perception and memory. In studying these issues, the investigators hope to extend our understanding of how visual and auditory perception operates and what factors influence visual perception and memory.
- The procedures – During the experiment you be seeing a number of objects depicted in photographs. You will be asked to make various judgments about these visual stimuli and you will indicate the nature of your judgments by drawing or responding to a questionnaire.
- The benefits – Participation in this experiment satisfies part of the research participation requirement of General Psychology (10213) or another psychology class. Understand that you may also satisfy a research participation requirement by taking part in other experiments or by completing an alternative activity designated by your professor. This is solely a research project, and you will receive no psychological, medical, or other personal benefits from your participation other than the partial satisfaction of the research participation requirement in your psychology class.
- The risks- Understand that participation in this project involves no risks to you. Neither the visual and/or auditory stimuli should cause you any discomfort, but if discomfort occurs notify the experimenter immediately and he or she will take steps to eliminate discomfort. The tasks will not be physically exerting.

I understand that I may withdraw at any time before or during the experiment at my option.

Recognizing the importance of avoiding bias in the results of this experiment, I agree not to discuss any of the details of the procedure with other participants. I understand that all of the research and evaluation materials will be confidentially maintained. The means used to maintain confidentiality are:

- My data will be given a code number for research identification, and my name will be kept anonymous.
- Data, along with consent forms, will be kept in a locked file cabinet.
- Only the investigators will have access to my identification data.

I understand that if I have questions concerning the research, I can call the following persons:

Jon R. Courtney, Principal Investigator
Department of Psychology
257-7410

Timothy L. Hubbard,
Co-Principal Investigator
Department of Psychology
Chair, TCU Committee on
Safeguards of Human
Subjects
257-7413

Dr. Donald Dansereau
Chair, Department of Psychology
Human Subjects Committee
257-7410

Jan Fox, TCU Coordinator
Research and Sponsored
Projects
257-7515

____

Participant's Name (PLEASE PRINT) Date

____

Participant's Signature Phone Number

____

TCU ID# Professor Course #

Appendix F

The Gold Study

Greet participants, and explain the informed consent. Have them fill out informed consent and wait for the experiment to begin.

You will be presented with four photographs of scenes for 15 seconds each. Please pay close attention to each picture and try to remember the main objects and the background in as much detail as possible. Try to remember everything in the picture, including its layout-that is the size and location of everything in the picture space. In other words, try to retain an exact copy of each picture in memory.

Any questions?

Start Power Point presentation. Immediately after the last picture is a presented handout booklets and read the following.

On each page you will see a cutout of the object from the pictures that you just viewed. Your task is to finish the picture by adding the boundaries and other aspects of the scene (shadows, background, etc.). Draw each picture in as much detail as possible. Don't worry if you are not a great artist; just do your best to represent everything you saw in the picture. Try to capture the layout of the picture; that is, try to draw everything in the same relative size and position as in the picture. After you draw each picture, make all the changes you think are necessary, and if you want to clarify any part of your drawing please feel free to use words as labels.

Wait until they finish the drawing task (10min)

Turn the page. You will be seeing the same scenes again, but this time your task is to rate each slide on a 5-point scale as to whether each picture is exactly the same or

slightly different than the one you saw during the first presentation. As in the example on the screen now, you see ranges from close-up to wide angle, when the camera is closer, less of the scene is visible, when the camera is further away, more of the scene is available. Circle the number that corresponds with your judgment on the scale ranging from (2) much too far to (-2) much too close. After you have completed this task please wait for further instruction. Any questions?

Show test pictures.

Debriefing.

In boundary extension, memory for a scene tends to include an area outside of the boundaries of the actual scene (e.g. Intraub, 2002). It is believed that the occurrence of boundary extension is characteristic of the dynamic nature of mental representations. It seems that the remembered positions of objects are influenced by anticipation of what is to come outside of the current view. Previous studies have used the method of drawing the object in the boundaries, here you drew the boundaries around the object. If this results in boundary extension, previous experiments are validated, if not something different might be going on.

Thank you for participating and please do not discuss this experiment with other potential participants.

VITA

Personal Background	Jon Ryan Courtney Born: December 15, 1977, Española, New Mexico USA
Education	2006: Doctor of Philosophy, Experimental Psychology, Texas Christian University; 2003: Master of Science, Experimental Psychology, Texas Christian University; 2000: Bachelor of Arts, Psychology, University of New Mexico.
Awards & Honors	2006: College of Science and Engineering Dean's Teaching Assistant Award; 2005-2003: Louis H. & Madlyn B. Barnett Fellowship, Fort Worth, TX; 2004: TCU Graduate Senate Travel/Research Grant; 1999: Psi Chi National Honor Society; 1998: Golden Key National Honor Society; 1997: New Mexico Lottery Success Scholarship, University of New Mexico; 1996: Regents Scholarship, New Mexico State University;
Sample Publications (Chronological)	Courtney J. R., Motes, M. A., & Hubbard, T. L. (in press). Multi- and unisensory visual flash illusions. Perception. Hubbard, T.L. & Courtney, J.R. (in press). Evidence for a separation of perceptual and cognitive dynamics. In L. Albertazzi (Ed.), Visual depictive thought. New York: Benjamins Publishing Company. Hubbard, T.L., Ruppel, S.E., & Courtney, J.R. (2005). The force of appearance: Gamma movement, naive impetus, and representational momentum. Psicologica, 26, 209-228.

ABSTRACT

EXAMINING MEMORY FOR AREA AND DISTANCE: UNTANGLING THE RELATIONSHIP BETWEEN MEMORY PSYCHOPHYSICS AND BOUNDARY EXTENSION.

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When an observer views a picture of a scene, his or her memory for that scene often includes details that were not present in the scene, but that might have been present just outside the boundaries. This has been referred to as *boundary extension* (Gottesman & Intraub, 2003; Intraub, 2004; Intraub & Richardson, 1989), and has been proposed to reflect the anticipatory nature of representation (Intraub, 2002). One possible contributing factor to boundary extension is a change in remembered distance (Hubbard, 1996). However, memory psychophysics studies examining memory for distance have found that people most often remember being closer to an object than they were at first sight, which would seem to reflect boundary restriction rather than boundary extension (Algom, 1992). The purpose of the four experiments presented in this dissertation were to find (a) if results such as those found in boundary extension and elsewhere are due to changes in remembered distances of objects, (b) apply theories drawn from boundary extension to ecologically rich stimuli, and (c) resolve inconsistencies between research on boundary extension and memory psychophysics. Experiments 1 and 2 examined memory for distance of close-up 3-D views by asking participants to step forward or backward and adjust themselves to the position in which they first viewed a scene. Results were

consistent with memory psychophysics and not boundary extension in that participants generally remembered being closer to the scenes (stepped forward). Experiment 3 used the same 3-D stimuli but used a different distance judgment (verbal rating) and found participants overall showed no change in distance memory. Experiment 4 examined area memory for boundaries of 2-D photographs while area of objects in the photographs were held constant, and found an effect consistent with boundary extension. The data from the four experiments revealed that boundary extension is likely not due to a displacement in depth, and theoretical claims made from studies examining 2-D views might not easily translate to the 3-D world. Implications for theoretical explanations of spatial memory, dissociations between memory for distance and area, and examinations of theories from a standpoint of ecological validity are discussed.