BOUNDARY EXTENSION AND NORMALIZATION FOR MEMORY OF ABSTRACT AND REAL-WORLD SCENES

by

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(Under the Direction of James M. Brown)

ABSTRACT

Boundary Extension (BE) is a widely reported memory phenomenon in which people recall seeing a wider-angle view of a scene than was actually seen. This effect is thought to be due to fundamental perception processes inherent in scene viewing that cause these complex stimuli to be remembered differently than simple objects. Certain image manipulations used in previous work suggest that another memory effect called normalization may be affecting responses depending on the characteristics of the pictures' contents and how they are presented to participants. This study examines the interaction of these two effects for abstract scenes, characterized by a lack of long-term memory associations with the image contents, and for scenes depicting the real world. Experiment 1 verifies the co-occurrence of BE and memory normalization for some images. Experiment 2 is the first known scene memory experiment using intact pictures of the real world that does not show BE.

INDEX WORDS: boundary extension, normalization, perception, memory, scene

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BS, Clemson University, 2009

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTERS OF SCIENCE

ATHENS, GEORGIA

2013

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ACKNOWLEDGEMENTS

I would like to thank Dr. James Brown for his helpful guidance and advice throughout this research project. Also, my thanks go out to all of the research assistants that helped collect data and to Aisha Siddiqui for introducing the topic of this thesis to me.

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CHAPTER 1

INTRODUCTION

It has long been unclear as to how the numerous discrete fixations, characteristic of saccades, produce a coherent representation despite inherent limitations of the human visual system. Evidence for these limitations is provided by errors of omission in visual memory for complex stimuli, such as change blindness, which have frequently been identified in behavioral research (Intraub, 2012; Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997; Simons & Rensink, 2005). Research on transsaccadic memory span suggests that it is more similar to robust, limited capacity short term visual memory than fragile, high capacity iconic memory (Irwin, 1991; Phillips, 1974). Since memory capacity suggests details of a visual scene are sparse between fixations, it is likely that saccades are integrated so seamlessly because of help from some kind of information extrapolation process. Boundary extension (BE), an error of commission characterized by the addition of visual information to memory for a scene, may be evidence of just such a predictive extrapolation (Intraub & Richardson, 1989). This phenomenon is characterized by subjects remembering a close-up view of a scene as wider-angle than what they actually saw. It has been suggested that the actual sensory detail processed during a fixation is only one part of what is used by the visual system to construct a representation (Intraub, 2010, 2012). Scanning behavior likely involves priming recognition for expected objects and features that lay within and just outside the current view (Bar, 2007). BE could be a result of integrating some of these primed expectations into one’s memory for a scene. If BE is in fact a byproduct of this process, it could provide a partial explanation for how fixations are sequentially integrated and rapidly processed while maintaining a cohesive stream of information.

Previous studies on BE typically present participants with a series of scene pictures to be remembered and then test these memories by showing either the original images again or a view of the same scene that is closer or wider-angle (i.e., a picture of the same scene taken from a closer or further distance). During presentation of the test images, participants are asked to determine if each image is the same, closer, or wider-angle than the version they previously saw (Intraub, Bender, & Mangels, 1992; Intraub & Richardson, 1989). Participants consistently respond that close-up views seen during study are wider-angle than the same close-up views seen during test. Wide-angle views seen during study tend to be reported as being the same or wider-angle than the same views seen at test. BE has been suggested to be a source-monitoring error caused by the incorporation of expected visual features, including things likely to be seen just outside the available view of a scene, with the actual sensory-based memory of the stimulus (Intraub, 2010; Johnson, Hashtroudi, & Lindsay, 1993). In Intraub's multisource model of scene perception (2010, 2012), these expectations are thought to be derived from the scene context associations, object associations, and amodal completion of objects and textures occluded by the view borders. The participant is unable to separate these primed expectations from the original scene information, resulting in memory of an expanded, wider-angle, view than the original stimulus. This implicit anticipation process is supported by BE being found in temporal conditions comparable to saccades (Dickinson & Intraub, 2008). As mentioned earlier, the memory extension bias is especially evident for scenes that appear to be very close-up views. This is thought to occur because close-ups elicit a greater sense of expectation of what lies beyond the boundaries of the image (Intraub et al., 1992). Memory for wider-angle views, depicting a more panoramic scene, tends to be veridical.

Boundary extension vs. memory normalization

A perception of image continuity seems to be a critical trigger for BE (Gottesman & Intraub, 2002; Hale, Brown, McDunn, & Siddiqui, 2013; Intraub, Gottesman, & Bills, 1998). When participants are presented scenes that suggest the image is a partial view of a more expansive world/scene, as typical photographs of the world do, BE tends to occur. In contrast, when the images of objects are manipulated to appear confined to a space consisting only of the immediately visible surface either veridical memory or a memory normalization effect tend to occur. Another factor that has consistently induced normalization is manipulation of the delay between study of the scenes and the memory test. When memory is tested after a long delay (48 hours) normalization tends to occur, while very short or immediate delays tend to result in BE (Intraub et al., 1992).

Normalization has been identified in several studies, and has traditionally been differentiated from BE by a clear distinction in the pattern of the participants' responses (Intraub et al., 1992). Subjects rate the test images on a 5-point scale: "1) Much closer up; object looks much bigger", "2) slightly closer-up; object looks slightly bigger", "3) the same", "4) slightly wider angle; object looks slightly smaller", "5) much more wide-angle; object looks much smaller". These values were then converted to a -2 to 2 scale, as in Intraub and Richardson (1989), with a rating of 3 becoming 0, a rating of 1 becoming -2, and a rating of 5 becoming 2. A graph of typical BE data is provided in Fig. 1, and a graph of normalization data is provided in Fig. 2 for comparison. Although Fig. 2 could be described as "typical" normalization, the magnitude of the effect and the symmetry between view presentation orders tends to vary depending on the experimental manipulation. Four view presentation orders are typically examined; close-up at study and close up at test (CC), wide-angle at study and wide-angle at test (WW), close-up at study and wide-angle at test (CW), and wide-angle at study and close-up at test (WC) (Intraub & Richardson, 1989). BE results, using the standard paradigm described earlier, are characterized by a pattern of responses indicating that close-angle images are remembered as being wider-angle and wide-angle images are remembered as being the same or wider-angle. To test for the characteristics of BE, researchers typically look for the mean boundary response of CC to be significantly less than zero, indicating that the participants tended to respond that the test image is closer-up than the study image, and WW is expected to be not significantly different from zero or less than zero. Also, the absolute values of the CW and WC presentation orders are expected to be significantly different from one another if BE has occurred (Intraub et al., 1992).

The pattern of results referred to as normalization is typically characterized by responses indicating that close-up images are remembered as being wider-angle and wide-angle images are remembered as being closer-up. This effect is characterized by symmetry in the data between the absolute values of CC and WW and also between the absolute values of CW and WC. Importantly, memory normalization must be distinguished from veridical memory. When CC and WW are not significantly different from zero on this scale, it indicates that participants correctly identified the test picture as being the same as the study picture. It is only when the mean boundary ratings for these presentation orders are symmetric *and* significantly different from zero that a normalization effect can be said to have occurred.

The current study

Recently, McDunn, Siddiqui, and Brown (under review) showed BE occurs even for abstract scenes with no real-world context or object familiarity. During pilot tests of these images it was noticed that changing the amount of difference between close-up and wide-angle views in the image set influenced the data, indicating stronger memory normalization when the difference between views is very large. Intraub, Bender, and Mangels (1992) reported a similar effect for pictures of real-world scenes, and suggested that participants tended to normalize their memory for the pictures toward an “episodic prototype” that may be an average view distance between the close-up and wide-angle pictures. If this is the case, it would expand evidence of averaging effects often reported for object memory to a similar normalization process for scene memory (Ariely, 2001; Chong & Treisman, 2003, 2005; Oriet & Brand, 2013).

This episodic prototype hypothesis was tested in the current study by systematically manipulating the view differential across four experimental conditions. If participants are comparing test images to an averaged view, signs of normalization should be stronger for sets of images with a large difference between close-up and wide-angle pictures. An averaged view memory would be more different from either the close-up or wide-angle pictures when the difference is large, resulting in more extreme ratings in the boundary response. In Experiment 1, abstract scenes were tested in four conditions with a progressive increase in the amount of view difference between close-up and wide-angle pictures. Consistent with the episodic prototype hypothesis, a stronger memory normalization effect was found when the view difference was increased. In Experiment 2, the abstract scenes were replaced with comparable real-world scenes using the same paradigm and four conditions. A strikingly different trend was observed, showing very strong memory normalization across all conditions.

CHAPTER 2

EXPERIMENT 1

Method

Subjects. A total of 199 students from the research pool at the University of Georgia participated in four between-subjects conditions (ranging from a large to small change between close-up and wide-angle views: 40%, 28%, 22%, and 16%) as fulfillment of partial course credit, with N's = 49 (40 F), 50 (35 F), 50 (24 F), 50 (31 F), respectively. All participants signed informed consent forms, had normal or corrected-to-normal vision, and indicated no history of an attention deficit disorder.

Stimuli. 40 unique abstract scenes (800 x 600 pixels) were created in Adobe Photoshop by creating a random black-dot background with a grey geometric figure appearing on top of the dots. The dots continued to the border of the images and were occluded by it and the main object in each image. The objects appeared to occupy most of the images so that they would serve as suitable close-up views. Wide-angle versions of these 40 close-ups were created by reducing the image size and continuing the dot background to the new borders. Images were shrunk by 40%, 28%, 22%, and 16% to create the wide-angle views for the four view change conditions. The same close-ups were used in each condition. Figure 3 shows an example of one of the stimuli at several views.

Abstract scenes were used in this experiment because they are well controlled in stimulus characteristics and have been shown to elicit BE (McDunn et al., under review). Unlike real-world pictures used in most BE studies, the abstract scenes do not vary from picture to picture in attributes that may influence memory such as perceived depth, clutter, content salience, and viewing distance. The perceived viewing distance that the picture depicts was the main concern. In previous studies, depicted main objects often exhibit extreme diversity in real-world size; for example, objects vary from a candlestick to a car in Intraub and Richardson (1989). Close-up pictures of these two objects are perceived by the viewer to be taken from very different view distances. Since the memory normalization effect is hypothesized to be sensitive to perceived view distance, this variable must be controlled. The abstract scenes are very consistent in this aspect.

Procedure. Images were presented using a computer running E-Prime v 2 and a monitor with a refresh rate of 85 Hz. Participants sat 80 inches from the monitor, creating a visual angle of 8° (height) x 11.1° (width) for the extent of the screen. Images encompassed the full screen. Participants were told that they would be presented with a series of images, and that their memory of them would be tested. 40 abstract scenes were then presented for 15 seconds each, 50% were in their close-up version and 50% were in their wide-angle version. Immediately following this study phase, the test images were presented one at a time. Half of the test images were presented as the same view shown during the study phase and half were presented as the close-up or wide-angle complimentary version. This resulted in the four equivalently occurring presentation states described in the introduction: close-angle study and test (CC), wide-angle study and test (WW), close-angle study and wide-angle test (CW), and wide-angle study and close-angle test (WC).

As the test images appeared, subjects rated them on a 5-point scale: “1) Much closer up; object looks much bigger”, “2) slightly closer-up; object looks slightly bigger”, “3) the same”, “4) slightly wider angle; object looks slightly smaller”, “5) much more wide-angle; object looks much smaller". These values were then converted to a -2 to 2 scale, with a rating of 3 becoming 0, a rating of 1 becoming -2, and a rating of 5 becoming 2. After each test image subjects were asked, "How sure are you about your previous response?", and rated their confidence on a 4-point scale: "1) Sure", "2) Pretty Sure", "3) Not sure", "4) Don't remember picture".

Results

Overall, subjects showed confidence in their responses across conditions. "Sure" was selected on 24% of trials, "pretty sure" was selected on 46.3% of trials, "not sure" was selected on 18.1% of trials, and "don't remember picture" was selected on 11% of trials. All trials where the subjects gave a response of "don't remember picture" were removed from analyses. Across conditions, of interest was the interaction of presentation order (CC, WW, CW, WC) by view change condition (40%, 28%, 22%, 16%). A repeated measures ANOVA showed this interaction to be significant, $F(9, 582) = 10.174$, $p < .001$. View change appeared to have a strong influence on boundary ratings. The standard three BE signifiers were tested to examine change in the pattern of the data from each view change condition. The first is that CC be significantly less than zero. Second, WW must not be significantly greater than zero. Also, a test showing a significant difference between the absolute values of CW and WC is indicative of an extension bias. Similar to the standard tests of BE, three tests were selected to verify a normalization effect. First, CC and WW must both be significantly different from zero to establish a distinction between normalization and veridical recollection. Additionally, their absolute values must not be significantly different from one another. Finally, the absolute values of CW and WC must also not be significantly different from one another.

Mean boundary ratings for the four presentation orders in the four view change conditions are listed in Table 1. For the smallest view change condition (16%) all indicators of

BE were found: CC was significantly different from zero in the negative direction ($t = -7.863$, $p < .001$.), WW was not significantly different from zero ($t = 1.249$, $p > .05$), and the absolute values of CW and WC were significantly different from one another ($t = -4.173$, $p < .001$). For the next smallest view change condition (22%) two out of the three typical signs of BE were found: CC was significantly different from zero in the negative direction ($t = -12.134$, $p < .001$.), WW was significantly different from zero in the positive direction ($t = 2.359$, $p < .05$), and the absolute values of CW and WC were significantly different from one another ($t = -5.127$, $p < .001$). Although WW indicated restriction, the absolute values of CC and WW were still significantly different from each other ($t = 4.056$, $p < .001$). For the 28% view change condition two out of three BE signifiers were found again: CC was significantly different from zero in the negative direction ($t = -6.875$, $p < .001$.), WW was significantly different from zero in the positive direction ($t = 4.895$, $p > .001$), and the absolute values of CW and WC were significantly different from one another ($t = -4.420$, $p < .001$). Similar to the 22% condition, the absolute values of CC and WW were significantly different from one another ($t = 2.647$, $p < .05$). For the largest view change condition (40%) the same two out of three pattern occurred: CC was significantly different from zero in the negative direction ($t = -10.026$, $p < .001$.), WW was significantly different from zero in the positive direction ($t = 7.380$, $p > .001$), and the absolute values of CW and WC were significantly different from one another ($t = -2.102$, $p < .05$). The difference between absolute values of CW and WC seemed to be approaching a lack of significant difference. Unique to this view change condition, an analysis of the difference between absolute values of CC and WW showed no significant difference ($t = 1.190$, $p > .05$), which suggests that normalization had a stronger effect on this condition than the others. For a comparison of all conditions by presentation order see Fig. 4.

The t-tests show that for the 16% change condition all three typical BE criteria were met, and there was no sign of normalization. For this condition it is concluded that BE occurred with no measurable effects of normalization. For the 22% and 28% change conditions, two out of three indicators of BE and one out of three indicators of normalization were found. It would seem that the overall trend is still to extend the remembered images, but there is now a significant normalization influence shown by the increase in the mean value for WW. Note that for CC and WW to be different from zero, the first indicator of normalization listed above, CC must be different from zero, the first BE indicator. Therefore, one of the BE criterion met by these two conditions is at least partially due to the normalization effect. Taken as a whole, it seems there are as many signs of normalization as BE for the 22% and 28% conditions. Finally, the 40% size change condition, hypothesized to show the greatest influence of normalization, met one out of three BE criteria (as stated above, CC being less than zero is no longer necessarily a sign of BE since CC and WW are symmetric) and two out of three normalization criteria. The third normalization criterion, no significant difference between absolute values of CW and WC, was nearly met. The overall trend shows WW, CW, and WC to increase in absolute value as the difference between close-up and wide-angle views gets more extreme, with CW changing at a faster rate than WC. CC seems to be relatively stable across conditions. It is clear from the data that the normalization effect increases systematically with the increase in view difference between close-up and wide-angle views. At the greatest relative view difference there is almost no sign of an extension effect, while at the smallest view difference there is no sign of normalization. The two conditions in between seem to show some mixture of the two effects. At larger view differences the memory normalization effect may simply be so strong that it overwhelms any extension that is occurring, making it difficult to detect.

It is important to address the possible confound that the abstract pictures may have incurred a response pattern that is atypical of images normally used in BE studies. Previous studies have only shown strong normalization effects when the delay between study and test was very long or the images were manipulated to appear as though they do not represent a truncated view of a larger scene. Although the amount of difference between close-up and wide-angle views is rarely reported in previous literature, figures in published studies such as Intraub et al. (1992) and Gottesman and Intraub (2002) suggest that large view changes have been used before without detecting the same degree of normalization as was found in the current study. There are several inherent differences from real-world scenes that could have influenced the data, but the data from the 16% condition would suggest that the normalization effects observed here are not simply a result of attenuated BE for these images. One possibility is that the abstract scenes used in this study were more sensitive to whatever is driving the normalization effect. Memory representations may have been freer to transform since the abstract objects have no schematically associated memories, whereas real-world scenes have familiar context within the images by which to scale them and create a detailed memory trace. The simplicity of the abstract images may also have contributed to the creation of a more generic memory for the set as a whole. Identifying an object as a chair or a table within a conference room could allow a viewer to establish a more specific memory for the scene due to deeper processing through semantic associations and detail analysis. The possibility that real-world scenes would be remembered differently led to Experiment 2, which used a different picture set under the same experimental conditions. Forty photographs exhibiting similar image structure as the abstract scenes were used in the next experiment to test the hypothesis that the strong normalization effect was due to the lack of associated real-world object sizes and scaling image context.

CHAPTER 3

EXPERIMENT 2

Method

Subjects. A total of 200 students from the research pool at the University of Georgia participated in four between-subjects conditions (ranging from a large to small change between close and wide-angle views: 40%, 28%, 22%, and 16%) as fulfillment of partial course credit, with N's = 50 (31 F), 50 (40 F), 50 (31 F), 50 (31 F), respectively. All participants signed informed consent forms, had normal or corrected-to-normal vision, and indicated no history of an attention deficit disorder.

Stimuli. 40 digital, grayscale, photographs (800 x 600 pixels) of constructed scenes were used as stimuli in Experiment 2. Each photograph consisted of a main object on a dark grey tablecloth and in front of a dark grey concrete wall. Camera distance from the main object was the same for each close-up picture in the set, and each main object was within 500 to 1000 cubic inches in actual size. These characteristics and setting were chosen so that the real-world scenes would have a similar construction to that of the abstract scenes (i.e., similarly sized main objects on similar backgrounds). Four sets of wide-angle versions of the close-ups were created in Adobe Photoshop to match the same view differences used in the four conditions of Experiment 1. Figure 5 shows an example of a stimulus used in Experiment 2 at several different views.

Procedure. The same procedure was used as for Experiment 1 with one exception. The overall luminance of the photographs was observed to be lower than the abstract scenes. Although image details could still be readily observed, lighting in the experiment room was reduced to a small lamp so that detail in the images displayed on the monitor would be more easily seen by the participants.

Results

Overall, subjects showed more confidence in their responses for the images in Experiment 2 than those in Experiment 1. Across conditions, "Sure" was selected on 35% of trials, "pretty sure" was selected on 49.6% of trials, "not sure" was selected on 11.2% of trials, and "don't remember picture" was selected on 3.2% of trials. Once again, all trials where the subjects gave a response of "don't remember picture" were removed from analyses. The improvement in memory confidence is expected since the abstract scenes contained no readily associable content to generate a strong memory trace. A repeated measures ANOVA showed the interaction of presentation order (CC, WW, CW, WC) by view change condition (40%, 28%, 22%, 16%) to be significant, $F(9, 588) = 19.165$, $p < .001$. Like with the abstracts scenes, the view change manipulation had a strong influence on boundary ratings for real-world scenes. The same criteria used in Experiment 1 were used to test for BE and memory normalization effects. Mean boundary ratings are reported in Table 2.

For the smallest view change condition (16%) there were no clear signs of BE and two of three indicators of normalization were found. CC was significantly different from zero in the negative direction ($t = -3.563$, $p < .01$.), but WW was also significantly different from zero ($t = 2.995$, $p < .01$). The absolute values of CC and WW were significantly different from one another ($t = -1,704$, $p > .05$), possibly indicating some extension bias. However, the absolute values of CW and WC were not significantly different from one another ($t = -2.191$, $p > .05$). While the results of this condition do show a significant asymmetry between responses to CC and WW, CW and WC no longer show asymmetry. The overall trend is clearly toward memory normalization. This finding is quite surprising, especially when considering the fact that abstract scenes showed exclusively BE at the same view change.

For the next smallest view change condition (22%) CC was significantly different from zero in the negative direction ($t = -5.595$, $p < .001$.), WW was significantly different from zero in the positive direction ($t = 4.480$, $p < .001$), the absolute values of CC and WW were not significantly different from one another ($t = -1.951$, $p > .05$), and the absolute values of CW and WC were not significantly different from one another ($t = -1.744$, $p > .05$). No signs of extension are present in this condition. Similarly, for the 28% view change condition CC and WW were significantly different from zero ($t = -7.642$, $p < .001$ and $t = 5.667$, $p < .001$ respectively) and the differences between the absolute values of CC/WW and CW/WC were not significant ($t = .903$, $p > .05$ and $t = -1.420$, $p > .05$ respectively). The largest view change (40%) showed the same trend as well. CC and WW were significantly different from zero ($t = -7.219$, $p < .001$ and $t = 5.542$, $p < .001$ respectively) and the differences between the absolute values of CC/WW and CW/WC were not significant ($t = -0.494$, $p > .05$ and $t = -0.753$, $p > .05$ respectively). All memory normalization indicators were found for the 22%, 28%, and 40% view difference conditions, and even the 16% view change condition showed strong normalization. For a visual comparison of the data from conditions in Experiment 2 by view presentation order see Fig. 6.

CHAPTER 4

GENERAL DISCUSSION

The data from these two experiments is quite puzzling in light of previous findings in BE studies. In Experiment 1, increasing the amount of view change between close-up and wide-angle versions of the images led to a drastic increase in magnitude of memory normalization. This finding is consistent with what is expected if participants are remembering a view of the stimuli that is an average of the two picture types in the set. The data suggest the abstract scenes are still being extended in a way similar to typical scenes. BE is found when the view difference is small and an averaging effect would be expected to have minimal effects on boundary responses. Normalization became more pronounced as the view difference was increased; however, an extension bias could still be detected even for the largest view difference condition. The significant asymmetry between CW and WC was the only sign of this response bias at the 40% condition. BE and normalization both seem to exert an influence on memory for the abstract images, with normalization becoming strong enough at larger view differences to overpower the more subtle extension effect.

As mentioned earlier, it is odd that previous experiments using similar view differences did not report this effect. However, this result could have potentially been attributed to a difference in visual memory for abstract shapes versus real objects. A similar difference has been reported in object memory studies. Size averaging across a series of object stimuli has been shown to be less extreme for real objects, which have associated long-term memory schemas, than random shapes (Hemmer & Steyvers, 2009; Heussen, Poirier, Hampton, & Silvio, 2011).

This led to the testing of real-world scenes in the subsequent experiment. It was expected that images of the real world, depicting objects and scene contexts anchored by long-term memory schemas, would be less susceptible to the strong normalization effect found for abstract scenes.

Contrary to the original hypothesis for Experiment 2, the real-world scenes generated stronger memory normalization than the abstract scenes, even at small view changes. This is a highly irregular finding given that the previous literature on scene memory ubiquitously reports BE for normal populations unless (1) there is a very long delay between study and test or (2) the images have been strongly manipulated to remove the perception of image continuity beyond the view borders. In both experiments the longest delay between study and test of a picture was about ten minutes, nowhere near the 48 hour delay that has been used to elicit normalization in the past (Intraub et al., 1992). One previous study that showed normalization involved using line drawings of an object on a blank, uniform background as stimuli (Gottesman & Intraub, 2002; Intraub et al., 1998). Note that photographed objects on a blank background did elicit BE in these studies. Gottesman and Intraub (2002) found that taking a cut-out of a photographed object and placing it on a white background in front of participants led to normalization. In contrast, placing a cut-out of a whole scene (essentially just a picture) on a board led to extension for memory of the scene. None of these previously used stimulus characteristics are particularly similar to characteristics of the images presented in Experiment 1 or 2, and previous literature gives the impression that it is more difficult to construct a stimulus that does not elicit BE than one that does. It is also very unlikely that the findings of Experiment 2 are simply due to random error since the data is very consistent across all four view difference conditions. The only sign of any extension bias in Experiment 2 is the significant asymmetry between CW and WC for the smallest view change. The fact that BE is not found with these real-world scenes suggests one of two possibilities: either something is anomalous with these pictures that causes them to not to yield BE or some confound is present with previously used picture sets that cause them to yield an extension bias.

Can canonical visual size account for BE?

The latter possibility brings into question what is actually being tested in this type of study. Are subjects reporting their memory for the scene as a whole, or are they reporting their memory for only the main object? Although subjects are asked to report on the scene as a whole, it is difficult to exclude the possibility that they are basing their judgments on the main object alone. If memory for the main object is indeed driving responses, then the objects' associated sizes based on prior experience, dubbed canonical visual size (Konkle & Aude, 2011), may be the source of the extension bias. Konkle and Oliva (2007) suggested that BE may be a result of a bias to remember objects as their canonical size since pictures that tend to be extended in memory (i.e., objects remembered as being smaller) depict close-up views of typically small things. This type of image is common in stimuli used for BE studies. A close-up of a small object results in a larger presentation of the item than is consistent with the canonical visual size subjects tend to remember. Based on Konkle and Oliva's studies (2007, 2011), it is predicted that subjects would respond that the same close-up presented at test as at study is "too close-up". Similarly, it is predicted that a wide-angle view of the same object would not elicit an extension response since it is smaller on the screen and thus closer to its canonical size.

In the current study, Experiment 2 utilized a set of pictures depicting objects within a very constrained real-world size. One possibility that needs to be addressed is that the canonical size of the object set used in this experiment may have fallen between the close-up and wide-angle views that were presented. This situation could lead to the normalized responses. However, several predictions inherent in this line of reasoning are not suggested by the data. First, it would be expected that changing the view difference between close-up and wide-angle pictures would lead to a shift away from normalization as the wide-angle pictures got further from the canonical visual size of the objects depicted in the scenes. As a result, it is expected that at least one of the experimental conditions would result in a clear overall bias toward extension or restriction. As mentioned earlier, the only sign of extension was the significant asymmetry between CW and WC in the 16% condition. Another prediction is that there should be no signs of an overall extension or restriction bias for the abstract scenes since they have no canonical visual size. However, it seems quite clear that the there is a significant extension trend for memory of these images despite their novelty to the participants of the experiment. Canonical visual size does not seem to be able to account for BE or the normalization seen here, but it may still be having some influence on memory responses for experiments showing a single main object on a blank background (conditions very similar to Konkle and Oliva (2007)).

The role of objects and backgrounds

We must return to the original possibility, that something is anomalous with these pictures that causes them to not to yield BE. An examination of the characteristics of these images suggests four salient differences from other image sets typically used in BE studies; all main objects are roughly the same size, the pictures have no color, all view distances are the same, and all pictures depict the same background/location. Object size is addressed in the previous section, and there seems to be no other potential explanation for why it would cause the reported data from this study. Also, there is no readily apparent reason why grayscale photos would be treated differently than color photos. The finding that BE occurs with line drawings of scenes, which were black and white, supports this assumption (Gottesman & Intraub, 2002;

Intraub et al., 1998; Legault & Standing, 1992). Uniform view distances for close-ups and wide-angle versions of the pictures allows normalization effects to be more clearly detected in the data, but the only way this could account for the disparity between Experiment 2 and other studies is if the variability of view distances in other stimulus sets could account for the BE effect on its own. This hypothesis is not well supported. The abstract scenes in Experiment 1 had no such view distance variability but still yielded extension effects. The only other difference is the stimulus set for Experiment 2 is the semi-uniform context/background for the pictures. Each main object was photographed in front of the same concrete-block wall. However, this image characteristic also seems inconsequential since the set of abstract images had similar consistency in backgrounds but still had an extension bias. Also, typical BE has been found for photographs of objects when the background was simply white or grey (Gottesman & Intraub, 2002).

Conclusions

At this point there is no clear reason why memory for the real-world scenes in this study normalized while previous studies show extension. There could be some differences in how global scene information and object specific detail is encoded and retrieved. These differences may be responsible for varying degrees of BE and normalization depending on what parts of the image are the focus of attention during memory encoding and/or what parts are used for retrieval to make a boundary judgment. Differences in processing characteristics of figure versus ground information in stimuli have been identified in previous work (Weisstein & Wong, 1986). Perhaps information encoded through different visual channels leads to different memory distortions. However, the complexity of the stimuli used in scene memory experiments makes it difficult to determine what factors are influencing the participants’ memory responses and encoding behaviors.

Despite the perplexing questions raised by Experiment 2, this study establishes several important findings. First, the previously observed normalization effect is confirmed to be averaging qualities of the images in a stimulus set and is sensitive to change in the relative view/size change between picture types. Second, BE and memory normalization are shown to co-occur in at least some types of scenes and likely represent distinct processes. Third, a bias toward memory for a canonical visual size of objects reported by Konkle and Oliva (2007) does not explain all BE findings well. Fourth, memory normalization, and not BE, can occur for at least some intact scenes. This last finding suggests that perception of image continuity beyond the view borders is not the only trigger necessary for BE to occur. The phenomenon seems to be more complex than previously thought. Further research is necessary to determine what causes memory for some images to normalize while others to extend.

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Table 1. Values indicate the mean boundary ratings for each relative view change condition by presentation state in Experiment 1. The standard error of the mean is shown in parenthesis.

* indicates $p < .05$: CC < 0, WW > 0, or absolute value CW ≠ absolute value WC.
† indicates $p > .05$: absolute value of CC not significantly different from absolute value WW.
(BE) indicates 3 out of 3 indicators of boundary extension.
(?) indicates mixed signs of both boundary extension and memory normalization.

Mean Boundary Responses for Experiment 1 (Abstract Scenes)				
Relative View Change	CC	WW	CW	WC
40% Change (?)	-.63 (.06)*†	.48 (.06)*†	.79 (.08)*	-1.01 (.07)*
28% Change (?)	-.48 (.07)*	.26 (.05)*	.48 (.08)*	-.90 (.09)*
22% Change (?)	-.64 (.05)*	.15 (.06)*	.32 (.06)*	-.80 (.06)*
16% Change (BE)	-.58 (.07)*	.07 (.05)	.30 (.06)*	-.64 (.08)*

Table 2. Values indicate the mean boundary ratings for each relative view change condition by presentation state in Experiment 1. The standard error of the mean is shown in parenthesis.

* indicates $p < .05$: For CC < 0, WW > 0, or absolute value CW ≠ absolute value WC.
† indicates $p > .05$: absolute value of CC not significantly different from absolute value WW.
(MN) indicates 3 out of 3 indicators of memory normalization.
(?) indicates mixed signs of both boundary extension and memory normalization.

Mean Boundary Responses for Experiment 2 (Real-World Scenes)				
Relative View Change	CC	WW	CW	WC
40% Change (MN)	-.31 (.04)*†	.30 (.05)*†	1.09 (.07)	-1.19 (.05)
28% Change (MN)	-.39 (.05)*†	.29 (.05)*†	.93 (.05)	-1.05 (.06)
22% Change (MN)	-.37 (.07)*†	.23 (.05)*†	.63 (.07)	-.78 (.08)
16% Change (?)	-.27 (.08)*†	.17 (.06)*†	.48 (.05)*	-.69 (.07)*

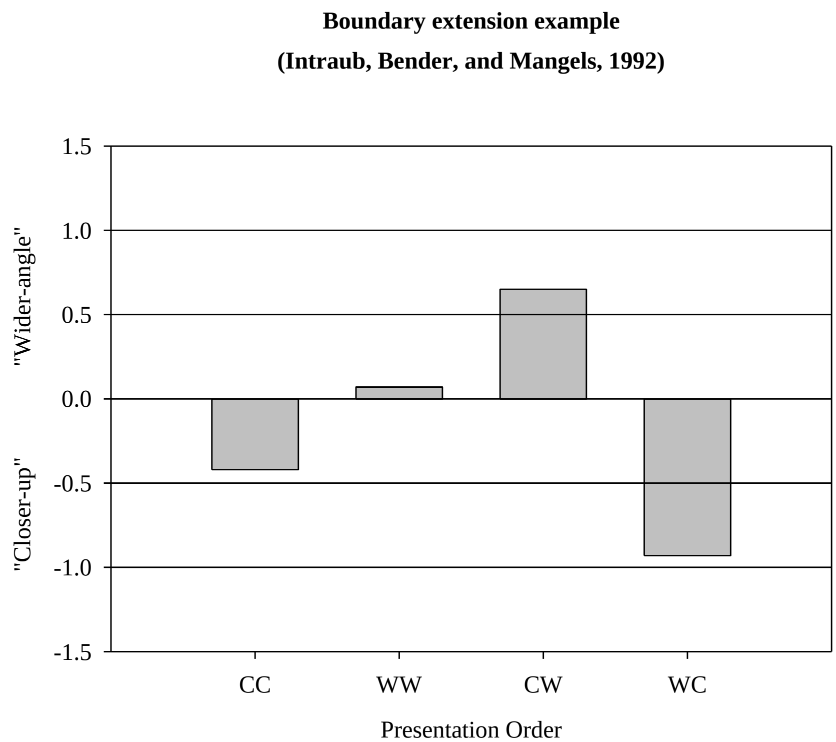

Figure 1. An example of a pattern of data indicating BE taken from Experiment 1 in Intraub et al. (1992). Presentation order indicates which image version (C = Close-up and W = Wide-angle) was presented at study and which was presented at test. A positive mean boundary rating indicates a response of more wide-angle and a negative rating indicates a response of closer-up to the test image.

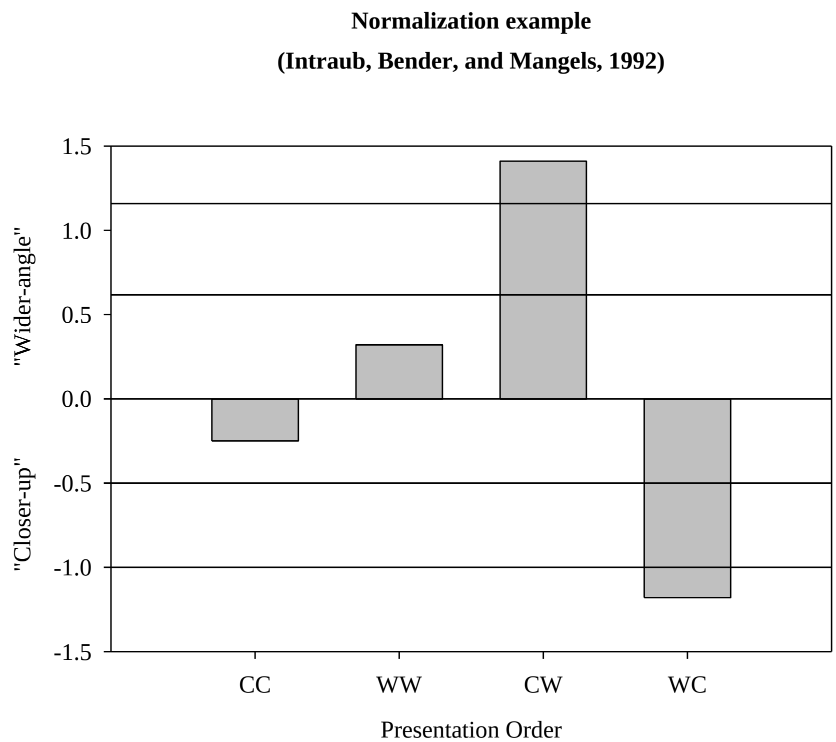

Figure 2. An example of a pattern of data indicating normalization taken from Experiment 2 in Intraub et al. (1992).

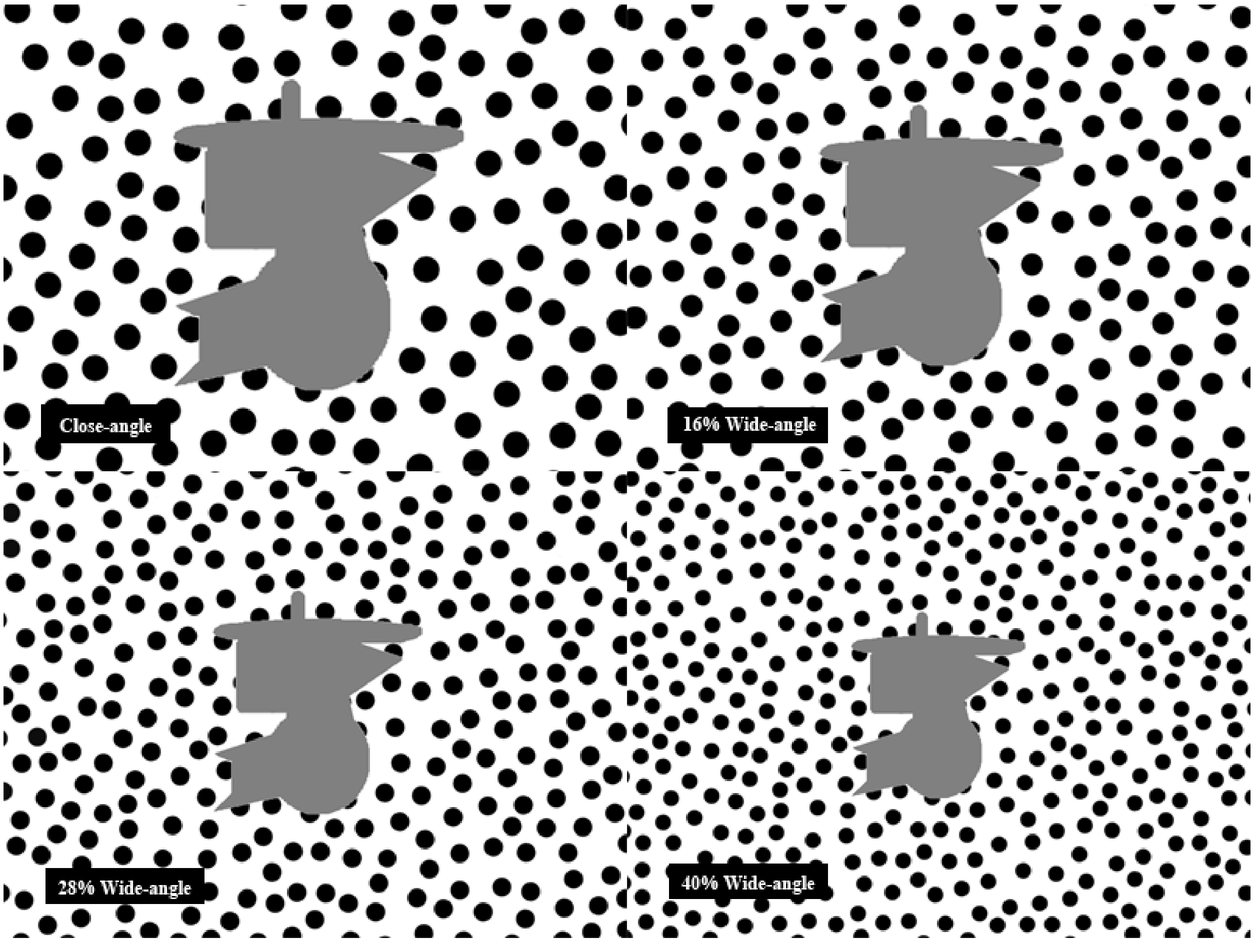

Figure 3. Example of abstract scene stimuli used in Experiment 1.

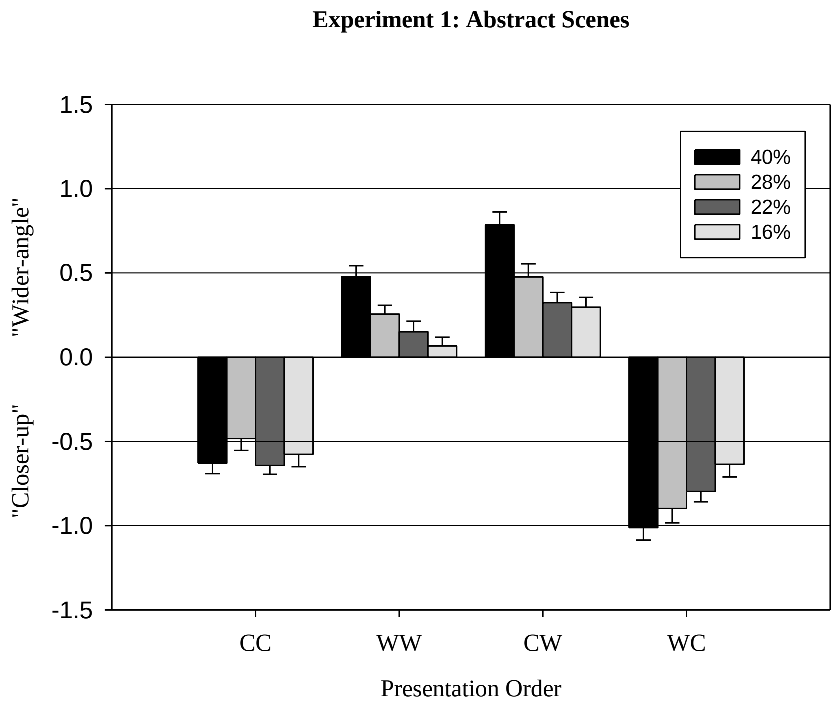

Figure 4. Mean boundary responses across presentation orders for each condition in Experiment 1. Error bars indicate standard error of the mean.

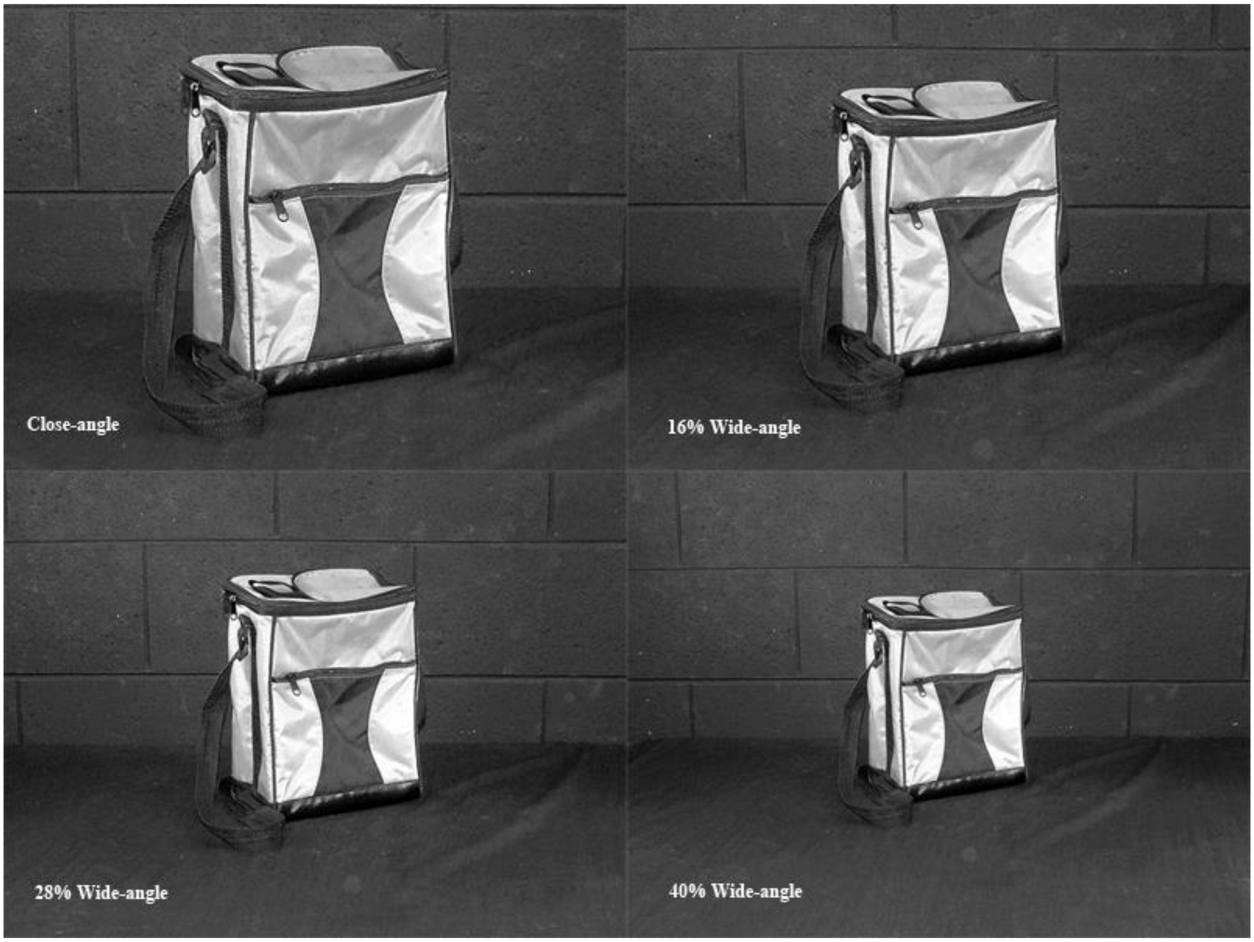

Figure 5. Example of scene stimuli used in Experiment 2.

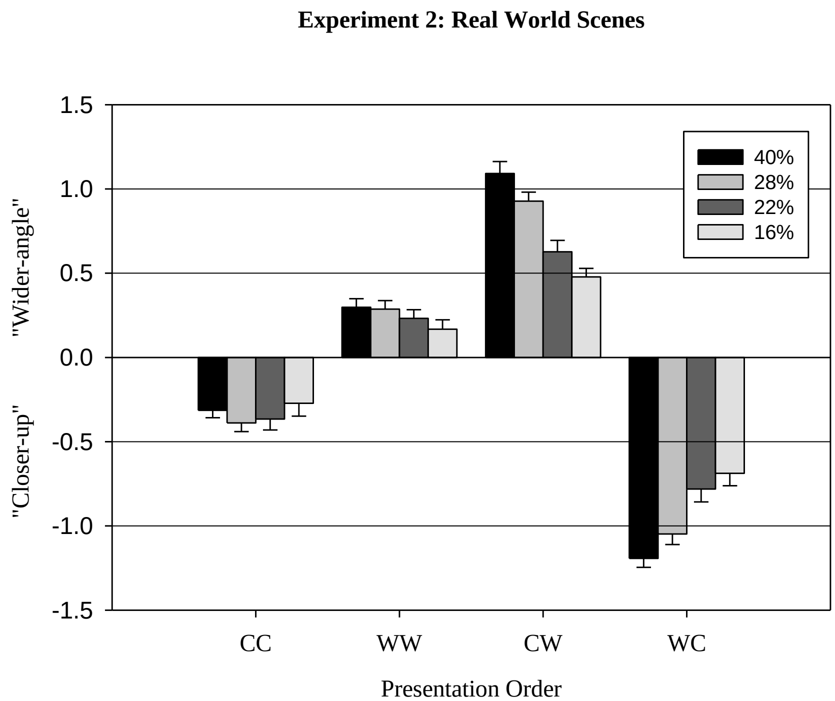

Figure 6. Mean boundary responses across presentation orders for each condition in Experiment 2. Error bars indicate standard error of the mean.