FALSE MEMORY

BEYOND A VIEW:

EFFECTS OF

BOUNDARY INTERPRETATION

by

Banjit Singh

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science in Psychological and Brain Sciences

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ABSTRACT

People remember seeing more of a real world scene than what was physically presented within the view-boundaries (boundary extension). Is scene construction in memory automatic or does it rely on boundary interpretation? In Experiments 1 and 2 (n = 208 in each), we created ambiguous boundaries by cutting 20 scenes into meaningful shapes (e.g., a heart, a hand). In both experiments participants were biased to interpret the boundary as either a shape (Shape Group) or a scene (Scene Group) before each stimulus presentation: 3 s (Experiment 1) or 340 ms (Experiment 2). Post-stimulus questions were also asked referring to the meaningful shape in the Shape Group and on the scene content in the Scene Group. After presentation, participant's memory for the expanse of each scene was tested. Rather than no boundary extension, surprisingly, the Shape Groups elicited significantly greater boundary extension than the Scene Groups. To strengthen the bias, in Experiment 3 (n = 318) we cut scenes into more complex shapes (familiar states of the U.S.). These stimuli were briefly presented (340 ms) either mirror-reversed or in their normal orientation; to increase task difficulty they were presented either upright or tilted. The Shape Group was instructed to quickly indicate if the state was "normal" or "reversed" (object-boundary bias) whereas the Scene Group was instructed to quickly indicate if the scene was indoors or outdoors (view-boundary bias). Boundary extension occurred and did not differ between groups – even in the fact of a demanding object-focused task. Results suggest that scene construction is

rapid and automatic, elicited by presence of scene content irrespective of the shape of a view.

Chapter 1

INTRODUCTION

The world is full of boundaries, from natural foliage and cave entrances to manmade windows and doors. These boundaries leave the observer with occluded views. An individual's visual field is similarly limited and is functionally similar to a window onto the world that permits the spectator to see only a portion of their environment at any given moment. However, even with these restrictions, people are still able to understand, navigate through, and act on the environment. A classic question is how the observer takes these truncated views and ends with a clear, coherent understanding of the world. One contributing factor may be the anticipation of the surrounding layout. There is a memory error that suggests that one of the ways the observer makes sense of and integrates views is the anticipatory representation of surrounding space. Referred to as boundary extension (BE), people falsely remember seeing just beyond the boundaries of the view that they are shown (Intraub & Richardson, 1989).

BE has been observed in memory tests given to a wide array of people and circumstances. It occurs in both long term and working memory, and when participants are given long (15 s) and short (250 ms) durations to view and study stimuli (Intraub et al., 1992; Intraub & Dickinson, 2008; Gagnier & Intraub, 2012). BE occurs with small memory sets (1-3 pictures) (Bertamini et al., 2005; Dickinson & Intraub, 2008) and large sets . Even participants informed of this phenomenon will still indicate that they remember seeing more of a scene (Intraub & Bodamer, 1993). Eye-

tracking research has shown that when participants are informed of the test and fixate the region near the boundaries of the stimuli, they still exhibit BE (Gagnier et al., 2013). Evidence of BE has been reported across the lifespan from infants to the elderly (Quinn & Intraub, 2007; Seamon et al., 2002). What cognitive processes could be responsible for this phenomenon?

One prominent account of BE, the *multisource model of scene representation*, (Intraub, 2010; 2012) provides a possible explanation. The observer has a sense of surrounding space (a framework that reflects what is in front, to the sides, above, below, and behind them). According to this view, when observers view a scene, the visual content elicits top down processes that 'fill out' this spatial framework with the anticipated continuation of the scene. These top down processes include amodal completion of objects (Kanizsa, 1979) and amodal continuation of surfaces (Yin et al., 2000; Fantoni et al., 2008), as well as expectations about the layout (Green & Oliva, 2009) and object-to-context associations (Bar, 2004). In the second stage of the multisource model, retrieval, people recall their mental representation, consisting of both visual and constructed information. Under specific conditions (e.g., the presentation of a close-up picture), memory for the constructed information just beyond the boundaries may be so similar to their visual memory, that they accept it as having been seen, leading them to remember a more expansive view than what they were shown. This is inherently a source monitoring error because the observer misattributes constructed information as visual information (Johnson & Raye, 1981; Johnson et al., 1993). Maguire & Mullaly (2013) suggest that the hippocampus may be highly involved in scene construction. If this is true, then damage to this area may lead to changes in BE.

Participants with bilateral hippocampal damage show that underlying the ability to reconstruct the past or predicting the future may be dependent on scene construction as people bring to mind a spatial representation of the event (Hassabis, Kumaran, Vann, & Maguire, 2007; Hassabis, Kumaran, & Maguire, 2007). To determine if the scene construction here and in the multisource model refer to the same set of processes, Mullally et al. (2012) conducted three separate boundary memory tests on control participants and participants with amnesia associated with bilateral hippocampal damage who showed a deficit in scene construction through a free imagination task. The researchers hypothesized that if this scene construction process was the same as described in the multisource model, it would lead to less or no BE for the brain-damaged participants.

Boundary tests revealed that these participants had attenuated levels of BE compared to control participants in the visual tasks. They did not display any directional distortion in the haptic task, whereas BE was found in control participants. Another brain area that minimizes BE when damaged is the ventromedial prefrontal cortex (vmPFC) (De Luca et al., 2018). These researchers reasoned that damage to the vmPFC led to lower rates of BE because the vmPFC initiates scene construction by predicting and coordinating activation of relevant schematic knowledge, which is used by the hippocampus to build the mental representation. Is scene construction limited to scenes, or will all boundaries lead to BE?

Intraub et al. (1998) sought to answer this question. They found that outline drawings of objects (e.g., traffic cone) set in scenic backgrounds led to BE (close-ups were remembered as much closer up, wide angle pictures were remembered as the same), but the same outline objects set in blank backgrounds led to normalization

memory errors (smaller objects were remembered as larger; larger objects were remembered as smaller). Participants were asked to rate test views on a scale ranging from ‘much closer up’ to ‘much farther away’ as is common in BE research. However, when they were shown the outline objects set in blank backgrounds and instructed to imagine a scenic background, results indicated BE. Results suggest that the boundaries of the white background with the objects drawn on it were not interpreted view boundaries, they were just the edge of paper on which the object was drawn. On the other hand, when participants had to imagine a scenic background for the same stimuli, the boundaries here *were* interpreted as view boundaries, eliciting scene construction. This illustrates that not all boundaries lead to BE, boundaries need to be interpreted as a view boundaries (an occluded view, like looking through a window).

Gottesman & Intraub (2002) provided converging evidence that boundary interpretation affects memory: view-boundaries elicit BE, but interpretation of the same boundaries as being the edge of the paper, i.e., an object boundary, do not. They found that, unlike line-drawn objects, photographs of objects in which the backgrounds were removed elicited BE. The researchers believed that the background for line-drawn objects may be interpreted as simply a blank page in which the object was drawn, whereas the blank background of photographed objects may be interpreted as the surface where the photo was taken. To test this, they took a different approach to creating conditions under which interpretation of the background and the boundaries of the view could be changed. They printed, cut out, and laminated the photographed objects. They intentionally took the objects in their hands and placed them inside an outline rectangle on a whiteboard in front of the participants. They theorized that the physical act of placing the objects onto the whiteboard might cause

participants to view the background and rectangular boundaries not an occluded scene with view-boundaries but as the medium on which the picture was placed, eliminating BE. They found that the same photographed objects that originally led to BE did not lead to BE with this placement process. Thus, Intraub et al. (1998) and Gottesman & Intraub (2002) both show that with an ambiguous background (a blank white field), participants could be biased to interpret the boundary of a display as either a view boundary (which elicits BE) or an object boundary (which does not).

The different impact of view boundaries and object boundaries on spatial memory has also been observed within scenes. Gottesman and Intraub (2003) placed small objects on top of bigger objects so that the small object was surrounded by the object-boundary of the larger object (see sandal on the towel in Figure 1). If all boundaries elicit BE, then participants would be expected to remember more of the towel around the sandal, as well as more grass around the edge of the view. They tested participants using a reassembly task where they gave cut-out photographs of the background and the two objects in multiple sizes and instructed participants to reassemble the scene from memory by selecting the appropriately sized background and objects. They found that both the small object (sandal) and the large object (towel) were reduced in size relative to the view boundary (indicating BE), but the small object (sandal) was not reduced in size relative to the large object (towel), indicating that BE did not occur at the object boundary. In a second experiment, they used a drawing task and found that when the small objects in the picture contained view boundaries (see the picture within a picture in the right panel of Figure 1), BE occurred at both view boundaries: for the scene as a whole, and for the fork within the picture frame. This demonstrates that BE occurs when the border signifies the edge of

a view, but not when the boundary is the edge of an object. Do these borders have to be rectangular, or will any shape elicit boundary extension?

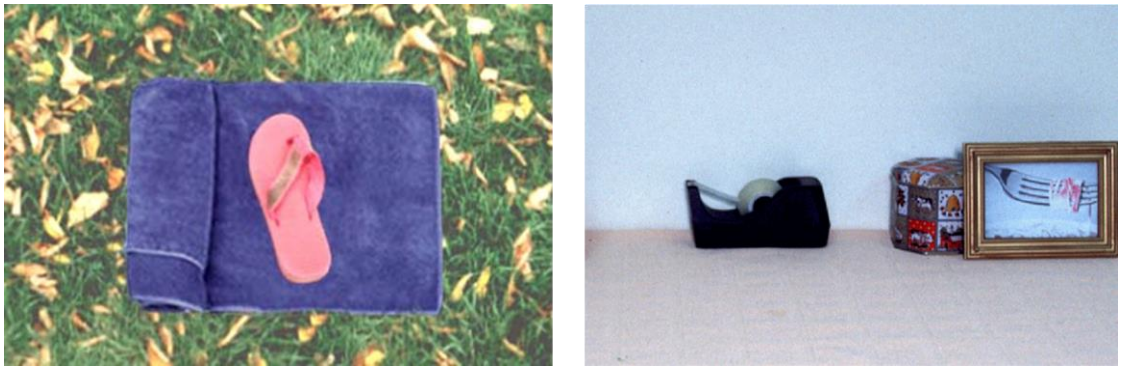

Figure 1: Stimuli taken from Gottesman & Intraub (2003). Left pane shows cluster consisting of a sandal and a towel. Right pane displays a picture in a picture, in which BE was found for the picture of the fork.

Daniels & Intraub (2006) cut scenes into rectangles, ovals, and irregular linear and curved views to determine if views must be rectilinear to elicit BE. They found that regardless of the shape of the view, BE was elicited. There was not a significant difference between the type of boundaries for how much BE was present. The boundaries were perceived as view boundaries, regardless of the shape. This finding is consistent with our perception of the world, as it is full of obstructed views of many shapes and sizes. However, the objects we see in the world are meaningful; perhaps if the content held inside a view was meaningless, scene construction would not be elicited.

To determine if BE is limited to meaningful objects and surfaces, McDunn et al., (2014) set meaningless objects in blank and dotted backgrounds (upper left panel of Figure 2). Another study (Mamus & Boduroglu, 2018) took real-life pictures and

traced the main objects into black backgrounds in a way that was unidentifiable (upper right panel of Figure 2). BE was found in the stimuli in McDunn et al. (2014) but not in Mamus & Boduroglu (2018). Meaningless abstract scenes can elicit scene construction, but do not always do so. This variation may be due to a difference in how the backgrounds were interpreted. Participants in McDunn et al. (2014) may have interpreted the background as a continuous surface so that the boundaries became view boundaries whereas in Mamus & Boduroglu (2018), the background was perceived as a finite area of the stimulus, so the boundaries were interpreted as object boundaries.

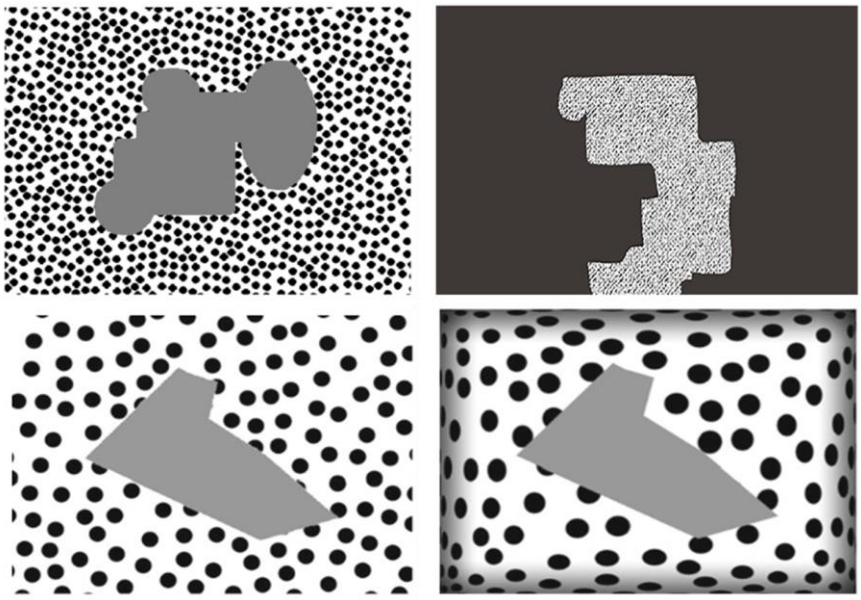

Figure 2: Upper left cell shows an example of a meaningless stimulus taken from McDunn et al., 2014. Upper right cell shows the tracing of the real life picture on a black background taken from Mamus & Boduroglu, 2018. Lower left cell shows meaningless stimuli without extremal edges from Hale et al., 2014. Lower right cell shows meaningless stimuli with extremal edges from Hale et al., 2014.

Altering the properties of the background can affect interpretation of the edges of ambiguous stimuli (Hale et al., 2014) Researchers used the stimuli from McDunn et al., 2014, and added extremal edges (bottom right cell of Figure 2). The extremal edges created the impression that views either ended at the boundary or were possibly curved forward or backward in depth rather than outwards. Due to this, they hypothesized that these extremal edges would cause participants to view the stimuli as an object rather than a truncated view of the world. They found BE in both non-extremal edge (lower left cell of Figure 2) and extremal edge stimuli, but the rates of BE were far lower in the extremal edge condition. This demonstrates that at least for ambiguous stimuli, changing properties of the edges can modify scene construction.

Research on the perception of objects versus holes provides an interesting means of conceptualizing the reinterpretation of boundaries as view boundaries versus object boundaries (e.g., Nelson & Palmer, 2001; Pinna and Tanca, 2008). Researchers found that same inner white region boundary (see left pane of Figure 3) could be interpreted in multiple ways. They found that when the contour of the shape was interpreted as being owned by the inner white region, the shape was seen as an object placed on the surrounding region and the boundary was owned by the shape itself. However, when the contour was owned by the surrounding gray region, the inner white region was perceived as a hole in the surrounding gray region. They found that they could manipulate this boundary ownership by changing depth as well as grouping and figural factors (Nelson & Palmer, 2001). Furthermore, they found that when the boundaries of the shapes were familiar and meaningful such as a handprint or pair of jeans, observers were more likely to perceive them as objects rather than holes. Similar results were found by Pinna and Tanca (2008), where they found that a

significant factor in perception was figure-ground segregation. When figure-ground segregation is ambiguous (such as in Rubin's famous face/vase illusion), then what is perceived as the figure and ground can shift.

All the reinterpretations of boundary ownership have occurred only with ambiguous backgrounds. Is this reinterpretation possible with real-world images? Simply using an unusual boundary (e.g., oval, irregular linear and curved views) was not enough to shift the boundary ownership, they were still perceived as view boundaries (Daniels & Intraub, 2006). We aimed to create a situation where, for real scenes, boundary ownership is plausible either way. We sought to determine if we could manipulate participants' perception such that the boundary would be interpreted as a view boundary (like a window: as in middle panel of Figure 3) or as an object boundary (like a puzzle piece: as shown in the panel on the right in Figure 3).

Figure 3: Left pane shows Nelson & Palmer's (2001) representation of an ambiguous figure and its various interpretations. The middle pane displays a stimulus with a view boundary; the right pane displays a stimulus with an object boundary.

In our current experiments, we attempted to create ambiguous boundaries by cutting scenes into meaningful objects (e.g., hand, cloud). Building off the results of Nelson and Palmer (2001), we hypothesized that by putting scenes into familiar shapes, participants would more readily view them having object boundaries rather than view boundaries. Furthermore, participants were given instructions to focus on the shape (ignoring the scene) . With these manipulations, we attempted to bias participants into viewing the stimuli as having object boundaries rather than view boundaries by focusing their attention on the meaningful object rather than the scene. This shift in interpretation would either eliminate (or minimize) scene construction, implying that boundary ownership is a factor for the elicitation of scene construction, or it would stay the same, demonstrating that scene construction invariably occurs in the presence of a scene.

For our first two experiments, we used a long-term memory task for either 3 s (Experiment 1) or 340 ms (Experiment 2). In Experiment 3, scenes were cut into other meaningful objects (U.S. state outlines) with a more demanding task to bias attention even more than in the first two experiments. Stimuli were shown for 340 ms in a working memory task. Details for the rationale of each experiment will follow in turn.

Chapter 2

EXPERIMENT 1

In Experiment 1, we attempted to bias the perception of boundary ownership to the scene (view boundary) or the meaningful shape (object boundary). Participants assigned to the Scene Group and the Shape Group received instructions to focus either on the scene or the shape of stimuli, respectively. They were instructed to view the stimuli in a way that would bias their interpretation into perceiving a view boundary (Scene Group) or object boundary (Shape Group). We also asked a post-stimulus question about each scene or shape to ensure that they were focused on the intended properties of the stimuli.

Stimuli were presented for 3 s each. The most common duration for BE research is 15 s (e.g., Intraub & Richardson, 1989; McDunn et al., 2017). However, this seemed too long for participants to maintain the intended bias. As other research using similar stimuli demonstrated no difference in BE when duration was reduced from 15 s to 5 s (Munger & Multhaup, 2016) and also found BE when the presentation rate was constant for a stimulus duration that was 4 s or 250 ms, we reasoned that 3 s provided a reasonable starting point. If BE occurs for scenes that are cut into meaningful shapes in the scene condition, the key question is whether biasing boundary ownership to the object would eliminate or minimize BE.

2.1 Methods

2.1.1 Participants

Participants were 208 University of Delaware native English-speaking students (160 females, 37 males, 9 nonbinary, and 2 who declined to report their gender) who

had volunteered to participate in the Department of Psychological and Brain Sciences Research Pool at the University of Delaware.

2.1.2 Stimuli

Photographs showed indoor and outdoor scenes from Kreindel & Intraub (2017) that included a tight close-up and slightly wider-angle view that zoomed out 30% (a sample stimulus pair is shown in Figure 4). Scenes included single objects or an object on a natural background. Each picture was cut into one of twenty distinct shapes using Photoshop© (e.g., a star, crescent, and puzzle piece; see footnote for full list of shapes[1]). Two additional scenes with unique shapes were created to serve as samples in the procedure. All twenty stimuli were presented on a black field (1024 x 768) and placed in one of six locations in a 2 x 6 matrix (3 columns x 2 rows).

[1] The other shapes were a heart, a diamond, a triangle, a banner, a squiggle, a hexagon, a spade, a club (cards), a house, a circle, a cloud, an arrow, a flower, an X, a tear drop, a hand, and a crown.

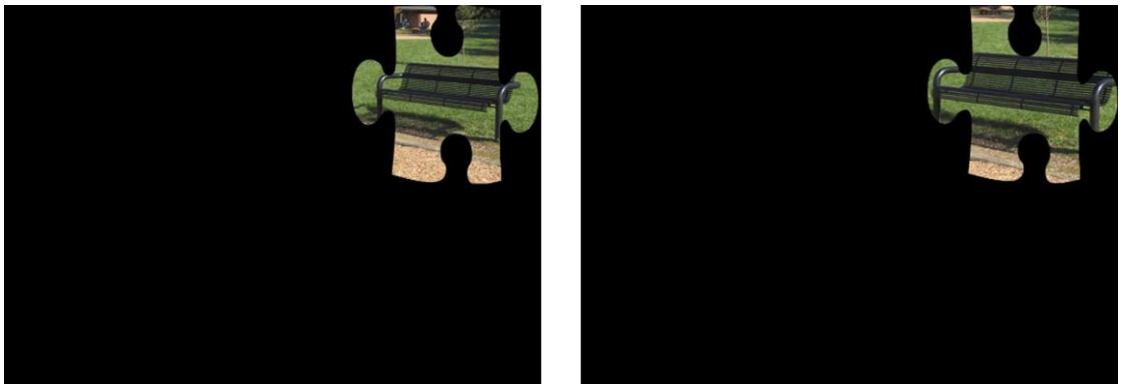

Figure 4: Left pane shows the close-up view; right pane shows the wider angle view.

2.1.3 Apparatus

This experiment was programmed using PsychoPy3 (v2021.2.1). All participants were tested online using the Pavlovia platform. They were instructed to only use either a laptop or desktop computer when invited to participate via the Research Pool system (SONA). At the end of the experiment participants were asked to click on the type of device used. To minimize differences in image size and visual angle across different participants' monitors, a "virtual chinrest" (VCR) program was implemented at the beginning of the experiment, based on Li et al. (2020)[2]. Participants held a card up to the screen and adjusted vertical bars to match the width and using this information, the program determined the screen pixel density. Next, participants completed a blind spot test, which the program used to measure their distance from the screen. With this information, their image size and visual angle were adjusted in the experiment.

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[2]We thank Lynn Baker and Alison Lobo in Timothy Vickery's Lab at University of Delaware for providing their PsychoPy3 code for the VCR, based on Li et al. (2020).

2.1.4 Design & Procedure

Participants clicked on a link that randomly assigned them to one of two groups. Our counterbalancing assured that each scene was shown as a close stimulus and a wide stimulus equally across participants. Test items were shown after all twenty stimuli had been presented and they were either the same view (CC, WW) or the alternate view (CW, WC). Thus, across the twenty test trials there were four stimulus views: close-up tested by the close-up (CC), wider angle tested by the wider angle (WW), close-up tested by the wider angle (CW), and wider angle tested by the close-up (WC). CC and WW trials are referred to as identity trials, and CW and WC trials are referred to as distractor trials. There were four counterbalanced conditions in each group ensuring that each scene had an equal number of stimulus views. We randomized the order of the scenes and the stimulus views, while making sure that no more than two stimulus views occurred consecutively. We created two pseudo-randomized orders in which the participants viewed the stimuli, leading to eight counterbalancing conditions in each group.

After signing up, participants received a link to the experiment in Pavlovia via SONA. First, they completed the VCR, then they moved on to the consent form and signified consent. After completing the VCR instructions and agreeing to the consent form, participant instructions were presented on the screen. In the Scene Group, participants were instructed to remember the scene and its location, without letting the shape distract them. They were instructed to think of the shape as an oddly-shape window through which they were viewing the scene. In the Shape Group, participants were instructed to focus on remembering the shape and its location on the screen without letting the scene in the shape distract them. Both groups were informed of a post-stimulus question relating to either the scene or the shape.

They then received two sample stimuli. The groups were asked a question regarding the scene or shape (see Figure 5). This was followed by a spatial test in which the participants were shown a 2 x 3 matrix of cells and were asked to indicate in which cell the scene/shape had been presented.

Figure 5: Left panel shows both group's test image, middle panel shows the Scene Group's question, and right panel shows Shape Group's question.

After the sample, participants self-initiated the experiment. Each of the 20 stimuli were preceded by a fixation point (1 s), remained onscreen for 3 s, followed by a blank screen (1 s) and the post-stimulus question regarding which scene/shape they just saw. Entering the letter corresponding to their choice initiated the fixation point for the next stimulus, and the process repeated until all stimuli had been presented.

Once all twenty stimuli were presented, test instructions were given to both groups. They were told that they would be shown the similar images from the sequence again and be asked to rate if the image is a lot closer (-2), a little closer (-1), the same (0), a little farther (1), or a lot farther (2) than the image they remember seeing in the sequence. The next screen asked them to rate their confidence in their

answer to the previous question as not sure (1), pretty sure (2), sure (3), or if they did not remember from the presentation (DRP). After that they were given the same spatial task that was given during the sample test. Lastly, they were asked how confident they were on the spatial task using the same confidence scale.

After the test, participants responded to a gender question (female, male, nonbinary, or prefer not to say), and indicated the type of device they had used (desktop, laptop, tablet, or smartphone). Each participant completed the experiment in less than 30 minutes and received 0.5 credit for completion.

2.2 Results and Discussion

In our preregistration, outliers were defined as participants whose proportion of DRP were equal to or more than 3SD from the group mean. Each participant viewed 20 stimuli: 5 CC, 5 WW, 5 CW, and 5 WC stimulus views. If a participant reported DRP for three out of the five stimuli with the same stimulus view, we removed data for all five stimuli. The mean proportion of DRPs was .02 (SD = 1.08) in the Scene Group and .03 (SD = 1.37) in the Shape Group, $t(201) = 1.28$, n.s. Mean confidence was 2.2 (SD = .35) in the Scene Group and 2.0 (SD = .37) in the Shape Group. The mean proportion of correct responses to the post-stimulus question in the Scene Group and Shape Group was .91 (SD = .09) and .92 (SD = .07), respectively, $t(206) = .46$, n.s. Both groups were attending to the task they were instructed.

The mean boundary rating and the .95 confidence interval for the identity trials in both groups are shown in Figure 6. In both groups, the CC trials led to BE. The WW trials did not lead to BE in the Scene Group, but those same pictures led to BE in the Shape Group. A 2 x 2 Mixed ANOVA, Group (Scene vs. Shape) x Stimulus View (CC vs. WW) revealed a significant main effect of Group, $F(1, 201) = 10.5$, $p = .001$,

$\eta^2 = .032$, $\eta^2_p = .050$, where the mean boundary rating was greater in the Shape Group compared to the Scene Group. There was a significant main effect of Stimulus View, $F(1, 201) = 88.34$, $p < .001$, $\eta^2 = .110$, $\eta^2_p = .305$, where boundary score was greater on CC trials compared to WW trials. There was no interaction found, $F(1, 206) < 1$. Our instructions led to a difference in the groups, but rather than leading to less BE in the Shape Group, it led to more, even resulting in BE in WW trials.

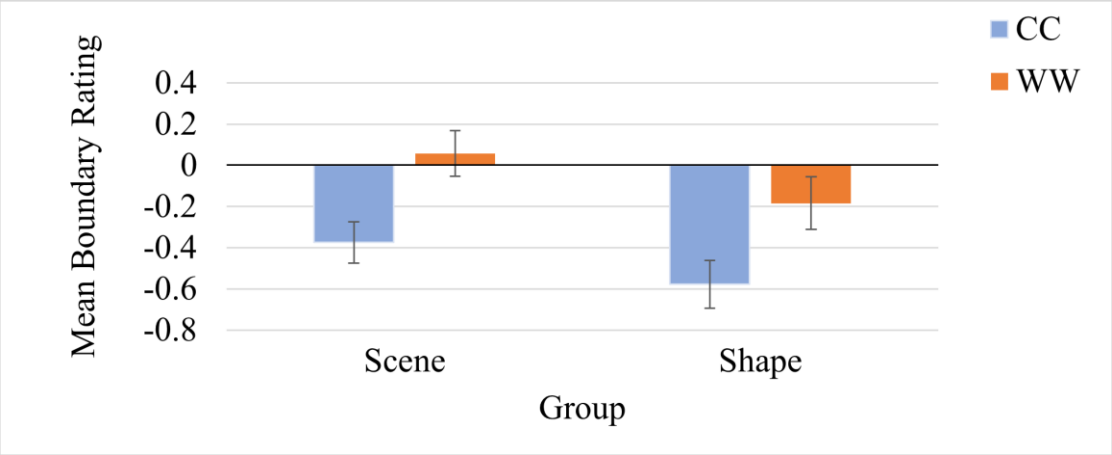

Figure 6: Mean boundary ratings for the identity trials in Experiment 1. Errors bars indicate .95 confidence intervals (CIs).

In the distractor results, the mean boundary rating for the Scene Group CW trials was .18 (SD = .64) and -.65 (SD = .64) for WC trials. The mean for the Shape Group CW trials was .04 (SD = .62) and -.59 (SD = .56) for WC trials. The distractor conditions provide another assessment of whether BE is occurring. If BE occurs, we expect an asymmetrical response on CW and WC trials. We expect that if the participants were shown the close-view, then tested with the wide-angle view they will find the picture to be the same or just a little wider because their memory includes an

extended background. In contrast, if they originally see the wide-angle view and then are tested with the close then that image will be rated as much closer. To assess the asymmetry, we calculated the asymmetry index provided by Yildirim and Intraub (2020):

Asymmetry Index = [Ratings to closer distractors * -1] – Ratings to wider distractors.

A 0 index would indicate a symmetrical error pattern. A positive index would indicate the asymmetrical response diagnostic of BE, whereas a negative index would indicate the asymmetrical response diagnostic of boundary restriction. The Scene Group's mean asymmetry index score was significantly greater than zero, $t(100) = 4.84$, $p < .001$, $dz = .48$, as was the Shape Group's, $t(101) = 6.26$, $p < .001$, $dz = .62$ (see Figure 7). There was no significant difference between them, $t(201) = .66$, n.s.

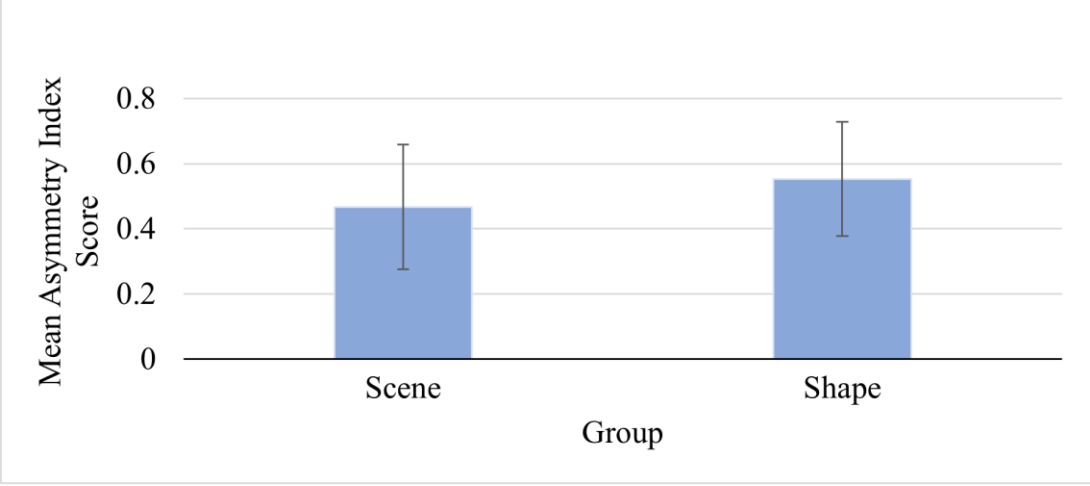

Figure 7: Mean asymmetry index scores in Experiment 1. Errors bars indicate the .95 CIs.

To determine this effect was not the result of one or two pictures driving BE, we found the mean boundary ratings for each picture, separated by group. We can see that most CC pairings result in BE (Figure 8). We found mixed results for WW boundary ratings, where most ratings centered around zero (Figure 9). We also conducted the same analysis on our distractor stimuli (Figure 10). Most pictures had a mean positive asymmetry index score, which indicates BE. This data shows us the saliency of BE, in that it occurred in most stimuli.

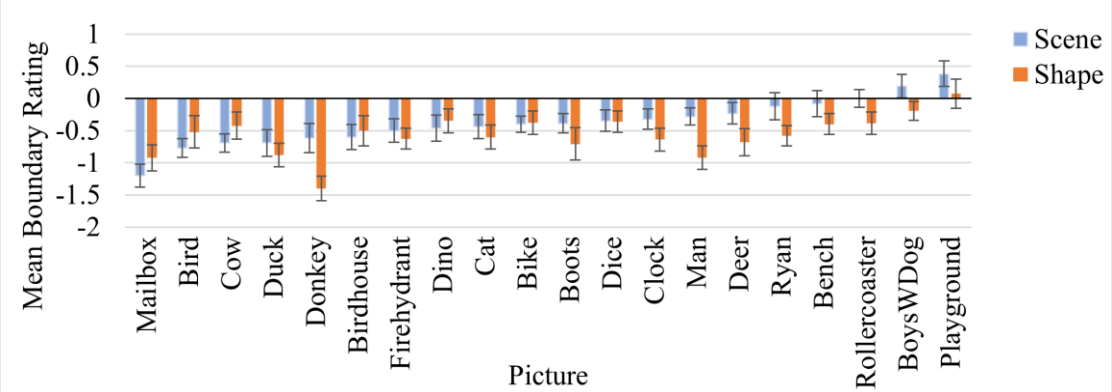

Figure 8: Mean boundary ratings for the picture analysis of the CC Stimulus View in Experiment 1. Error bars indicate the .95 CIs. The blue ratings are of the Scene Group; the orange are of the Shape Group.

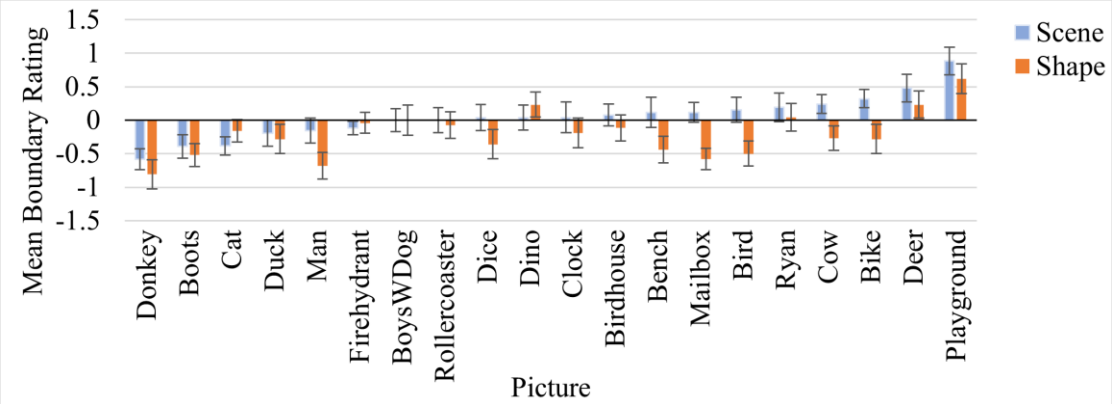

Figure 9: Mean boundary ratings for the picture analysis of the WW Stimulus View in Experiment 1. Error bars indicate the .95 CIs. The blue ratings are of the Scene Group; the orange are of the Shape Group.

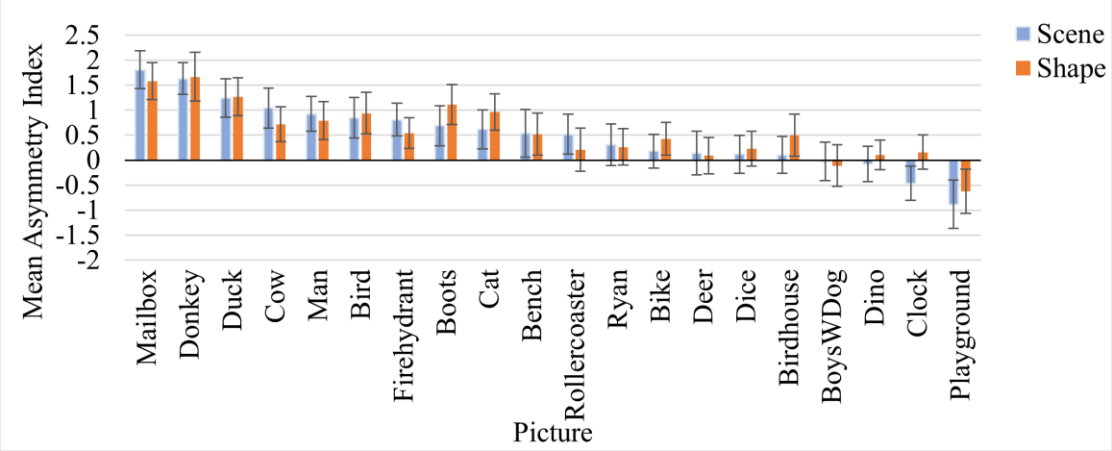

Figure 10: Mean asymmetry index scores for each picture in Experiment 1. Error bars indicate the .95 CIs. The blue ratings are of the Scene Group; the orange are of the Shape Group.

Participants' mean confidence ratings for the spatial task were 2.01 (SD = .39), in the Scene Group and 1.99 (SD = .42) in the Shape Group, t(201) = .037, n.s. Correct identification of stimulus' spatial location was poor in both groups, although it was better than chance (.16). In the Scene Group mean proportion correct was .35 (SD =

.20); and when compared to chance, $t(100) = 8.99$, $p < .001$, $dz = .89$. In the Shape Group mean proportion correct was .35 (SD = .22); and when compared to chance, $t(100) = 8.05$, $p < .001$, $dz = .80$. There was not a significant difference between the groups, $t(201) = .032$, n.s. We were curious to see that if participants did not pick the correct cell, were they at least accurate in identifying the row or column. In column accuracy, the mean proportion correct in the Scene Group (M = .28, SD = .16) was significantly different from chance (.20), $t(100) = 5.36$, $p < .001$, $dz = .53$ as well as the Shape Group (M = .23, SD = .12), $t(101) = 2.20$, $p = .030$, $dz = .22$. However, results differed in the row accuracy. Mean proportion correct in the Scene Group (M = .41, SD = .15) was not significantly different from chance (.40), $t(100) = .380$, n.s., but the Shape Group (M = .47, SD = .15) was better than chance, $t(101) = 4.33$, $p < .001$, $dz = .43$.

In sum, cutting scenes into meaningful shapes did not prevent BE. Participants remembered seeing the world beyond the oddly shaped views. However, not only did BE occur in the Scene Group, it also was evident in the Shape Group. Surprisingly, the Shape Group elicited slightly greater BE than the Scene Group. This was a surprising result, however, prior research on the effects of divided attention on BE provides a possible explanation. In a dual task situation, in which participant's attention was drawn away from a scene, BE was greater than when attention was focused on the scene (Intraub et al., 2008). Thus, it may be that scene construction was automatically elicited in both conditions of our experiment, but that the attentional demand of focus on the shape of the view created an effect similar to a dual task. We next ask if a briefer duration might provide a strong bias in Shape group, that in this case would

lead to reduced BE. In Experiment 2, we conducted the same experiment again, with a shorter duration.

Chapter 3

EXPERIMENT 2

In Experiment 2 we repeated Experiment 1 except for the stimulus duration, which we reduced to 340 ms, reasoning that a brief masked presentation of a scene might not provide sufficient time to shift boundary ownership. There have been many studies that have found BE with brief presentation (Intraub et al., 1996; Liu et al., 2016). We selected a duration of 340 ms (similar to Intraub et al., 1996, and one of the conditions in Dickinson and Intraub, 2008). The key question was whether given a brief presentation, the biasing questions in the Shape Group versus the Scene Group would be more likely to limit boundary ownership to object boundaries versus view boundaries, respectively.

3.1 Methods

3.1.1 Participants

Participants were 208 University of Delaware native English-speaking students (157 females, 33 males, 14 nonbinary, and 4 who declined to report their gender) who had volunteered to participate in the Department of Psychological and Brain Sciences Research Pool at the University of Delaware).

3.1.2 Stimuli and Apparatus

The same stimuli and apparatus as were used in Experiment 1 were used in Experiment 2.

3.1.3 Design and Procedure

The design and procedure were identical to Experiment 1 except that stimulus duration was reduced to 340 ms.

3.2 Results and Discussion

After removing our outliers as stated in the preregistration, the proportion of DRP was .033 (SD = 1.40) of trials in the Scene Group and .037 (SD = 1.41) of trials in the Shape Group, $t(206) = .693$, n.s. Participants mean confidence ratings were 2.1 (SD = .40) in the Scene Group and 1.8 (SD = .44) in the Shape Group. The mean proportion accuracy for the post stimulus question in the Scene Group (M = .90 SD = .01) was significantly different than chance, $t(103) = 80.2$, $p < .001$, $dz = 7.87$. as well as the Shape Group (M = .93 SD = .01), $t(103) = 86.5$, $p < .001$, $dz = 8.48$. The groups showed had a significant difference, $t(206) = 4.74$, $p < .001$, $dz = .658$, where participants in the Shape Group did slightly better.

The mean boundary rating and the .95 confidence interval around the mean on CC and WW trials for both groups are shown in Figure 11. BE was found in CC trials for both groups, but only the Shape Group found BE in WW trials. A 2 x 2 Mixed ANOVA, Group (Scene vs. Shape) x Stimulus View (CC vs. WW) revealed a significant main effect of Group, $F(1, 206) = 10.4$, $p = .001$, $\eta^2 = .03$, $\eta^2_p = .05$, where the mean boundary score was greater in the Shape Group compared to the Scene Group. There was also a significant main effect of Stimulus View, $F(1, 206) = 46.05$, $p < .001$, $\eta^2 = .06$, $\eta^2_p = .18$, negative boundary score was greater on CC than WW trials. Looking at the graph, it seems as though there is an interaction effect where the difference between the CC and WW ratings are higher in the Shape Group compared to the Scene Group, but the analysis did not show an interaction effect, $F(1, 206) = 3.$

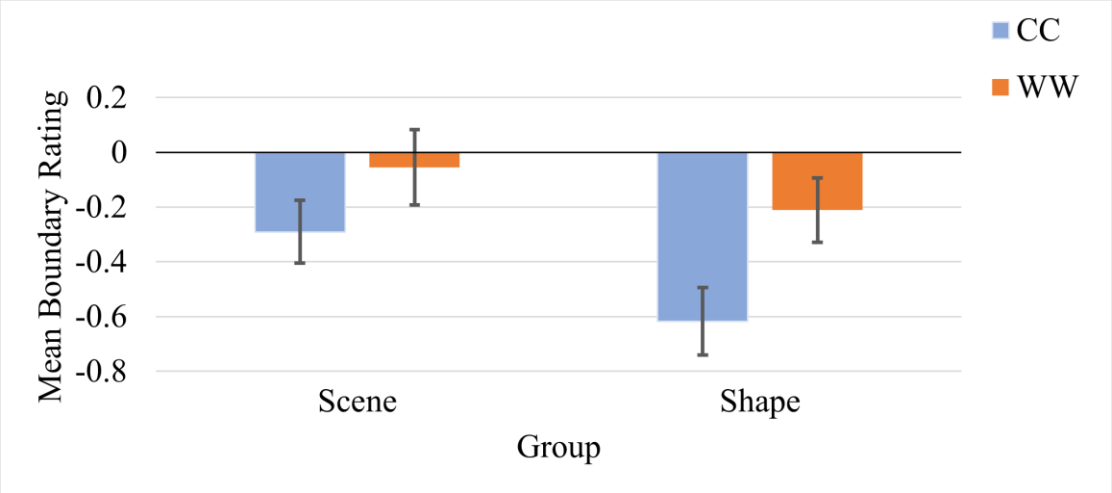

Figure 11: Mean boundary ratings for the identity trials in Experiment 2. Error bars indicate the .95 CIs.

The mean boundary ratings in the Scene Group's CW trials were .08 (SD = .85) and -.44 (SD = .61) for WC trials. The means for the Shape Group's CW trials were -0.14 (SD = .57) -0.59 (SD = .60) for WC trials. When the Shape Group participants were presented with a close-up picture and tested with a wider view, they still thought that the view was too close. The Scene Group's mean asymmetry index was significantly different from chance, $t(103) = 2.79$, $p = .01$, $dz = .274$, as well as the Shape Group, $t(103) = 7.61$, $p < .001$, $dz = .747$. There was a significant difference between the groups, $t(206) = 2.40$, $p = .02$, $dz = .333$; participants in the Scene Group had a lower mean asymmetry score than the Shape Group, indicating that BE occurred at a higher rate in the Shape Group. These results are portrayed in Figure 12.

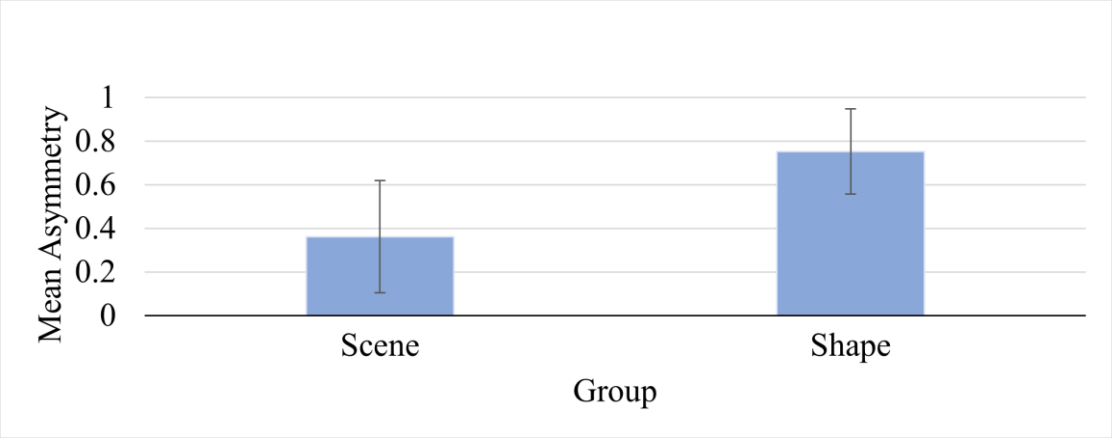

Figure 12: Mean asymmetry index scores in Experiment 2. Error bars indicate the .95 CIs.

Just as for Experiment 1, we conducted a picture analysis to determine that these results were not being driven by a few pictures but occurred holistically. We found comparable results to Experiment 1, as most CC pairings showed BE, and of those that did not, only of them showed boundary restriction in the Shape Group (see Figure 13). WW pairings also resulted in similar trends, where most pictures had either had no distortion or BE (Figure 14). Our distractor results only had a few pictures showing boundary restriction, whereas most showed BE (Figure 15).

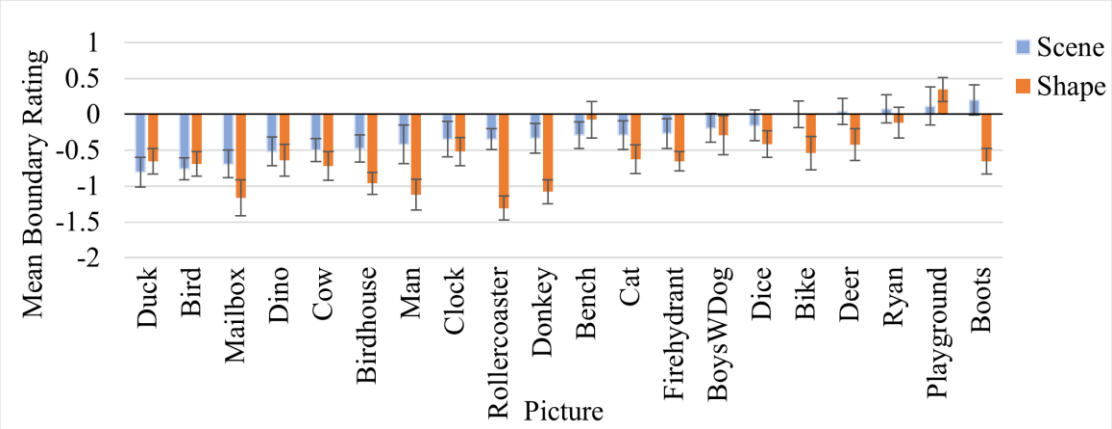

Figure 13: Mean boundary ratings of the picture analysis of the CC Stimulus View in Experiment 2. Error bars indicate the .95 CIs. The blue ratings are of the Scene Group, the orange are of the Shape Group.

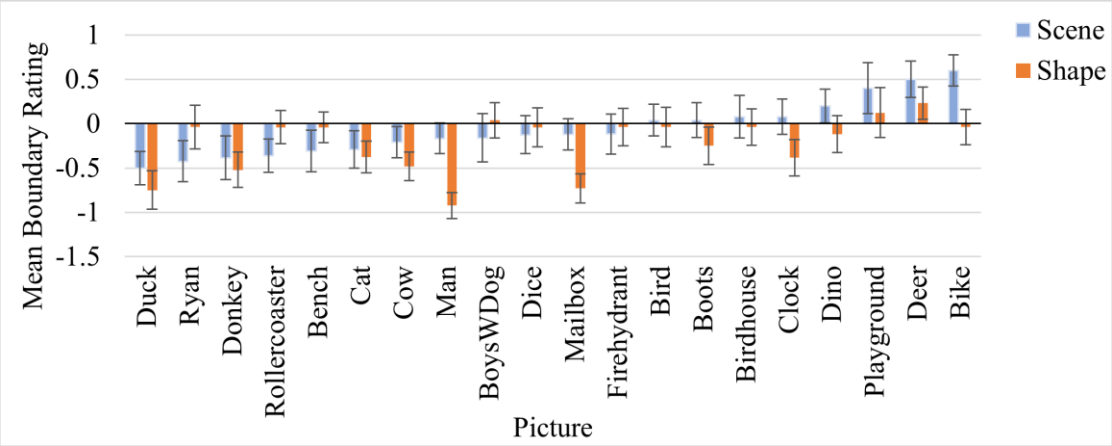

Figure 14: Mean boundary ratings of the picture analysis of the WW Stimulus View in Experiment 2. Error bars indicate the .95 CIs. The blue ratings are of the Scene Group, the orange are of the Shape Group.

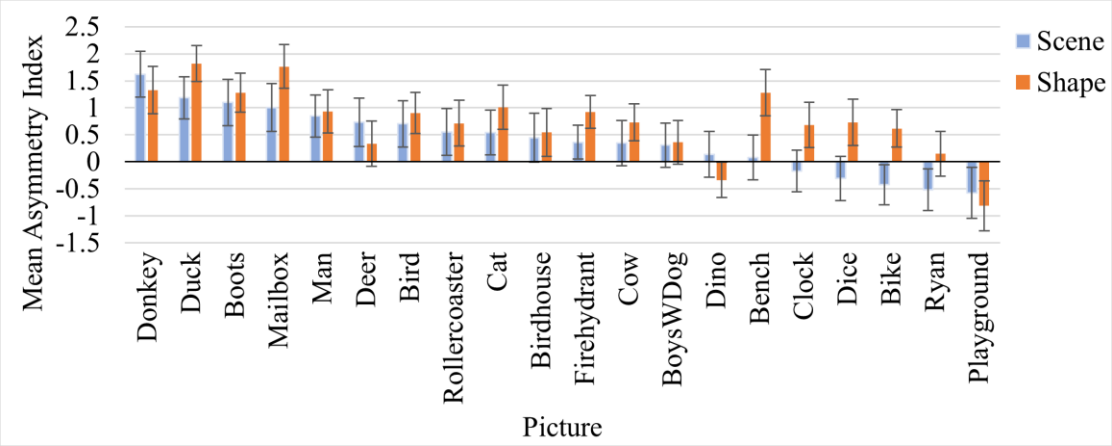

Figure 15: Mean asymmetry index scores for each picture in Experiment 2. Error bars indicate the .95 CIs. The blue ratings are of the Scene Group, the orange are of the Shape Group.

Participants' mean confidence ratings for the spatial task were 1.92 (SD = .43), in the Scene Group and 1.83 (SD = .43) in the Shape Group. In the spatial task, the Scene Group's mean proportion correct (M = .25, SD = .15) was better than chance, $t(103) = 5.45$, $p < .001$, $dz = .54$ as was the Shape Group's (M = .28, SD = .15), $t(103) = 7.62$, $p < .001$, $dz = .75$. They were not statistically different from each other, $t(206) = 1.37$, n.s. The Scene Group chose the correct column but the incorrect cell (M = .26, SD = .13) better than chance, $t(103) = 4.93$, $p = .004$, $dz = .48$, as well did the Shape Group (M = .23, SD = .10), $t(103) = 2.96$, $p < .001$, $dz = .29$. However, their results differed in the incorrect cell row accuracy. The mean proportion correct in the Scene Group (M = .39, SD = .12) was not significantly different from chance, $t(103) = -.71$, n.s., but the Shape Group (M = .43, SD = .14) was, $t(103) = 2.35$, $p = .021$, $dz = .23$.

In sum, the brief presentation in Experiment 2, did not change the pattern of results observed in Experiment 1. Again, the Shape Group exhibited greater BE, even more so in the case of a brief presentation. The attention explanation provided in

Experiment 1 can explain these surprising results. Either scene construction occurs automatically in response to scene structure (forcing interpretation of boundaries as view boundaries), or our task was simply not strong enough to bias perception in the Shape Group from view-boundaries to object boundaries. In Experiment 3 we took a different approach, using more complex object shapes and demanding tasks which focused participants on the contours of the meaningful shapes in the Shape Group.

Chapter 4

EXPERIMENT 3

In Experiment 3, we cut scenes into more complex shapes, outlines of U.S. States (TX, NY, CA, FL). We created a more demanding task that would require participants to attend to the contours of each state in working memory. We implemented a normal/reversed task, where participants had to identify whether a state was normal or mirror reversed after viewing the state for 340 ms. The stimuli were tilted 45° leftward, upright, and 45° rightward, which would add a mental rotation aspect to our task (Shepard & Metzler, 1971). Our goal was to focus their attention on the contours of the object, so that the boundary would be assigned to the state. However, we wanted people to be able to remember the stimuli, so instead of making this a long-term memory design like the first two experiments, we made it a working memory experiment.

We had three between participant groups, the Baseline Control Group, the Shape Group, and the Scene Group. The Baseline Control and Shape Group were given the normal/reversed task, but the Baseline Control Group was not given a boundary memory task. The Scene Group was given an indoors/outdoors scene task and given a boundary memory task. If scene construction will occur when a scene is presented regardless of the interpretation, then the Scene and Shape Group should elicit BE similarly. However, if boundary ownership is a factor of scene construction and our task is strong enough, then the Shape Group's instructions and task should lead to less or no BE.

4.1 Methods

4.1.1 Participants

Participants were 318 University of Delaware native English-speaking students (214 females) who had volunteered to participate in the Department of Psychological and Brain Sciences Research Pool at the University of Delaware). Of these, eight were excluded prior to analysis because, contrary to instructions, they did not use the requested online device (laptop or desktop computer).

4.1.2 Stimuli

Stimuli were 24 close-up images from Kreindel & Intraub (2017: Experiment 2) and Intraub & Dickinson (2008). They were cut into four U.S. state-shapes (New York, California, Florida, and Texas): upright and 45° rotated to the left or right using Pixlr©. Eight additional stimuli were created to serve as practice trials.

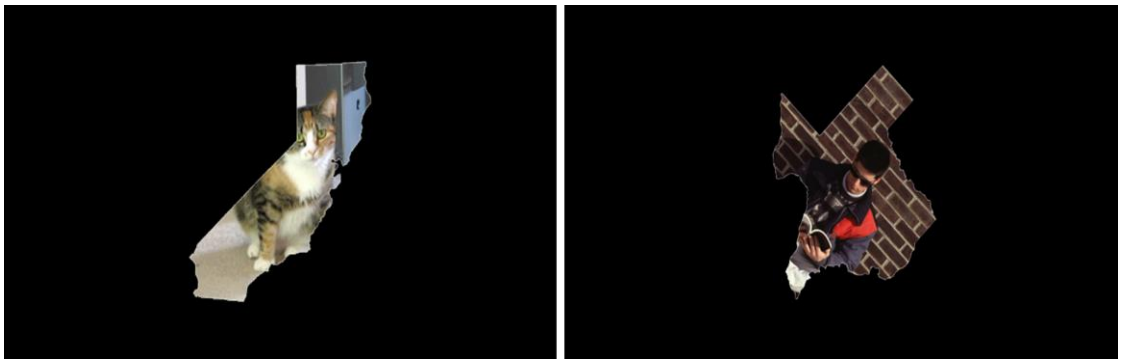

Figure 16: The left pane shows a cat in reversed upright California. The right pane shows a man in a 45° rightward tilted Texas.

4.1.3 Apparatus

This online experiment was programmed using PsychoPy3 (v2021.2.3) and hosted on the Pavlovia platform. Participants signed up using SONA software administered by the Research Pool. We used the same VCR program as in experiments 1 and 2 to control image size and visual angle across different participants' monitors.

4.1.4 Design and Procedure

Participants were randomly assigned to one of three groups (between-group variable): Baseline Control Group, Shape Group, or Scene Group. The within-participant variable was the orientation of the stimulus (upright, 45° leftward tilt, and 45° rightward tilt). The order of the stimuli was pseudo-randomized such that no more than two orientations (0°, 45° leftward, 45° rightward) were consecutively presented. There were an equal number of normal and reversed states as well as orientations. Participants followed instructions for the virtual chin rest and then decided to proceed or exit the program after reading the consent form. Instructions followed.

The Baseline Control Group and the Shape Groups were instructed to focus all their attention on the briefly-presented state. Their task was to report if the state was normal or reversed. The Shape Group was told after their primary response, the stimulus would reappear and they would be given the same boundary memory task as Experiments 1 and 2. In contrast, the Scene Group was instructed to attend to the scene as if they were looking at the world through a state-shaped window and indicate as quickly as possible if the scene was an indoor scene or an outdoor scene. As in the Shape Group, they were instructed to rate the second image's boundary by the same boundary memory task.

In the 24 experimental trials, participants viewed a yellow fixation point on a black field and pressed the spacebar to initiate the trial. The fixation point remained on screen for 500 ms, followed by the stimulus for 340 ms and a visual noise mask. Participants were instructed to indicate their response during the mask, which timed out after five seconds. Following the task, only the Scene and Shape Groups were given the boundary memory task. Then participants rated their confidence using the same rating scale as the prior experiments. The Baseline Control Group's trials ended after they were given feedback. The Scene and Shape Group's procedure is shown in Figure 17.

After the test, participants responded to a gender question and indicated the type of device they had used (tablet and smartphone users were taken out). All sessions were completed within a half hour and participants were awarded .5 credits.

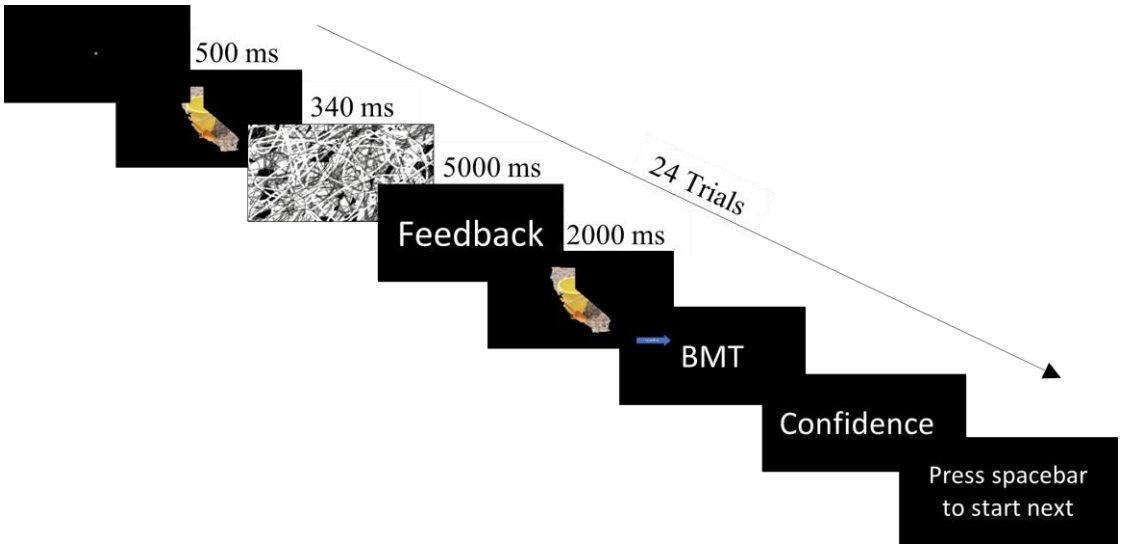

Figure 17: The procedure for the Scene and Shape Group.

4.2 Results and Discussion

As stated in our preregistration, we only allowed people who could identify at least three out of four states' outlines to sign up for our study. However, as the semester went on, too few participants signed up. To solve this problem, we opened the experiment for everyone, but we put the four states quiz as part of the experiment and then filtered out participants who failed to name three or more. We also removed participants who had DRPs more than or equal to 3SD from the mean.

There was a significant difference in the mean number of DRPs between the Scene Group (M = .59, SD = 1.14) and the Shape Group (M = 2.24, SD = 3.95), $t(192) = 4.00$, $p < .001$, $dz = .58$. Participants' mean confidence ratings were 2.3 (SD = .49) in the Scene Group and 2.3 (SD = .48) in the Shape Group. This was not in our preregistration, but we also compared participants' mean confidence ratings for left tilt, no tilt, and right tilt. A one-way ANOVA found no significant difference between left tilt (M = 2.32 SD = .51), no tilt (M = 2.33 SD = .50), and right tilt (M = 2.33 SD = .52) across groups, $F(2,392) < 1$. An analysis of the normal/reversed task for the Baseline Control and Shape Group revealed that the Shape Group was fully attending to the task as the mean proportion correct for the Shape Group (M = .69, SD = .17) was not statistically different from the Baseline Control Group (M = .73, SD = .14), $t(195) = 1.84$, $p = .07$, $dz = .26$.

Analysis of boundary ratings showed that BE occurred in both groups. The mean boundary rating in the Shape Group (M = -.26 SD = .40) was significantly lower than 0 (same), t $t(95) = 6.63$, $p < .001$, $dz = 6.77$, as was the Scene Group's (M = -.22 SD = .40), $t(99) = 5.45$, $p < .001$, $dz = 5.45$. To compare the groups, a 2 x 3 Mixed ANOVA, Group (Scene, Shape) x Tilt (Left, None, Right), was conducted on the boundary ratings. There was no main effect of Group $F(1,192) = 1.12$, or Tilt,

F(1,192) = 1.12, nor was there an interaction effect, F(1,192) = 2.44. The results of this analysis are shown in Figure 18.

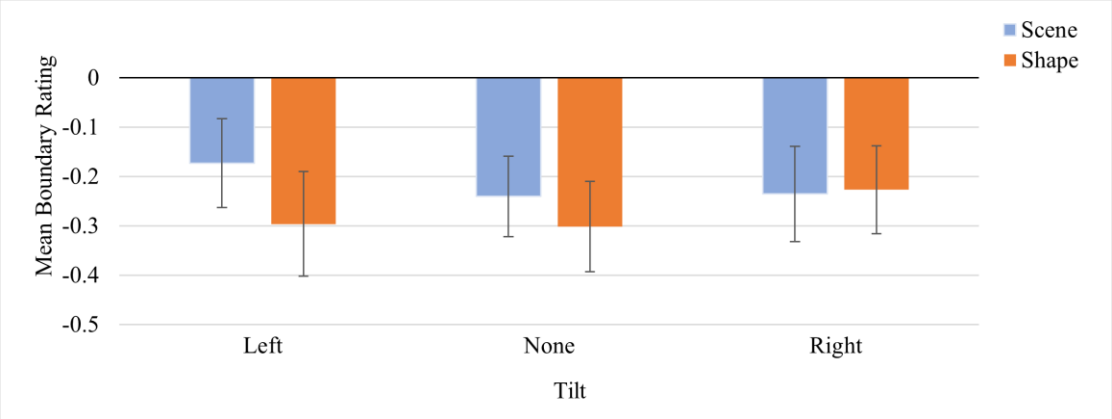

Figure 18: Mean boundary ratings across groups and tilt. Error bars indicate the .95 CIs.

To determine that BE occurred holistically, we calculated the mean boundary rating for each picture with tilt as a factor and found that most pictures elicited BE or no directional distortion for the Scene Group (Figure 19) and Shape Group (Figure 20).

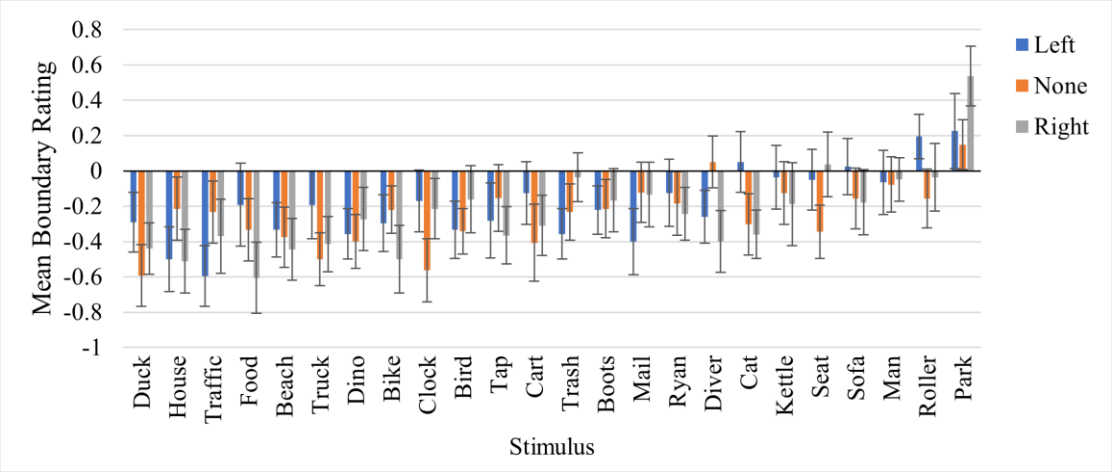

Figure 19: Mean boundary ratings of the picture analysis of the Scene Group of Experiment 3. Error bars indicate the .95 CIs. The blue ratings refer to the leftward tilt, orange refer to no tilt, and gray refer to rightward tilt for each picture.

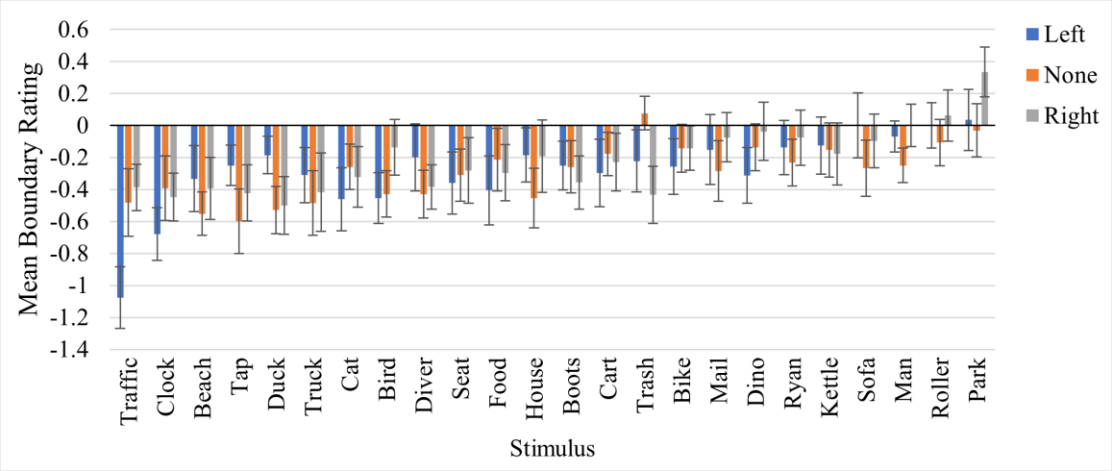

Figure 20: Mean boundary ratings of the picture analysis of the Shape Group of Experiment 3. Error bars indicate the .95 CIs. The blue ratings refer to the leftward tilt, orange refer to no tilt, and gray refer to rightward tilt for each picture.

We were curious about whether the different levels of tilt led to different reaction times for the normal/reversed task between left tilt, (M = 1090 ms, SD = .47), no tilt (M = 1000 ms, SD = .43), and right tilt (M = 1060 ms, SD = .45), but this effect was not significant $F(2,394) = 2.36$. This was not in our preregistration, but we wanted to see if there may be any correlation between the boundary rating and the normal/reversed proportion correct in the Shape Group. We theorized that if there was not a correlation between these two factors, it would provide more support for scene construction occurring regardless of interpretation and we found that there was not one, $r(93) = .03$, $p = .80$.

During analysis, it was clear that some participants in the Shape Group may not have attended the primary task. To address this, we excluded the boundary ratings for the Shape Group participants whose normal/reversed proportion correct fell below the 95% confidence interval of the mean. This excluded participants who got less than 16 correct than the 24 trials (41 excluded). An independent samples t-test looking at the boundary ratings found that the Scene Group (M = -.22 SD = .40) and these Shape Group participants (M = -.27 SD = .37) were not statistically different from each other, $t(153) = .85$, $p = .40$.

To explore the data further we eliminated responses in which participants' confidence ratings were 'not sure.' We reasoned that a difference may be observed if we removed cases where participants reported a lack of confidence. We conducted an independent samples t-test in boundary ratings between the Scene Group (M = -.21 SD = .43) and the Shape Group (M = -.29 SD = .19) and again, there was no significant difference, $t(153) = 1.07$, $p = .29$.

In sum, both the Shape Group and the Scene Group exhibited significant BE, and no difference between the groups was observed. Even the demands of determine whether tilted U.S. states were normal or reversed, focusing attention on familiar object contours had no effect on BE. In this working memory task, the Shape Group did not show the heightened BE we observed in the long-term memory tasks in Experiments 1 and 2. Conducting a correlation between the normal/reversed task accuracy and boundary ratings revealed that these tasks seem to be independent of one another. Results suggest that the presence of scene properties automatically elicits scene construction.

Chapter 5

GENERAL DISCUSSION

Boundary extension was elicited by photographs of scenes that were cut into meaningful shapes, such as a hand, heart, or puzzle piece (Experiments 1 & 2) or U.S. states (Experiment 3). Tasks intended to bias interpretation of the boundaries as object-boundaries, eliminating BE did not eliminate BE. Tasks included instructions, post stimulus questions, and a spatial position task (Experiments 1 & 2) and in Experiment 3, a demanding normal/reverse task with scene cut into the shapes of familiar U.S. states (Experiment 3). In fact, in the long-term memory tests in Experiments 1 and 2, BE was greater in the Shape Group. In Experiment 3, the same amount of BE occurred in both groups. As we will discuss, scene construction seems to be elicited by the presence of a scene. Boundary ownership automatically is perceived as a view boundary, even when the boundary itself is a meaningful shape.

In Experiment 1 (3 second duration), our instructions intended to bias boundary to the object led to a change in BE; the mean boundary ratings in our identity trials (CC, WW) showed more negative boundary ratings in the Shape Group compared to the Scene Group, indicating more BE in the Shape Group. The WW trials in the Shape Group led to a mean boundary rating significantly lower than zero (indicating BE), whereas there was no directional distortion in the Scene Group. The distractor trials (CW, WC) found BE in both the Scene and Shape Group, but the difference between them was not significant. While finding higher BE in the Shape Group was not what we predicted, previous research has found that when participants have divided attention when viewing scenes, it can lead to higher BE (Intraub et al., 2008).

The multisource model posits that if the quality or resolution of visual memory is lessened, the difference between the visual information and the constructed information becomes fuzzier, and people are not as able to distinguish them as well, leading to a higher acceptance of constructed memory as visual memory, resulting in more BE. Our participants viewed the stimuli as having a view boundary, and the Shape Group's post stimulus question drew their attention away from the scene. In a sense imposing a shape interpretation may have created a situation like the dual-task condition in Intraub et al. (2008). This may have led to a weaker memory for visual information and caused the Shape Group participants to accept more of the constructed space as having been seen than the Scene Group. Other factors such as demands on object perception such as changing an object's colors to be abnormal or inverting the views have also been shown to lead to higher BE (Hale et al., 2016; Beighley & Intraub, 2016).

We reasoned that if we gave the same instructions but limited the duration to a brief glimpse (340 ms), then this might provide a strong means of shifting the boundary ownership (Experiment 2). However, we found comparable results in Experiment 2. The mean boundary ratings for the identity trials had more BE in the Shape Group compared to the Scene Group. The WW ratings for the Shape Group led to a mean boundary rating lower than zero, while the Scene Group had no directional distortion, just as in Experiment 1. Our distractor trials led to BE in both groups, but in brief presentation, BE was prevalent more in the Shape Group than the Scene Group. The Shape Group's CW trials led to a mean boundary rating lower than zero, indicating that participants thought that the picture was too close up even when tested with a wider picture. The results from these two experiments indicate that scene

construction occurs automatically in the presence of a scene, or perhaps our task, even in brief presentation, was not strong enough to shift boundary ownership.

In Experiment 3, we created a more demanding task where participants had to attend to the contours of a more complex set of objects (shapes of U.S. states) while on two thirds of the trials, likely needing to mentally rotate the objects to decide if they were normal or reversed. Given the nature of the normal/reversed task, we hypothesized that participants would have to focus closely to the contour of the states, interpreting the boundaries as object boundaries. Importantly, there was no difference in normal/reversed performance between the Shape Group and Baseline Control Group, suggesting that the Shape Group was fully attending to the task.

In the boundary rating task, however, both groups showed BE, and there was not a significant difference between the groups nor was there an effect of rotation on BE. The lack of a difference between groups may be due to the working memory design of Experiment 3 compared to the long-term memory design of the first two experiments. This not only causes a longer period between presentation and test; it also includes a larger memory set size (twenty stimuli vs. one stimulus). These factors create a larger load on memory, which leads to weaker memory and more errors for the stimuli. This could explain why BE for the close views was greater for Experiments 1 and 2 compared to Experiment 3. Memory errors were more prevalent, which may have also accentuated the difference between the Scene and Shape groups.

Another possibility for the lack of difference may be due to the task itself. We ran a correlation to see if there was a relationship between the boundary rating and normal/reversed proportion correct for the Shape Group to see if attending more to the normal/reversed task led to less BE, as they may have attended to the scene less. There

was no correlation between those two measures, so perhaps it could be that the normal/reversed task is a completely independent process that does not affect scene construction. The spatial tasks in Experiments 1 and 2 were also a memory task, which may have been interfering with the visual memory for the stimuli, but the normal/reversed task may not have that property.

Before we accept the conclusion that scene construction is automatically elicited when a scene is presented, there are a couple of follow-up studies that we are running. One explanation is that depth cues in scenes are what trigger scene construction to elicit. In one experiment, we are replicating Experiment 2 but with line drawing versions of our scenes. They are clearly scenes, but without strong depth cues which may allow perception of object boundaries. We also created an experiment with a thicker border that has a contrasting color from the background. Perhaps causing the shape to stand out more will result in an easier manipulation of the boundary perception. If these steps do not eliminate or reduce BE, it may simply be the case that depictions of scenes invariably elicit scene construction.

In conclusion, attempts to change the interpretation of view boundaries to object boundaries by cutting scenes into meaningful shapes and creating tasks that focus on the shapes did not eliminate boundary extension. Boundary extension may be a strong chase of "good continuation." There is evidence that Gestalt grouping processes can occur without attention (Lamy et al., 2006). Perhaps scene construction beyond the edge of a view is a similar type of process. People are capable of understanding occluded views of the world, through foliage, crowds, and apertures. There is adaptive value in placing an occluded view into its larger expected context

and anticipating upcoming layout, whether the shape of the view is rectangular or abstract or meaningful shape.

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Appendix

IRB/HUMAN SUBJECTS APPROVAL

Institutional Review Board
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

DATE:	November 10, 2020
TO:	Helene Intraub, PhD
FROM:	University of Delaware IRB
STUDY TITLE:	[1672763-1] Spatial Cognition and Attention
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
EFFECTIVE DATE:	November 10, 2020
REVIEW CATEGORY:	Exemption category # *(3)*

Thank you for your New Project submission to the University of Delaware Institutional Review Board (UD IRB). According to the pertinent regulations, the UD IRB has determined this project is EXEMPT from most federal policy requirements for the protection of human subjects. The privacy of subjects and the confidentiality of participants must be safeguarded as prescribed in the reviewed protocol form.

This exempt determination is valid for the research study as described by the documents in this submission. Proposed revisions to previously approved procedures and documents that may affect this exempt determination must be reviewed and approved by this office prior to initiation. The UD amendment form must be used to request the review of changes that may substantially change the study design or data collected.

Unanticipated problems and serious adverse events involving risk to participants must be reported to this office in a timely fashion according with the UD requirements for reportable events.

A copy of this correspondence will be kept on file by our office. If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.

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