EXAMINING THE EFFECTS OF REAL-WORLD EXPERIENCE ON LAB-BASED SCENE MEMORY

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Abstract

Boundary extension (BE) is as an error in scene memory, such that participants retrieve details beyond the given boundaries of a scene image. Boundary contraction (BC) is the opposite effect, whereby participants retrieve less context within the boundaries of a given scene image. Some research supports the view that BE reflects (re)construction of the scene from an internal representation that was formed, whereas other research supports the view that BE (and BC) emerge from image-based properties. This study tested the influence of familiarity on scene recognition through the comparison of lab-based encoding of images of pre-experimentally familiar (real-world) places with images of unfamiliar places. There was a tendency for BC across both image conditions, with evidence of maintained, and an instance of greater, BC for familiar than unfamiliar scene images. Importantly, the lack of evidence for increased BE with greater familiarity favours an image-based theoretical account of BE and BC.

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Table of Contents

Abstract ii

Acknowledgements iii

Table of Contents iv

List of Tables vi

List of Figures vii

Chapter 1: Introduction and Literature Review 1

1.1 Scene Construction Theory 1

1.1a Internal Representations and Memory 2

1.1b Multisource Model 3

1.2 Visual Composition Theory 4

1.3 Influence of Prior Knowledge and Experience 5

1.4 Aims of Current Study 6

Chapter 2: Method 8

2.1 Participants 8

2.2 Stimuli 10

2.2a Pilot Testing for Stimuli Selection 10

2.2b Scene Image Stimulus Sets 11

2.3 Procedure 14

2.3a Consent and Pre-screening Survey 14

2.3b RSVP Boundary Rating Task 14

2.3c Familiarity Ratings 16

2.4 Statistical Analysis 16

Chapter 3: Results 18

3.1 Bologna Sample 18

3.2 Toronto Sample 22

Chapter 4: Discussion 25

4.1 Summary of Findings ... 25
4.2 Findings in Context ... 25
4.3 Limitations and Future Directions ... 29
4.4 Conclusions ... 33
References ... 34
Appendix A ... 39
Appendix B ... 42
Appendix C ... 44
Appendix D ... 49
Appendix E ... 50

List of Tables

Table 1 *Demographic Characteristics of Participants* 9

Table 2 *Toronto Subsamples* 9

Table 3 *Boundary Ratings from Slider Scale Responses* 18

List of Figures

Figure 1 *Examples of Familiar and Unfamiliar Scene Images* 12

Figure 2 *Diagram of Example Trial* 15

Figure 3 *Boxplot of Familiarity Rating by Image Condition* 17

Figure 4 *Mean Boundary Rating and Standard Error by Image Condition* 19

Figure 5 *Range of Boundary Responses for Each Participant by Image Condition* 20

Figure 6 *Mean Boundary Rating by Mean Familiarity Rating for Each Image Condition* 23

Figure 7 *Images That Showed the Highest BE and BC* 24

Chapter 1: Introduction and Literature Review

There are many biases that influence the way in which we perceive and represent the world around us. One such bias is boundary extension (BE), a visuospatial phenomenon that is observed as an error in scene memory, such that participants incorporate details beyond the given boundaries of a scene image that was previously viewed (Intraub, 2010, 2012; Intraub & Richardson, 1989). In typical demonstrations of BE, participants briefly view an image and are then asked if they recognize a subsequent image of the scene as appearing closer than, farther than, or identical to the original image. The idea is that at initial presentation of an image, the brain extends the representation beyond its given boundaries, so that at test, the same image will be perceived by the observer as closer in view than what was seen before, yielding BE. In this way, BE may be considered a bias in incorporating additional context within the internal representation formed during perception. Here we test whether this bias is influenced by pre-existing representations of the scene represented by the image studied.

1.1 Scene Construction Theory

When an internal representation of a scene image is formed, participants engage in scene construction; embodying visual and spatial information to represent the view of a scene in their mind's eye (Hassabis & Maguire, 2007). Incorporating extra visual detail and context as a product of scene construction is thought to drive BE and relies on the hippocampus (HPC) (Maguire et al., 2016). Recent research has implicated the HPC and ventromedial prefrontal cortex (vmPFC) in BE: individuals with lesions to these regions show a paradoxical effect, such that they are not vulnerable to BE and, instead, show more accurate scene memory than controls (De Luca et al., 2018; Mullally et al., 2012). Together with complementary neuroimaging evidence (Chadwick et al., 2013), these findings have been interpreted in terms of scene construction theory of HPC and vmPFC function, whereby the HPC and vmPFC are viewed as playing critical roles in constructing scenes and integrating scenes within a broader schema, respectively (Maguire et al., 2016; Mullally et al., 2012; Mullally & Maguire, 2013).

Scene construction theory would predict BE as the viewers attempt to reconstruct the previously viewed scene, incorporating additional context from experience-driven processing. By this same view, contraction of boundaries would not be expected. Separate research, however, has found evidence of an opposite effect, known as boundary contraction (BC), and even normalization[1] – regression toward an average view of a scene image– calling into question theories of BE that are grounded in scene construction. Indeed, the first study to observe the tendency to extend boundaries of a scene image by Intraub and Richardson (1989) noted that, at times, participants contract the boundaries of a scene. This study, and many others to follow, found that BE is strongest for close-up views, and as the viewing angle of the scene image increases, extension of boundaries decreases. As views become increasingly wider in angle and more surrounding context is incorporated into the scene, normalization and BC are more commonly observed (Bainbridge & Baker, 2020; Lin et al., 2022).

1.1a Internal Representations and Memory

When viewing an image quickly, especially those with a greater level of detail, participants may only extract the gist of the image. At test, participants may rely on a more general gist representation rather than a reconstruction of a partial view of a larger scene, leading to

[1] The effect of normalization has been reported when the pattern of boundary responses shows no clear directional bias and is thought to be fundamentally different from BE and have different underlying mechanisms (Intraub et al., 1998), occuring most often when there is lack of context surrounding the object (McDunn et al., 2016). Other studies have suggested that this is not the case, and that normalization represents a transition point between extension and contraction that corresponds with the "goodness of view" or prototypical view of a scene (Lin et al., 2022; Park et al., 2021).

normalization as a result of memory, rather than a perceptual effect (McDunn et al., 2016). Spatial details are important for the gist of a scene, allowing the observer to make inferences about what they are perceiving (Oliva & Torralba, 2006). An internal representation formed using this information must be formed to have something to compare to when the initial sensory input (i.e., the first presentation of the scene image) is removed and replaced by the test image. Schemas can be thought of as “reference templates” that are used to assimilate new information (Gilboa & Marlatte, 2017, p. 618). The vmPFC is involved in this process and activated when schemas are activated during gist extraction (Gilboa & Marlatte, 2017); this may explain the lack of BE effects shown in those with lesions to the vmPFC similar to those with lesions to the HPC (De Luca et al., 2018). Intraub (2010) noted the importance of reference frames for representation of a scene, highlighting the spatial nature of this representation. In cases of damage to the HPC and surrounding brain structures within the medial temporal lobe, gist and semantic representation s are though to compensate for lack of detail in memory (Robin & Moscovitch, 2017). Even if there is damage to the HPC, gist and semantic details are retained for remote memories, where deficits are in the reconstruction of events and recall of specific details (Rosenbaum et al., 2009). Therefore, it is assumed that previous experience with a scene will affect how visual information is assimilated through the reference from afforded by the schema for a given scene context.

1.1b Multisource Model

Intraub has since proposed the multisource model (Intraub, 2010), which is centered on the idea that multiple sources of information are processed in collaboration to achieve the goal of perception, including sensory, spatial, contextual, and amodal information. The fundamental principle is that we perceive images as a proxy view of a scene that is continuous beyond the given view; we can reasonably expect what is likely to exist beyond that window. Amodal processing refers to top-down processing of an image in its larger context that continues beyond the given view provided by an image (Intraub, 2010; Intraub & Bodamer, 1993). Participants can readily predict what may exist beyond the boundaries of a given image based on schemas, that is, abstract knowledge structures that allow one to form representations or expectations based on previous experience (Alba & Hasher, 1983; Brewer & Treyens, 1981; Ghosh & Gilboa, 2014).

1.2 Visual Composition Theory

Bainbridge and Baker (2020) took recent interest in the stimuli used in BE studies and noted that image stimuli typically comprise one focal or central object against a simple, uniform background. In their investigation of how the visual composition of scenes elicits BE and BC, Bainbridge and Baker found that BE most often occurred for images that contained very few objects and that were taken from a close-up perspective, which they referred to as object-oriented. By contrast, BC was found to most often occur for images that had several objects presented from a farther distance and that were generally concentrated along the midline or horizon, referred to as scene-oriented (Bainbridge & Baker, 2020). They also argued that scene-oriented images (i.e., those with a more complex view of a wider array of objects) better represent a natural, more realistic scene than object-oriented images that are more typically used as stimuli in studies of BE. Bainbridge and Baker (2020) further noted that scene-oriented images largely result in a symmetric distribution of extension and contraction. They posited that it is the visual composition (distance of objects from view, distance between objects, and the number of objects present) of a scene that drives our subsequent memory for scenes rather than an automatic process that integrates sensory and schematic information (Bainbridge & Baker, 2020).

1.3 Influence of Prior Knowledge and Experience

BE research has suggested that the background, or context surrounding the focal object, is important to activate amodal processing to yield BE (Gottesman & Intraub, 2002; Hale et al., 2015; Intraub, 2010; McDunn et al., 2016). The image itself provides contextual information that guides what can be expected around the focal point and most salient aspect of the image, which is most prominent in close-up views (Intraub et al., 1998). In the case of wide-angle views of scenes that include more visual elements and detail, normalization or BC may occur because the plethora of information presents greater visual processing demands and hinders extrapolation of information beyond the given view, decreasing amodal processing and decreasing BE. Schemas could also hold a prototypical view associated with a scene, one that is highly probabilistic (Lin et al., 2022) and thought of subjectively as the "best-looking view" (Konkle & Oliva, 2007; Park et al., 2021). A prototypical view of a scene informs our internal representation, leveraging prior knowledge and our understanding of statistical regularities in our environment to increase representational accuracy, especially in the presence of noise or uncertainty (Lin et al., 2022). Perhaps expectations formed by amodal processing during perception are informed by schemas, and this attention to schemas leads to incorporation of detail beyond what was available in the scene image but could realistically exist beyond the image boundaries. If one has prior experience and therefore a pre-existing representation of the scene, this extrapolation process may look different compared to an image from a scene the observer has never seen or experienced before. Taken together, this suggests an interaction between schematic knowledge and visual perception that could expect prior knowledge and experience of a scene to lead to, and possibly enhance, BE because of increased amodal processing, or lead to increased contraction because of processing demands and competition between amodal processing and visual perception.

Prior knowledge and experience with objects and scenes have not been previously considered in studies investigating BE and BC. How might visual properties of objects and scenes interact with the internal representations for stimuli that are familiar? We spend more time in familiar than unfamiliar places, so our knowledge and experience with these places may induce a bias in the extent of spatial context that we recall when a scene is highly familiar. Thus, it is possible that pre-existing memory representations of visual-spatial context and/or schematic information interact with perception when a scene is highly familiar versus unfamiliar. Therefore, comparisons of pre-experimentally familiar to unfamiliar stimuli may provide insight as to how internal representations and prior experience influence how an image is perceived, informing our understanding of the role of schematic information and experience on scene memory.

1.4 Aims of Current Study

The stimuli used in BE studies are typically comprised of close-up, object-centered images, and, to the best of our knowledge, BE has only been studied with pre-experimentally unknown scenes. There may be a difference observed in the bias if participants have prior experience with the scene stimuli. If we accept top-down processing beyond the scope of view of an image to occur as an automatic, intrinsic process, there may be differences in the internal representation if the observer knows what exists beyond the boundaries of a given image, compared to an image in which the view is naïve to what exists beyond the boundary. The objective of the current study is to examine how pre-experimental familiarity with a scene may show a difference in the extent of spatial context recalled for images that are sourced from environments that participants are familiar with. If scene construction best accounts for BE, then participants would be expected to be more prone to (re)constructing the context surrounding an object (i.e., BE) for familiar scenes that are associated with strong internal representations of objects and their surrounding context. If, on the other hand, BE and BC are consequences of the properties of images, participants would be expected to be less prone to BE if the scene contains a single object and the image is taken from a distance, whether the scene is familiar or unfamiliar.

Chapter 2: Method

2.1 Participants

Two independent samples were collected, one from Bologna, Italy, and another from Toronto, Canada.

There were 51 participants in the sample from Bologna, Italy. Two participants were excluded that reported they did not fully understand the study instructions. Participants were young adults, aged 18-35, recruited through the undergraduate participant pool for course credit at the University of Bologna. Participants were tested in person at the University of Bologna. This study was approved by the Bioethics Committee of the University of Bologna. Informed consent was obtained from all participants.

There were 195 participants in the sample from Toronto, Canada. Participants in this sample were young adults (ages 18-35) who live or have lived in Toronto, Canada and were fluent in English. This sample was comprised of four subsamples collected[2] (see Table 2 for breakdown). Participants were recruited through York University's Undergraduate Research Participant Pool (URPP), word-of-mouth and advertisements in Toronto (WOM), and through Prolific (https://www.prolific.co. The first three samples collected (URPP, WOM, Prolific 1) were tested on familiar Toronto landmarks. The fourth sample (Prolific 2) was tested on familiar landmarks located within Canada and the United States, including the landmarks from Toronto used with the previous samples[3]. In the analyses, participant data from all Toronto samples were combined. All participants were either compensated with course credit through URPP or compensated $15/hr. Unlike Bologna participants, all participants in Toronto were all tested

[2] In the Toronto sample, there was difficulty recruiting participants for York University that were familiar with Toronto stimuli. We then opted to recruit from other sources such as word of mouth and via Prolific.
[3] The stimulus set was expanded to include more landmarks outside of Toronto (within Canada and the United States) in attempt to get higher familiarity ratings of familiar stimuli from participants.

online. The second prolific sample was tested on Zoom (https://zoom.us/) with an experimenter present to help ensure compliance with the experimental condition, including use of a monitor and placement. This study was approved by the Research Ethics Boards of Baycrest Health Sciences and York University. Informed consent was obtained from all participants.

Prior to data collection, we ran a power analysis through G*Power 3.1. This calculation determined that 36 participants were needed to achieve 80% power (α= 0.05) with an effect size of 0.35 with a repeated-measures ANOVA (between factors). Consistent effect sizes have not been reported in the literature. A review by Hubbard et al. (2010) found that only one study reported effect size for BE, *d*=1.86, a large effect (Chapman et al., 2005). Since then, studies have BE have not reported effect size but have found a range of effects. We opted for a low to moderate effect size for a more conservative estimate.

Table 1

Demographic Characteristics of Participants

	Bologna	Toronto
Number of participants	49	195
Males, *N* (%)	34 (69.4)	79 (40.5)
Age at assessment (years), *M (SD)*	30.06 (4.66)	23.04 (5.15)
Education (years), *M (SD)*	18.0 (3.16)	15.0 (2.37)

Table 2

Toronto Subsamples

	URPP	WOM	Prolific 1	Prolific 2
Number of participants	107	17	48	23
Time collected	April 2023	April – May 2023	May 2023	July – August 2023
Familiar landmark stimuli	Toronto	Toronto	Toronto	North America

Note. Information about each of the subsamples that comprised the Toronto sample. Participants were recruited through York University's undergraduate participant pool (URPP), through word of mouth (WOM), and through Prolific. The second prolific sample was tested on a set of familiar landmark stimuli that included scene images from throughout North America, including Toronto.

2.2 Stimuli

2.2a Pilot Testing for Stimuli Selection

Participants. There were 150 participants in the Bologna pilot sample, recruited through the undergraduate participant pool for course credit at the University of Bologna. There were 113 participants in the Toronto pilot sample, recruited through the Undergraduate Research Participant Pool for course credit at York University.

Landmark and Image Stimuli Collection. First, familiar landmarks were searched for using Google (https://www.google.ca/) based on what would be most recognizable to participants in the respective city they were tested in. Second, unfamiliar landmarks were selected by finding a landmark that was similar in terms of the architectural features and overall visual appearance to each chosen familiar landmark and was hypothesized to be unknown to most participants in the respective city they were tested in (see example of familiar image and unfamiliar counterpart in Figure 1). A list of 30 familiar and 30 unfamiliar image stimuli was generated for each of the Bologna and Toronto participant samples to be subject to pilot testing. Images of each landmark were collected using Google Images; images were selected for depictions of landmarks that were central to the image, included a view of the whole landmark (as unobstructed as possible), and depicted a ground-view perspective (as best as possible).

Image Processing. All images were processed using the GNU Image Manipulation Program (GIMP) 2.10.30 (https://www.gimp.org/), a free and open-source image editor to calculate the proportion of the area of the central object in each image and to resize images accordingly. To equate image quality and resolution across images, images were resized to 800*600 pixels in GIMP. Images of landmarks were chosen so that the landmark was positioned in the centre of the image and was positioned parallel to the view of the image as much as possible. There is evidence to suggest that object orientation and aperture (Dickinson & LaCombe, 2014) and size (Bertamini et al., 2005) can influence how participants extend boundaries. Therefore, we omitted landmarks that are very tall and narrow or very small when selecting potential stimuli.

Pilot Procedure for Image Selection. All 60 images generated during landmark and stimuli collection were tested to generate a list of familiar and unfamiliar image stimuli to be used as stimuli in the experiment. In a pilot test run separately for the Bologna and Toronto samples, participants were shown each of their respective 60 images one at a time. Participants were asked to rate their familiarity with each landmark image on a Likert-scale from 1 ("Very familiar") to 4 ("Not familiar") and asked if they had visited the place before. Based on their individual responses, the 20 most familiar (with a rating less than 2.5) and most visited landmarks were selected for the familiar image stimulus set to be used in the experiment, and their respective unfamiliar counterparts were selected as unfamiliar stimuli (given that they each were rated as unfamiliar, with a rating greater than 2.5), providing the 20 unfamiliar images.

2.2b Scene Image Stimulus Sets

In both samples, stimuli consisted of a total of 40 coloured 800*600-pixel scene images, 20 familiar and 20 unfamiliar. Familiar scene images captured well-known landmarks within the city of Bologna and throughout the country of Italy for Bologna participants. For the Toronto sample, familiar scene images captured well-known landmarks within the city of Toronto for participants recruited through York University, word-of-mouth, and the first Prolific sample. Each of the buildings depicted in the unfamiliar scenes were located outside of the cities in which participants were tested and were rated as unfamiliar by participants who participated in the pilot study. Due to difficulties with recruiting participants who were familiar with the Toronto stimuli, an additional sample collected through Prolific in which the familiar image stimuli were expanded to include well-known landmarks in Canada and the United States. (See Figure 1

Examples of Familiar and Unfamiliar Scene Images for a pair of representative examples in each sample and see Appendix A for a full list of landmark stimuli used in each sample).

Figure 1

Examples of Familiar and Unfamiliar Scene Images

A

B 

Note. Images in the left column are familiar scene images, and images in the right column are unfamiliar scene images for participants in (A) Bologna, Italy, and (B) Toronto, Canada. A, first column: Fountain of Neptune in Bologna, Italy. A, second column: Fountain of Neptune in Messina, Italy. B, first column: Hockey Hall of Fame, Toronto, Ontario, Canada. B, second column: Buffalo Savings bank, Buffalo, NY, USA. (See Appendix for image sources).

Image Processing Analysis. The goal was for the landmarks to occupy on average a proportion of 0.3-0.4 of the total image area. The proportion of the image covered by the area of the landmark however was significantly different between the stimuli used in the Bologna sample (M=0.35, SD=0.12) and the Toronto sample [M=0.40, SD=0.07; $t(136)$=1.98, p=.010] with a small effect, measured using Cohen's d (d=.042). There was no difference in the proportion of the area occupied by the landmark in unfamiliar images between samples (p=.241), but a difference was found between familiar images (p=.01, cohen's d=.133). Within each sample, there was no difference in familiar and unfamiliar images in Italy (p=.43) or Canada (p=.804).

North America Subsample Stimuli Selection. In an attempt to achieve higher familiarity ratings in a second sample collected through Prolific for Toronto, we had participants rate their familiarity with a list of 50 scene images of well-known landmarks located in Toronto from the initial pilot experiment as well as additional landmarks, outside of Toronto, located throughout Canada and the United States that had not been included in the initial pilot experiment. Participants were presented with the name of all 50 landmarks and asked to rate their familiarity with each item, using a Likert-scale from 1 (“Very familiar”) to 4 (“Not familiar”) and if they had visited the place before. Based on each participant’s responses, 20 landmarks with the highest familiarity ratings were chosen along with their unfamiliar counterparts to be used in the main experimental task.

2.3 Procedure

2.3a Consent and Pre-screening Survey

In both samples, participants were presented with the consent form and, upon providing informed consent, they were then asked to provide basic demographic information, including their age, gender, and years of education, through Qualtrics (https://www.qualtrics.com/). In the Toronto sample, they were asked about their personal experience living in and visiting Toronto.

2.3b *RSVP Boundary Rating Task*

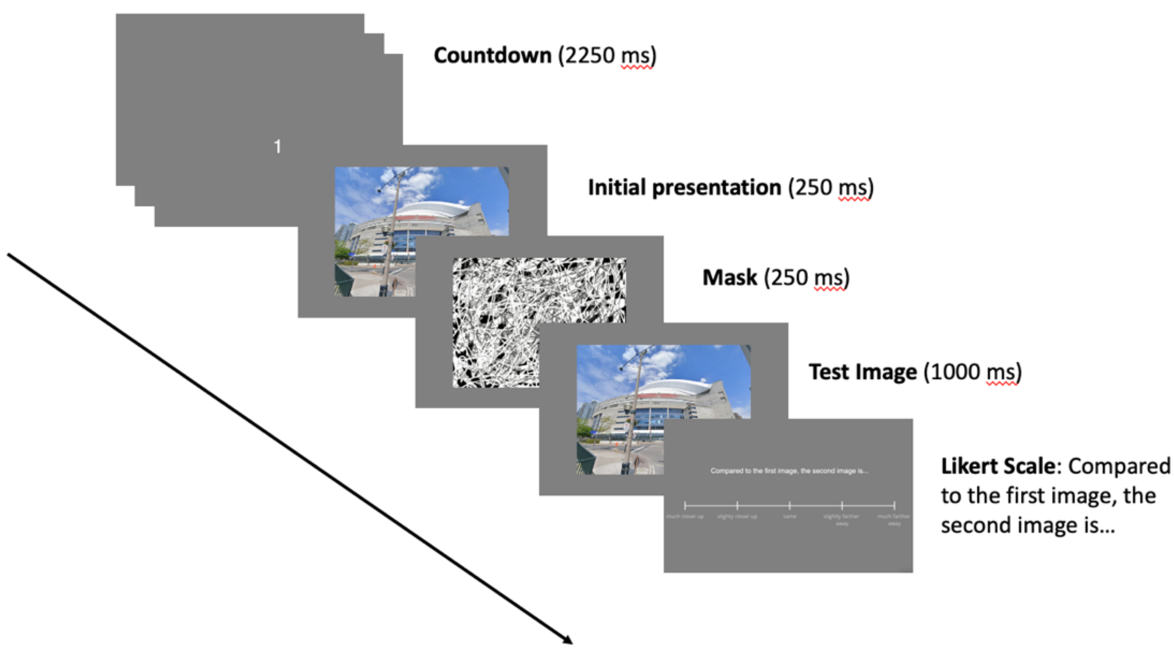
The main experiment was programmed using PsychoPy (Peirce et al., 2019) and hosted through the online platform Pavlovia (https://pavlovia.org/). Participants recruited in the second Prolific sample completed this task while on Zoom in the presence of the experimenter. Participants viewed 20 familiar and 20 unfamiliar images, randomly intermixed. Each image was presented for 250ms[4] within a rapid serial visual presentation (RSVP) format previously used to assess BE and BC (Bainbridge & Baker, 2020; Lin et al., 2022; Park et al., 2021). The viewing

[4] Studies of BE and BC typically display images for either 250ms or 15s, and studies have yielded BE when showing images for as rapidly as 42ms (Intraub & Dickinson, 2008), showing that the assessment of the comparison image is impacted within the first 265ms of the onset of the image (Czigler et al., 2013). We thus opted for 250ms, as BE occurs rapidly.

angle of the images was not altered.[5] Immediately following the first image, participants viewed a 250ms mask similar to masks used in previous studies of BE/BC (Czigler et al., 2013; Liu et al., 2016). As in previous BE/BC paradigms (Bainbridge & Baker, 2020; Lin et al., 2022), participants were then presented with the same image at the same viewing angle as the first presentation for 1000ms (see Figure 2). There were 40 of these trials for each 40 scene images: participants saw the image twice within each trial.

Figure 2

Diagram of Example Trial



Immediately following the second presentation, participants were presented with a recognition task in which they were asked to make a judgement on whether the test image was the same or different from the study image using a slider rating scale. The responses for this

[5] It is common practice in BE studies to have different image conditions in which the test image is the same or different from the initial presented image in terms of the viewing angle (i.e., close- up or wide-angle view).

continuous scale ranged from "much closer up" [-100] to "slightly closer up" [-50] to same view [0] to "slightly further away [50] to "much farther away" [100]. Participants were able to adjust the slider until they clicked on the continue button to advance to the next trial.

2.3c *Familiarity Ratings*

After the RSVP task, participants completed a final survey through Qualtrics in which they were presented with the same 40 images that were presented in the experiment and asked about their subjective experience with the landmark represented in each image. A first question asked participants to rate their familiarity with each landmark on a Likert-scale ranging from 1 ("Very familiar"), 2 ("Somewhat familiar"), 3 ("A little familiar), to 4 ("Not familiar"). Participants were then asked if they had visited the place before. Ratings of landmark familiarity served two purposes: it ensured that participants were staying on task, and they had a sufficient number of familiar images on which to base analyses. Responses to the question if participants had visited the place before were used as an additional check to gauge participants' familiarity and prior experience with landmarks. These responses were not used in the analysis but are shown in Appendix .

2.4 Statistical Analysis

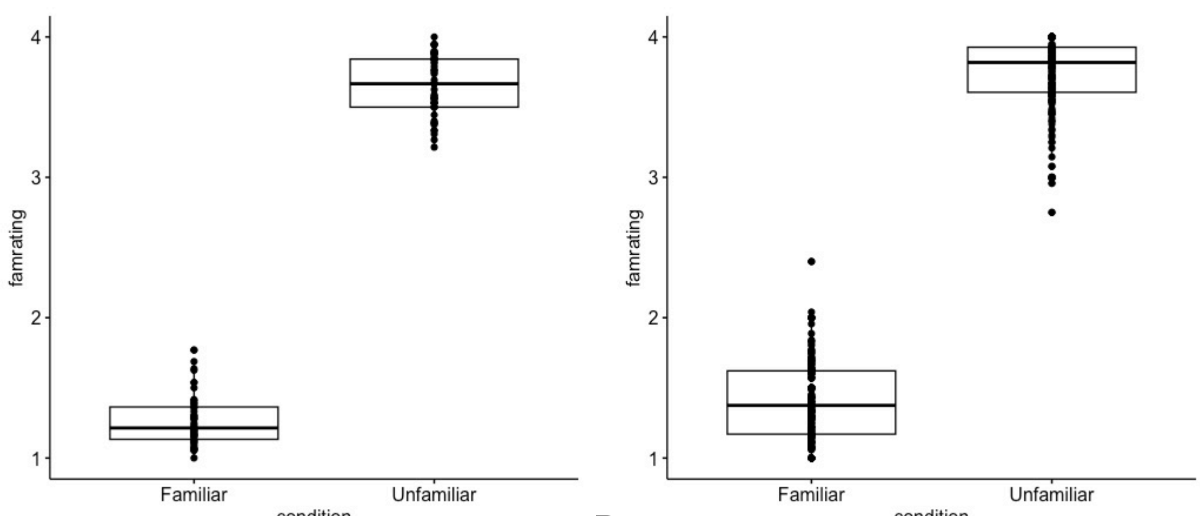
Statistical analyses were conducted using R studio (R Core Team, 2022). The raw score from the slider response was used to measure BE [-100,-1] and BC [1,100]. The mean slider response rating was compared between familiar and unfamiliar landmarks to determine the directionality and strength of the effect of familiarity on the bias. A t-test was used to see if the mean slider ratings for each image condition were greater than zero (showing an average contraction effect) or less than zero (showing an average extension effect). A repeated-measures ANOVA was used to compare means for each comparison group. Pearson's correlations were used to examine the relationship between familiarity rating and boundary response for each image.

In both samples, participants' responses for each image were assessed, and if an image from the familiar condition was rated as unfamiliar (score > 2.5) by a participant, then their rating for that image was excluded. The same was done for unfamiliar images if they were rated as familiar (score < 2.5). A boxplot of familiarity ratings is shown in Figure 3.

Outliers in both samples were assessed using the *rstatix* package in R (Kasssambara, 2023). Outliers were detected using boxplot methods in which they were indentified as extreme if the value of a given boundary response was above three times the interquartile range above the third interquartile range or below the first interquartile range. No participants in the Bologna sample and eight participants in the Toronto sample were identified as extreme outliers with respect to their boundary ratings (for both familiar and unfamiliar images). These outliers were excluded from the analyses.

Figure 3

Boxplot of Familiarity Rating by Image Condition



A **B**

Note. (A) Bologna, Italy sample; (B) Toronto, Canada sample. Reported with outliers.

Chapter 3: Results

3.1 Bologna Sample

For the Bologna sample, on average, images in both conditions showed BC, and this was significantly different from zero for familiar images, with a mean boundary rating of 5.91 (*t*[48]=3.57, p<.001, *95%CI*=[2.58, 9.25]), and unfamiliar images, with a mean boundary rating of 3.74 (*t*[48]=2.22, p=.03, *95%CI* =[0.35, 7.13]). This finding indicates an overall contraction effect, although it is the case that both BE and BC were observed in both image conditions (see Table 3). A repeated-measures ANOVA showed that familiar images showed greater BC than unfamiliar images [F(1,48)=5.55, p=.023, η^2=.009] (Figure 4). This is also reflected in the range of participants responses shown in Figure 5. The effect is relatively small (η^2=.009), reflected in no correlation between the mean slider response and the mean familiarity rating for each image in the familiar image condition (R=.314, p=.177), and in the unfamiliar image condition (R=-.028, p=.905) (Figure 6). Across all image stimuli, the five scene images that yielded the most BE and the five that yeilded the most BC (or least BE; shown in Figure 7) were visually examined for any patterns or features that may have been biased toward BE and BC, none were notable in these images.

Table 3

Boundary Ratings from Slider Scale Responses

	Bologna, Italy		Toronto, Canada			
Image condition	Familiar	Unfamiliar	Familiar		Unfamiliar	
n	49	49	187[a]	195[b]	187	195
M (SD)	5.91 (11.6)	3.74 (11.8)	4.90 (18.4)	1.58 (24.2)	4.25 (17.2)	0.79 (23.9)
Range	-23.0, 34.5	-38.2, 36.4	-72.1, 55.0	-98.4, 55.0	-63.4, 61.6	-94.1, 61.6
t	3.57	2.22	3.62	0.90	3.38	0.46
p-value	<.001	.030	<.001	.368	<.001	.644
CI	[2.58, 9.25]	[0.35, 7.13]	[2.23, 7.58]	[-1.87, 5.03]	[1.77, 6.73]	[-2.59, 4.17]

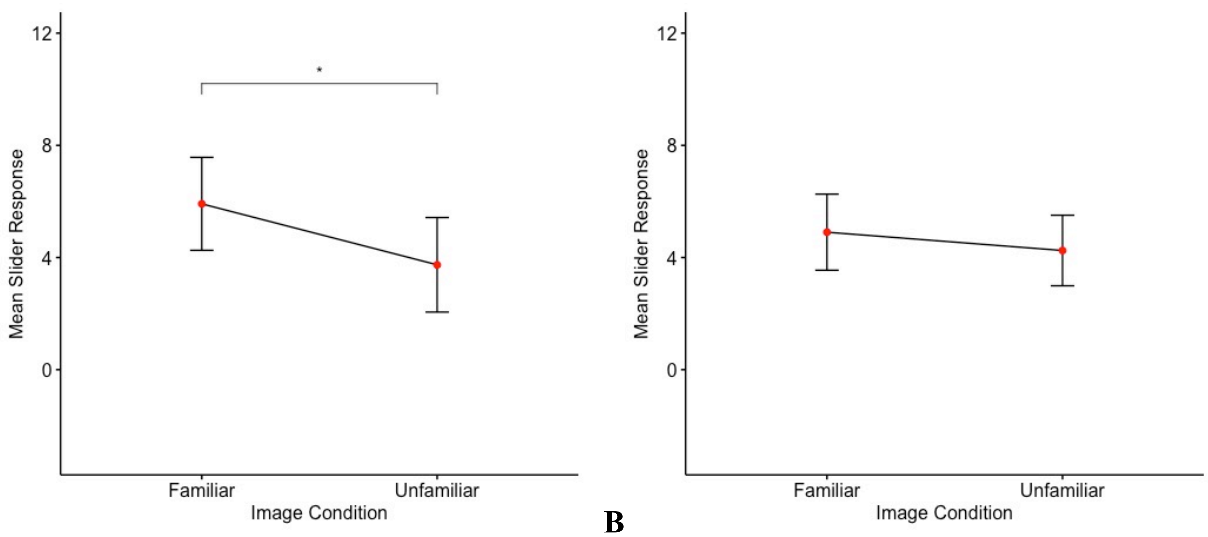
Note. The responses for this continuous scale range from “much closer up” [-100] to “slightly closer up” [-50] to same view [0] to “slightly further away [50] to “much farther away” [100]. A negative value reflects BE, and a positive value reflects BC. The range is based on the average responses for each participant across all trials for each image condition. A t-test used to test if mean boundary rating was significantly different from zero.

[a] n=187 without outliers

[b] n=195 with outliers.

Figure 4

Mean Boundary Rating and Standard Error by Image Condition



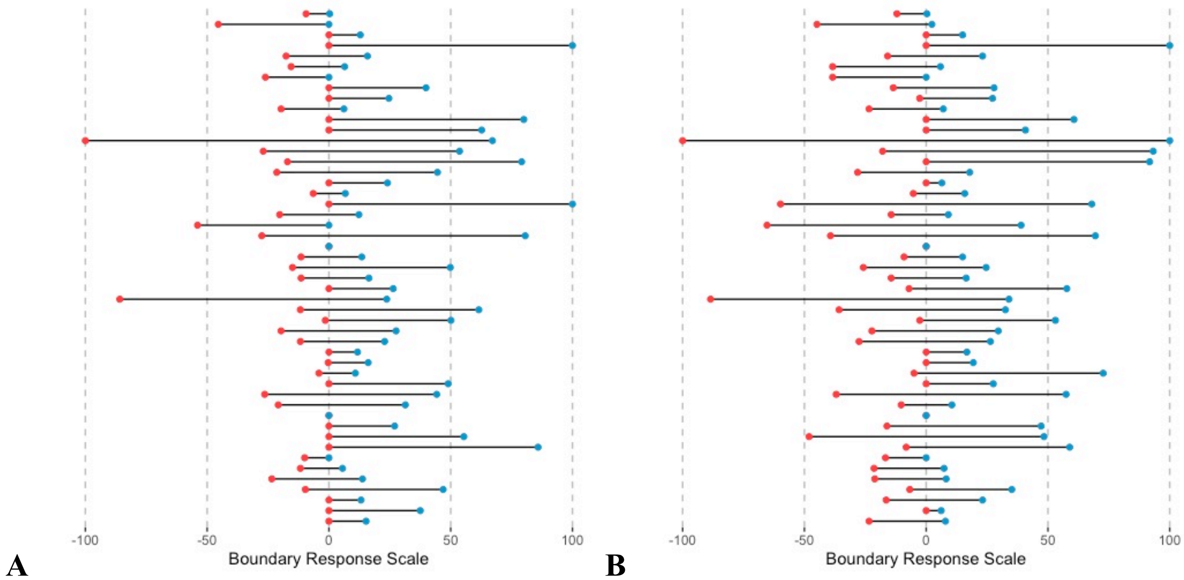
A **B**

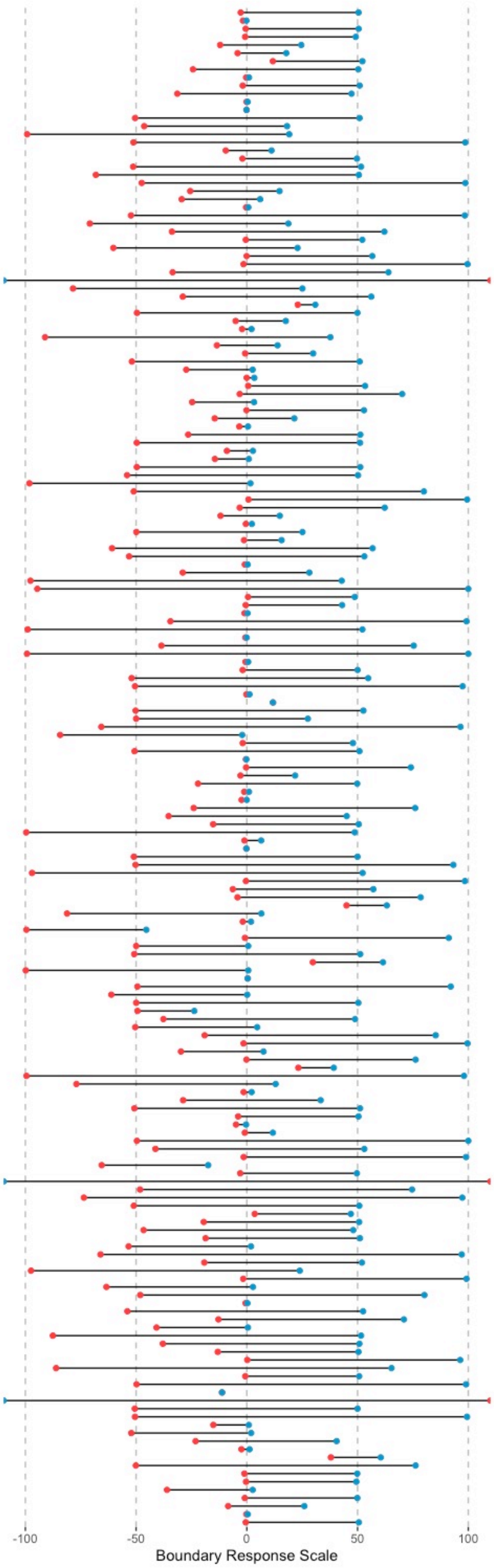
Note. The mean boundary responses for each image condition are shown with standard error in the (A) Bologna, Italy sample, and in the (B) Toronto, Canada sample. All reported without outliers.

*p<.05

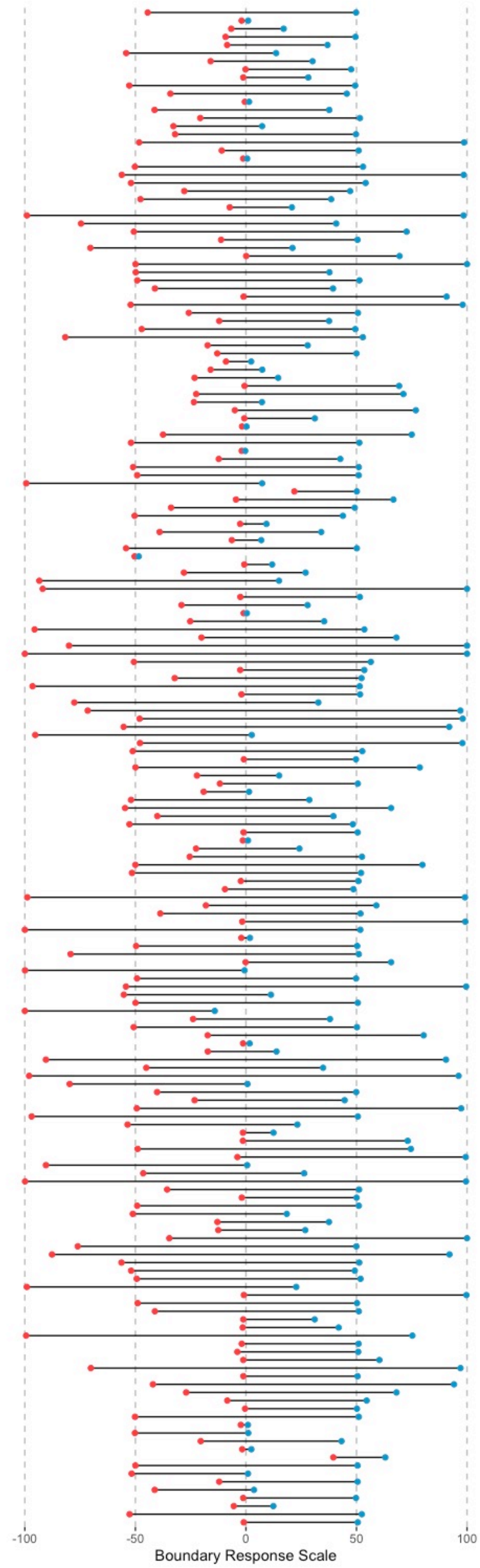
Figure 5

Range of Boundary Responses for Each Participant by Image Condition




-100
-50
0
50
100
Boundary Response Scale

C


-100
-50
0
50
100
Boundary Response Scale

D

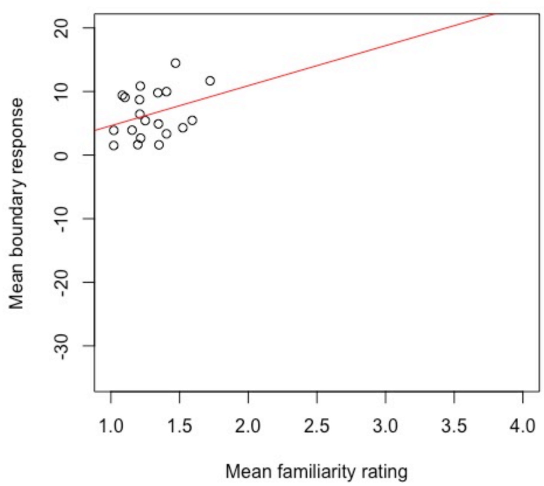
Note. Ranges are shown for each participant, with the red dot corresponding to the minimum value and the blue dot corresponding to the maximum value for boundary responses across all trials in each image condition. First row: Bologna, Italy sample for the (A) familiar and (B) unfamiliar image conditions. Second row: Toronto, Canada sample for the (C) familiar and (D) unfamiliar image conditions.

3.2 Toronto Sample

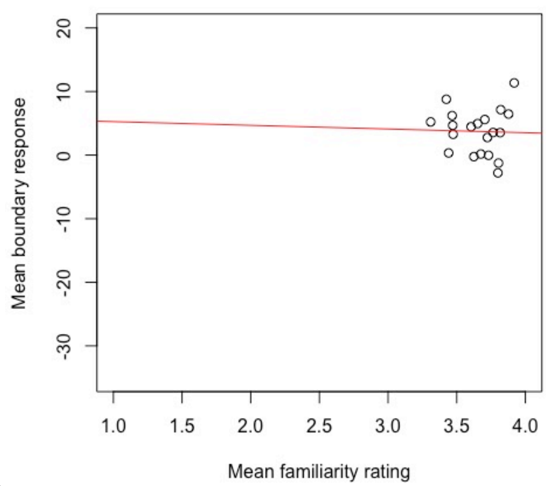
For the Toronto sample, on average, images in both conditions appeared to show BC for familiar images with a mean boundary rating of 4.90 (t[183]=3.62, p<.001, *95%CI*=[2.23, 7.58]) and unfamiliar images with a mean boundary rating of 4.25 (t[186]=3.38, p<.001, *95%CI*=[1.77 6.73]). However, without the removal of outliers the mean boundary ratings were not greater that zero (see Table 3), showing no directional bias, or normalization. Both BE and BC were also observed in both image conditions in this sample (see Table 3). A repeated-measures ANOVA showed that boundary ratings were not significantly different between familiar and unfamiliar images [$F(1,183)=0.555$, $p=.457$, $\eta^2=.0005$] (Figure 4) [with outliers: $F(1,191)=0.89$, $p=.347$, $\eta^2=.0004$]. Ranges of participants responses show variability between participants (Figure 5). Not surprisingly, a correlation between the mean slider response and the mean familiarity rating for each image was not apparent in the familiar image condition (R=.147, p=.342) (Figure 6) or the unfamiliar image condition (R= .040, p=.778) (with outliers: R=1.00, p=.321). Across all image stimuli, the five scene images that yielded the most BE and the BC (shown in Figure 7) were visually examined for any patterns or features that may have been biased toward BE and BC, none were notable in these images.

Figure 6

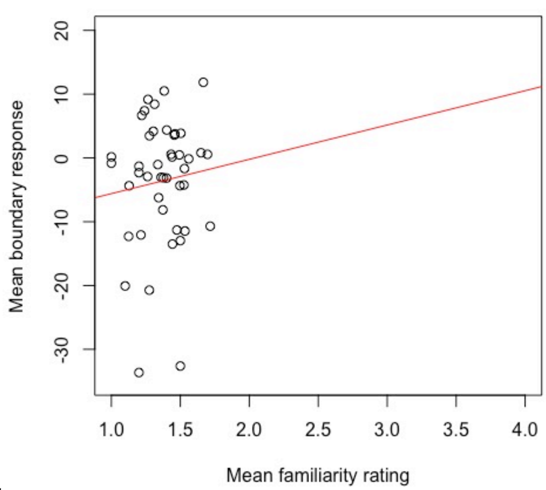
Mean Boundary Rating by Mean Familiarity Rating for Each Image Condition



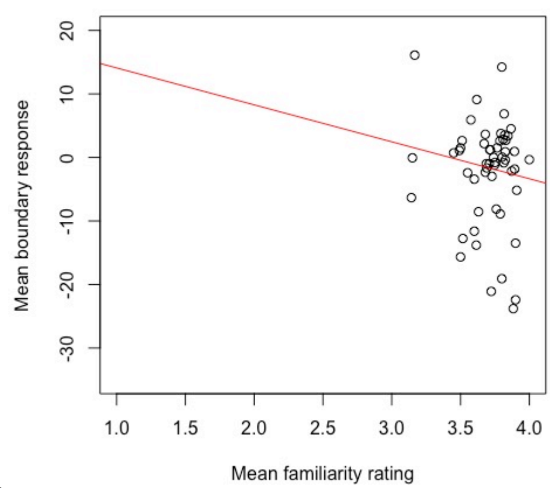
A



B



C



D

Note. First row: Bologna, Italy sample; second row: Toronto, Canada sample. First column: familiar image condition; second column: unfamiliar image condition. Reported without outliers.

Figure 7

Images That Showed the Highest BE and BC

Note. Row 1 [Images with the greatest BC (Bologna)]: Basilica of St. Francis of Assisi, Basilica of Santa Maria Novella, House in Spain, Notre-Dame Cathedral, Verona Arena. Row 2 [Images with the greatest BC (Toronto)]: Christ Church Cathedral, Basilica of Our Lady, Budweiser Stage, Hotel Imperial Reforma, Opera House Zurich. Row 3 [Images with the greatest BE (Bologna)]: Tauron Arena Krakow, Basilica of San Simplicio, St. Stephen's Basilica, Helsinki Cathedral, Beijing National Stadium (showed least BC). Row 4 [Images with the greatest BE (Toronto)]: National Museum of the American Indian, Montreal Biosphere, Desert Dome, Hungarian Parliament, Dallas Hall. (See Appendix for image sources).

Chapter 4: Discussion

4.1 Summary of Findings

The current study examined pre-experimental familiarity on biases in scene memory – BE and BC – to better understand the mechanisms that give rise to those biases. Participants' memory of pre-experimentally familiar and unfamiliar scene images was tested. Overall, both subsequent recognition of familiar and unfamiliar scenes was found to elicit BC, consistent with previously established findings for greater contraction of scene image stimuli that are taken from a wide angle and have farther percieved viewing distances (Bainbridge & Baker, 2020; Lin et al., 2022; Park et al., 2021). There was evidence to suggest participants show BE for some images, but we saw stronger and more consistent evidence for BC. Scenes containing Italian landmarks that were pre-experimentally familiar to participants in Bologna resulted in significant greater BC relative to unfamiliar scenes, albiet with a small effect size, whereas scenes containing Toronto and North American landmarks that were pre-experimentally familiar to participants in Toronto did not show evidence of additional BC over and above that observed for unfamiliar scenes. Unfamiliar images appeared to show greater BC than familiar images but this difference was not significant. Although findings of BC were mixed across Italian and Canadian participants, a lack of evidence of greater overall BE for familiar than unfamiliar scenes provides support for theories that take into account image-based properties of scenes.

4.2 Findings in Context

Our image stimuli consisted of a central, focal object (landmark) that sometimes included other smaller objects, like people, cars, signs, and parts of other surrounding buildings. These object-centered images may be expected to elicit BE because they have the potential for participants to extrapolate beyond the view of the landmark. Due to the size of the landmark and the space depicted in our stimuli, however, this may have reflected a more scene-oriented composition. It may not be surprising, therefore, that our images, whether unfamliar or familiar, elicited BC overall. This finding is also corroborated by the consistent finding in the literature that wide-angle scenes yield greater BC, especially at a greater viewing distance (Lin et al., 2022; Park et al., 2021). Other research has shown a bidrectional effect (normalization) or weak boundary effect (Intraub et al., 1992, 1998; McDunn et al., 2016). Previous research has shown that stimuli that depict "naturalistic scene images," defined as those with "[many] objects dispersed across a spatial layout" (p 537), yeild both BE and BC (Bainbridge & Baker, 2020). Our results showed evidence of both BE and BC for scene images with lack of a directional bias in the Canadian sample (Table 3). Our findings align with what would be predicted by Bainbridge and Baker's visual composition theory, and less so with scene construction or Intraub's multisource model as these theories would similarily have predicted BE.

In our study, we observed a directional effect in the Italian sample and a pattern perhaps more consistent with normalization in the Canadian sample. In both samples, both presentations of each image, at initial presentation and at test, were the same, which may have elicited normalization as this may be expected to restrict the mean of range of responses to be close to zero (showing no directional bias). Many participants often responded with values close to zero with the slider scale and even asked after the study if the images were all the same.

Normalization or regression toward an average view does not solely account for the BC effect observed in our samples, nor does it account for the difference in the magnitude of this effect between familiar and unfamiliar images observed in the Italian sample. These findings may reflect the transition point found by Lin and collegues, if participants are more inclined to remember the landmark in a view that is most familiar to them or that appears the most ideal.

Viewing distance and depth have been found to largely contribute to the directionality of the bias. Research has shown this to reveal a systematic, underlying mechanism that puts BE and BC on a contiuum (Lin et al., 2022). The transition between extension and contraction occurs where no directional bias or normalization occurs. This is thought to occur toward the protoype view of a scene, the view with the highest-probability (Lin et al., 2022) or the view that “looks the best” (Park et al., 2021). Perhaps this explains the weak directionality of the bias observed in our data.

We used stimuli with which participants had prior experience and that combined elements of object-oriented images (landmark was the central focus) and scene-orientated images (visual information surrounding the landmark included multiple objects), as per Bainbridge and Baker (2020). The landmarks included in the image stimuli of the current study can be thought of as very large objects. Some of these objects are pre-experimentally experienced in their entirety, such as when they are viewed in pictures, but when experienced in person, only a portion of the landmark is typically perceived in a single view up close due the large size of the landmark and even from afar due to occlusion by the surrounding landscape. The stimuli used in studies by Park et al. (2021), Lin et al. (2022), and most other studies of BE include much smaller objects against larger backgrounds or scenes with buildings that are on a much smaller scale. The prototypical view or optimal vantage point of a scene containing a building or landmark may be one that includes the whole landmark or a part of the whole, and it might not be possible to experience this view from a ground-level perspective.

When participants remember a previously viewed scene image, they engage in reconstruction of the scene (Hassabis & Maguire, 2007) which may predict more BE for familiar images because participants will have difficulty distinguishing what details were present in the image and what details are readily recalled when they think about and remember the stimuli.

Understanding what is percieved from an image embedded within its larger context underlies the process of filling in contextual and conceptual details (i.e., amodal processing) that is thought to drive the BE effect (Intraub, 2012). If scene construction or multisource theory account for biases in scene recognition, then BE should be greater for pre-experimentally familiar than unfamiliar scenes, because participants should have a richer internal representation or schema, leading to a greater tendency for scene (re)construction or filling in. In the current study, however, when a difference between familiar and unfamiliar scenes was observed, it tended to be in the direction of BC. This finding was significant only in the Italian sample, but even the Canadian sample did not show a greater tendency towards BE.

Our scene image stimuli reflected the more naturalistic scene stimuli used by Bainbridge and Baker (2020). The visual composition may be most prominent and lead to BC is the spatial expanse of the scene is widens. The main difference between our scene stimuli and those typically used in studies of BE is the size of the objects (in this case landmarks) and the scenes in which they are situated. The size of the object relative to its surroundings has been shown to lead to BE when the focal object takes up a large proportion of the image, although this has only been explicitly tested with small objects (Bertamini et al., 2005; Konkle & Oliva, 2007). The visual composition of the image appears to be most prominent for our stimuli in determining the direction and extent of the bias observed.

However, it may be the case that scene construction theory and the multisource model interact with the visual components of a scene. The results are most consistent with what would be predicted by the visual component theory, although the observation that familiarity lead to greater BC for familiar images relative to unfamiliar images shows that pre-experimental familiarity with the stimuli impacted how participants percieved and subsequently remembered the scene images. If we think this is due to the difference in the internal representation formed when participants see a scene image, than the visual composition of the image cannot solely explain the difference in the contraction effect between image conditions.

4.3 Limitations and Future Directions

There may be alternative reasons we did not find BE for familiar versus unfamiliar scenes. Perhaps participants' processing of the whole image and the surrounding context was compromised with our stimuli. The saliency of the landmark itself could draw attention inward, truncating the internal representation formed of the image and resulting in prevention of amodal processing. The focus detracted from the surrounding context may have an effect similar to that found by McDunn and collegues (2016) showing that lack of percieved context around the image leads to normalization. Having previous experience with the landmark and the context in which it is embedded may place fewer demands on processing the surrounding context of the scene, resulting in reduced BE and increased BC or perhaps normalization.

There are other explanations as to why we may not have found greater BE or BC for familiar than unfamiliar scene. The similiarity of boundary ratings between familiar and unfamiliar images for Canadian participants may be due to their subjective familiarity with the landmarks themselves. We used a validation check to achieve a sufficient sample of pre-experimentally familiar images to compare with unfamiliar images. It is possible, however, that despite similarity in familiarity ratings of images between Italian and Canadian participants, the Canadian participants were less familiar with their respective familiar stimuli than were the Italian participants. We tested a sample of younger adults, many of them students, who do not necessarily live in close proximity to the familiar landmarks in Toronto and may not have seen them in person as as frequently as the participants in the Italian sample have with their respective familiar landmarks. The landmarks located across North America cover a more expansive geographical region, even within the city of Toronto, compared to the Italian landmarks. Participants in the Toronto sample may have visited the Toronto and North American landmarks less frequently that the Bologna participants visited Italian landmarks. These differences in degree of familiarity the landmarks may contribute to the discrepancy in the findings between our samples. Participants were not queiried about the las ttime they had visited the landmarks or how frequently the landmarks were visted. In future work, asking these questions would provide more insight into and better characterize participants' prior experience with the landmark stimuli.

Another difference between the Bologna and Toronto samples is that while the former were tested in person, the latter were tested virtually. Virtual testing of participants limits experimenter control over the precise testing environment, particularly in the size of the monitor, distance of the monitor from participants, and quality of the image viewed. We attempted to reduce some of these variables by testing a subsample of the Toronto participants on Zoom in the presence of an experimenter who could provide setup and viewing instructions. Although it is not possible to rule out this explanation, we view it as unlikely, as the previous finding of BC for scenes containing buildings was successfully replicated in both samples. Nevertheless, a next step for this research is to recruit a separate sample of Toronto participants who are highly familiar with Toronto and North American landmarks and to test them in person to ensure consistency in viewing conditions.

Yet another explanation for differences across samples may relate to the composition of the scene images. A significant, albeit modest, difference was found in the proportion of the total image area occupied by the landmark betweens samples, which may have influenced the direction and magnitude of the bias. The familiar landmarks in the Canadian sample took up more of the total image area than the familiar landmarks in the Italian sample. This was not the case for the unfamiliar landmarks, no difference was found. Although, the effect size for the difference between familiar images was small, this may have impacted the difference in BC because bigger relative object size has been shown to increase BE (Konkle & Oliva, 2007), and may in turn decrease BC for wide-angle or images taken at a far distance.

Another issue that arises relates to differences in the way in which landmarks and their surroundings become familiar to participants. Exposure to well-known landmarks may be through first-hand experience with the landmark itself, through photographs or other depictions of the landmark from an unobstructed, wide-angle view that is not experienced from street level, or through some combination. Moreover, participants might rely on an internal representation derived from a prototyipcal view of a landmark extracted from multiple experiences viewing photographs of the landmark, personally navigating to the landmark, or both, whereas others may rely on a single view based or even a specific episode navigating to it. This is further complicated by the images of landmarks that were used, which might not match the views that are most familiar to our participants. One solution is to instruct participants to take photographs of landmarks that they visit regularly, but this is not always feasible.

A related approach is to use stimuli that have increased pre-experimental familiarity or richer re-experiencing for participants, such as rooms within their home. Although the scenes themselves would vary across participants, the same central objects could be used, and there may be greater flexibility for the experimenter to adjust each image in terms of viewing angle and distance. A tailored approach would also allow for the use of central objects that range in size and number to further test the effects of object- vs. scene-oriented images. A common approch in the BE literature is to have conditions in which the test image could be the same or different from the initial presentation of the image. These image conditions may help address demand characteristics imposed by the view of the initial and test presentation of the images being the same. Varying image conditions also allows for exploration of the effect of viewing angle on this bias. It was not possible to implement this practice in the current study because we could not obtain multiple viewing angles or distances for all landmarks of interest. Having only one viewing condition in our study design (images were always the same) may have also contributed to a smaller bias or effect. The use of smaller objects than the landmarks used in our stimuli may also allow us to assess the interaction between BE/BC and familiarity better because their size allows for more control when selecting images and manipulating parameters of interest, such as viewing angle, distance, and surrounding context.

A study design that affords more control over the image selection and manipulation of the view also allows us to introduce a “recall” version of the task, where participants have the ability to manually adjust the boundaries of each image at test. Having participants manually adjust image boundaries can better show how participants represent the boundaries of the image in their internal representation of the scene. The proportion of the area that the focal object occupies in the test image that participants have adjusted the boundaries for can be compared to the porportion of the area the focal object occupies in the initial presentation of the scene image. This will provide a more objective way to measure BE/BC for scene images. This task might also help address demand characteristics imposed onto participants in the “recognition" version of this task (as utilized in the current study), especially when the view of the initial presentation and the test image are the same. In the current study, the image conditions (familiar and unfamiliar images) were randomized and the RSVP paradigm used to combat this issue.

4.4 Conclusions

The findings of the current study are most in line with what would be predicted by visual composition theory. That the addition of images containing familiar landmarks resulted in similar, and in the case of Bologna participants greater, BC is inconsistent with theories suggesting that biases in recognizing scene images are due to the (re)constructive nature of memory for scenes. Additional research is needed to assess the influence of prior experience on biases in perception and memory of boundaries. Our stimuli reflect more naturalistic scene stimuli, unlike stimuli traditionally used in BE studies, but like traditional stimuli, are object-centered. The landmarks used in our stimuli are very large objects, showing a difference in scene memory bias compared to smaller objects typical of BE stimuli. This shows that viewing distance, size and salience of the object, and the surrounding context may be important to show the bias is manifested. Further, we showed some evidence that pre-experimental familiarity has an effect on the extent to which participants show a directional bias, that is, BC with landmark-based stimuli. If the small BC effect and normalization reflects a prototypical view of our images, more ressearch is needed looking into varying viewing angles of landmarks to determine whether these effects occur at this transition point, or represents a regression toward a mean view across the stimulus set. This would shine light on whether our stimuli can yeild BE and can further disentangle scene construction theory and the multisource model, and visual component theory. The current study supports the idea the visual properties of the scene image do impact biases in scene memory. However, this study also shows that it is not visual properties alone that account for the bias, but rather that prior experience may interact with those visual properties. Understanding these biases requires consideration of the complex interplay between prior experience and stimulus properties.

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Appendix A

Landmark Image Stimuli

Table A1

Stimuli Used for Participants from Bologna, Italy

Familiar Landmark	Location	**Unfamiliar** Landmark	Location
Fountain of Neptune	Bologna, Italy	Neptune's Fountain	Messina, Italy
Basilica of San Petronio	Bologna, Italy	Church of St. Sava	Belgrade, Serbia
Colosseum	Rome, Italy	Beijing National Stadium	Bejing, China
Milan Cathedral	Milan, Italy	Helsinki Cathedral	Helsinki, Finland
St. Peter's Basilica	Rome, Italy	University of Notre Dame	Indiana, IN, United States
Pantheon	Rome, Italy	Thomas Jefferson Memorial	Washington, DC, United States
Basilica of Santa Croce	Florence, Italy	Guesthouse of the Abbey of San Pietro di Sorres	Borutta, Italy
Basilica of Santa Maria Novella	Florence, Italy	St. Stephen's Basilica	Budapest, Hungary
Trevi Fountain	Rome, Italy	Cathedral of Ferrara	Ferrara, Italy
Victor Emmanuel II Monument	Rome, Italy	Palais of Justice	Strasbourg, France
Verona Arena	Verona, Italy	Tauron Arena Krakow	Krakow, Poland
Basilica of St. Francis of Assisi	Assisi, Italy	Speyer Cathedral	Speyer, Germany
Doge's Palace	Venice, Italy	House in Spain	Andalusia, Spain
St. Mark's Basilica	Venice, Italy	Greek Orthodox Church Esslingen	Esslingen, Germany
Basilica of St. Anthony of Padua	Padua, Italy	Basilica of San Simplicio	Olbia, Italy
Hungarian Parliament Building	Budapest, Hungary	Palace of the Parliament	Bucharest, Romania
St. Angelo Bridge	Rome, Italy	Castel del Monte	Andria, Italy
Leaning Tower of Pisa	Pisa, Italy	Tiger Hill Pagoda	Suzhou, China
Notre-Dame Cathedral Paris	Paris, France	Notre-Dame Basilica Montreal	Montreal, QB, Canada
Brandenburg Gate	Berlin, Germany	Cairo Citadel	Cairo, Egypt

Note. Each row consists of familiar landmarks, and their visually similar matched unfamiliar counterpart.

Table A2

Stimuli use for participants from Toronto, Canada

Familiar		**Unfamiliar**	
Landmark	Location	Landmark	Location
Aga Khan Museum	Toronto, ON, Canada	Islamic Museum	Thornbury, Australia
The Alamo	San Antonio, TX, United States	Mission San Luis Rey de Francia	Oceanside, CA, United States
Fairmont Banff Springs Hotel	Banff, AB, Canada	Chateau Chambord	Chambord, France
The Big Nickel	Sudbury, ON, Canada	Aldar Headquarters	Abu Dhabi, United Arab Emirates
Brooklyn Bridge	New York City, NY, United States	Chain Bridge	Budapest, Hungary
Budweiser Stage	Toronto, ON, Canada	**Jones Beach Theatre**	Wantagh, NY, United States
Canadian Museum of Natural History	Montreal, QB, Canada	National Museum of the American Indian	Washington, DC, United States
Four Seasons Centre for the Performing Arts (Canadian Opera Company building)	Toronto, ON, Canada	**Orchestra Hall**	Minneapolis, MN, United States
Casa Loma	Toronto, ON, Canada	**Boldt Castle**	Alexandria Bay, NY, United States
Cathedral Church of St. James	Toronto, ON, Canada	**St. Peter in Chains**	Peterborough, ON, Canada
Chateau Frontenac	Quebec City, QB, Canada	New York State Capitol	Albany, NY, United States
Cinderella's Castle	Orlando, FL, United States	Neuschwanstein Castle	Schwangau, Germany
Cloud Gate	Chicago, IL, United States	La Geode	Paris, France
Convocation Hall	Toronto, ON, Canada	Dallas Hall, Southern Methodist University	University Parks, TX, United States
Walt Disney Concert Hall	Los Angeles, CA, United States	Guggenheim Museum Bilbao	Bilbao, Spain
Elgin Winter Garden Theatre	Toronto, ON, Canada	**Edmonton Princess Theatre**	Edmonton, AB, Canada
Golden Gate Bridge	San Francisco, CA, United States	Akashi Kaikyo Bridge	Kobe, Japan
Gooderham Building	Toronto, ON, Canada	**Hotel Imperial Reforma**	Mexico City, Mexico
Hockey Hall of Fame	Toronto, ON, Canada	**Buffalo Savings Bank**	Buffalo, NY, United States
Jefferson Memorial	Washington, DC, United States	The Rotunda, University Virginia	Charlottesville, Virginia, United States
Lincoln Memorial	Washington, DC, United States	Tempio Canoviano	Veneto, Italy
Massey Hall	Toronto, ON, Canada	Broad Street Market	Harrisburg, PA, United States
Metropolitan Museum of Art	New York City, NY, United States	Petit Palais	Paris, France
Montreal Biosphere	Montreal, QB, Canada	Desert Dome	Omaha, NE, United States

New City Hall	Toronto, ON, Canada	**Da Vinci Tower Dubai**	Dubai, United Arab Emirates
Notre-Dame Basilica Montreal	Montreal, QB, Canada	Basilica of Our Lady	Guelph, ON, Canada
Old City Hall	Toronto, ON, Canada	**Cincinnati City Hall**	Cincinnati, OH, United States
Ontario Legislative Building	Toronto, ON, Canada	**St. Louis City Hall**	St. Louis, MO, United States
Osgoode Hall	Toronto, ON, Canada	Berlin Opera House	Berlin, Germany
Parliament Hill	Ottawa, ON, Canada	Hungarian Parliament	Budapest, Hungary
Pioneer Village Station	Toronto, ON, Canada	Kuggen	Gothenburg, Sweden
Princes Gate at Exhibition Place	Toronto, ON, Canada	**Arco da Rua Augusta**	Lisbon, Portugal
Radio City Music Hall	New York City, NY, United States	Paramount Theatre	Seattle, WA, United Sates
Ripley's Believe it or Not Museum	Niagara Falls, ON, Canada	Ripley's Believe it or Not Museum	Gatlinburg, TN, United States
Rogers Centre	Toronto, ON, Canada	**Fukuoka PayPay Dome**	Fukuoka, Japan
Roy Thomson Hall	Toronto, ON, Canada	**Soumaya Museum**	Mexico City, Mexico
Royal Alexandra Theatre	Toronto, ON, Canada	Opera House Zurich	Zurich, Switzerland
Royal Ontario Museum	Toronto, ON, Canada	**Military History Museum**	Dresden, Germany
Scotiabank Arena	Toronto, ON, Canada	**Little Caesars Arena**	Detroit, MI, United States
St. Andrew's Church	Toronto, ON, Canada	**Christ Church Cathedral**	Montreal, QB, Canada
St. Lawrence Market	Toronto, ON, Canada	Columbia Market House	Columbia, PA, United States
Stewart Building	Toronto, ON, Canada	**Maryland Club**	Baltimore, MD, United States
Telus Sphere, Science World	Vancouver, BC, Canada	Eurosat – CanCan Coaster in Europa-Park	Rust, Germany
Toronto Metropolitan University	Toronto, ON, Canada	**Ghent Market Hall**	Ghent, Belgium
Toronto Reference Library	Toronto, ON, Canada	Bellevue Art Museum	Bellevue, WA, United States
Union Station	Toronto, ON, Canada	**St. Paul Union Depot**	St. Paul, MN, United States
University of Toronto, Main Building	Toronto, ON, Canada	**Westmount City Hall**	Westmount, QB, Canada
United States Capitol Building	Washington, DC, United States	Minnesota State Capitol	St. Paul, MN, United States
Vari Hall, York University	Toronto, ON, Canada	Rotunda Museum	Scarborough, United Kingdom
The White House	Washington, DC, United States	Virginia State Capitol	Richmond, VA, United States

Note. Each row consists of familiar landmarks, and their visually similar matched unfamiliar counterpart. Landmarks in bold were the landmarks used in the samples in which participants were only tested on Toronto landmarks (familiar) and their unfamiliar counterparts (URPP, WOM, Prolific 1).

Appendix B

References for Image Sources Used in Figures

Figure 1

Fountain of Neptune (Bologna) (https://www.bologna.bo/piazza-nettuno/)
Fountain of Neptune (Messina) (https://discovermessina.it/luoghi/fontana-del-nettuno/).
Hockey Hall of Fame
(https://en.wikipedia.org/wiki/Hockey_Hall_of_Fame#/media/File:Hockey_Hall_of_Fame,_Toronto.jpg)
Buffalo Savings Bank (https://buffaloah.com/a/main/545/ext/ext.html)

Figure 6

Bologna, Italy

Basilica of St. Francis of Assisi (https://www.getyourguide.com/basilica-of-santa-clare-l142161/)
Basilica of Santa Maria Novella (https://en.m.wikipedia.org/wiki/File:Santa_Maria_Novella.jpg)
House in Spain, Notre-Dame Cathedral (https://marbellaselectproperties.es/property/4004-2/)
Verona Arena
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Christ Church Cathedral (https://travelask.ru/questions/939694-christ-church-cathedral-e2ad6dd1-7abf-4356-8eb6-c89d4282ba44)
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Opera House Zurich (https://upload.wikimedia.org/wikipedia/commons/3/37/Opernhaus_Z%C3%BCrich%2C_Switzerland.JPG)

National Museum of the American Indian (https://www.si.edu/sites/default/files/newsdesk/building/nmai.jpg)

Montreal Biosphere (https://www.flickr.com/photos/campobaeza/8125311335)

Desert Dome (https://www.flickr.com/photos/jpellgen/27972301221)

Hungarian Parliament (https://www.re-thinkingthefuture.com/case-studies/a6330-hungarian-parliament-building-hungary-a-notable-landmark-of-hungary/)

Dallas Hall (https://bpb-us-w2.wpmucdn.com/blog.smu.edu/dist/3/246/files/2021/10/smu-dallas-hall-01.jpg)

Appendix C

Information Queried for Scene Images

Table B1

Mean and Frequency of Responses Queried About Landmarks (Bologna Sample)

Familiar				**Unfamiliar**			
Landmark	Boundary Rating (*M*)	Familiarity Rating (*M*)	Number of Participants Visited	Landmark	Boundary Rating (*M*)	Familiarity Rating (*M*)	Proportion Participants Visited
Fountain of Neptune	6.0	1.63	.73	Neptune's Fountain	5.57	2.92	.12
Basilica of San Petronio	3.54	1.46	.78	Church of St. Sava	6.47	3.63	0
Colosseum	5.62	1.15	.78	Beijing National Stadium	0.66	3.29	.04
Milan Cathedral	12.78	1.21	.82	Helsinki Cathedral	-4.21	3.52	.02
St. Peter's Basilica	0.81	1.77	.71	University of Notre Dame	3.39	3.83	0
Pantheon	5.25	2.17	.57	Thomas Jefferson Memorial	4.78	3.29	.04
Basilica of Santa Croce	8.34	2.65	.24	Guesthouse of the Abbey of San Pietro di Sorres	3.74	3.60	.02
Basilica of Santa Maria Novella	9.09	2.17	.47	St. Stephen's Basilica	2.31	3.35	.02
Trevi Fountain	8.72	1.23	.76	Cathedral of Ferrara	10.42	3.00	.06
Victor Emmanuel II Monument	10.16	1.52	.65	Palais of Justice	7.01	3.35	0
Verona Arena	9.62	1.46	.71	Tauron Arena Krakow	-4.1	3.58	0
Basilica of St. Francis of Assisi	10.66	2.98	.18	Speyer Cathedral	6.43	3.65	0
Doge's Palace	11.47	2.31	.53	House in Spain	12.87	3.81	0
St. Mark's Basilica	5.45	2.00	.55	Greek Orthodox Church Esslingen	8.16	3.92	0
Basilica of St. Anthony of Padua	7.62	3.27	.12	Basilica of San Simplicio	-3.29	3.60	0

Hungarian Parliament Building	7.08	2.27	.31	Palace of the Parliament	5.85	3.46	.02
St. Angelo Bridge	1.32	2.50	.37	Castel del Monte	3.29	2.94	.16
Leaning Tower of Pisa	-0.51	1.17	.57	Tiger Hill Pagoda	1.44	3.35	0
Notre-Dame Cathedral Paris	13.32	1.67	.49	Notre-Dame Basilica Montreal	1.1	3.17	.02
Brandenburg Gate	9.73	2.02	.27	Cairo Citadel	7.03	3.40	.06

Note. n=49. Proportion Participants Visited columns show the proportion of the number of participants that responded "yes" to the question "Have you visited this place before?" out of the total number of participants that responded to this landmark.

Table B2

Mean and Frequency of Responses Queried About Landmarks (Toronto Sample)

Familiar				**Unfamiliar**			
Landmark	Boundary Rating (*M*)	Familiarity Rating (*M*)	Number of Participants Visited	Landmark	Boundary Rating (*M*)	Familiarity Rating (*M*)	Proportion Participants Visited
Aga Khan Museum	-	-	-	Islamic Museum	-	-	-
The Alamo	-	-	-	Mission San Luis Rey de Francia	-	-	-
Fairmont Banff Springs Hotel	-6.23	1.34	.56	Chateau Chambord	2.18	3.67	.22
The Big Nickel	6.13	1.64	.8	Aldar Headquarters	-12.6	3.86	0
Brooklyn Bridge	3.71	1.58	.6	Chain Bridge	3.63	3.68	.1
Budweiser Stage	14.48	1.38	.41	Jones Beach Theatre	11.11	3.8	.22
Canadian Museum of Natural History	-	-	-	National Museum of the American Indian	-22.42	3.9	0
Four Seasons Centre for the Performing Arts (Canadian Opera	5.60	1.45	.36	Orchestra Hall	1.62	3.57	.33

Company building)							
Casa Loma	5.21	1.45	.33	Boldt Castle	1.09	3.49	.13
Cathedral Church of St. James	0.45	1.5	.44	St. Peter in Chains	0.62	3.73	.18
Chateau Frontenac	-7.35	1.5	.67	New York State Capitol	4.56	3.44	.33
Cinderella's Castle	-12.07	1.21	.5	Neuschwanstein Castle	-2.15	3.87	0
Cloud Gate	0.56	1.43	0	La Geode	0.72	3.45	0
Convocation Hall	-12.3	1.13	.63	Dallas Hall, Southern Methodist University	-13.81	3.61	.25
Walt Disney Concert Hall	-	-	-	Guggenheim Museum Bilbao	1.49	3.5	0
Elgin Winter Garden Theatre	0.46	1.5	.32	Edmonton Princess Theatre	5.82	3.8	.09
Golden Gate Bridge	-2.34	1.39	.27	Akashi Kaikyo Bridge	-6.33	3.14	.13
Gooderham Building	6.41	1.41	.43	Hotel Imperial Reforma	14.23	3.8	.11
Hockey Hall of Fame	3.21	1.51	.34	Buffalo Savings Bank	2.96	3.75	.13
Jefferson Memorial	-12.97	1.5	.33	The Rotunda, University Virginia	-0.06	3.15	.33
Lincoln Memorial	0.81	1.65	.14	Tempio Canoviano	-11.62	3.15	0
Massey Hall	-11.3	1.48	.44	Broad Street Market	6.68	3.8	.22
Metropolitan Museum of Art	11.86	1.67	.33	Petit Palais	0.02	3.74	.17
Montreal Biosphere	-20.07	1.1	.8	Desert Dome	-15.66	3.5	.6
New City Hall	6.98	1.3	.43	Da Vinci Tower Dubai	4.85	3.89	.07
Notre-Dame Basilica Montreal	0.17	1.0	.4	Basilica of Our Lady	16.11	3.17	0
Old City Hall	0.45	1.33	.44	Cincinnati City Hall	6.17	3.82	.11
Ontario Legislative Building	-1.06	1.38	.67	St. Louis City Hall	2.64	3.51	.18
Osgoode Hall	-	-	-	Berlin Opera House	3.75	3.89	0
Parliament Hill	5.15	1.21	.69	Hungarian Parliament	-15.0	3.73	.13
Pioneer Village Station	-0.42	1.14	.67	Kuggen	0.03	3.9	.33

Princes Gate at Exhibition Place	10.3	1.3	.44	Arco da Rua Augusta	6.39	3.79	.12
Radio City Music Hall	-0.59	1.05	.2	Paramount Theatre	2.3	3.75	0
Ripley's Believe it or Not Museum	-2.87	1.84	.45	Ripley's Believe it or Not Museum	8.7	3.84	.09
Rogers Centre	8.85	1.23	.59	Fukuoka PayPay Dome	6.37	3.75	.17
Roy Thomson Hall	0.14	1.45	.45	Soumaya Museum	5.91	3.58	.08
Royal Alexandra Theatre	0.85	1.5	.29	Opera House Zurich	13.09	3.67	0
Royal Ontario Museum	9.75	1.24	.51	Military History Museum	7.59	3.82	.11
Scotiabank Arena	6.03	1.27	.69	Little Caesars Arena	6.0	3.72	.21
St. Andrew's Church	2.16	1.56	.38	Christ Church Cathedral	30.38	3.7	.2
St. Lawrence Market	-3.28	1.29	.44	Columbia Market House	-1.35	3.6	.31
Stewart Building	5.49	1.7	.24	Maryland Club	7.52	3.83	.07
Telus Sphere, Science World	5.5	1.03	.75	Eurosat – CanCan Coaster in Europa-Park	7.86	3.8	0
Toronto Metropolitan University	2.90	1.34	.42	Ghent Market Hall	1.44	3.89	.06
Toronto Reference Library	-1.3	1.2	.63	Bellevue Art Museum	2.4	3.81	.13
Union Station	12.48	1.27	.62	St. Paul Union Depot	4.35	3.8	.07
University of Toronto, Main Building	6.37	1.5	.4	Westmount City Hall	1.46	3.68	.18
United States Capitol Building	-0.83	1.0	.25	Minnesota State Capitol	-0.79	3.75	.25
Vari Hall, York University	-	-	-	Rotunda Museum	-3.42	3.6	.33
The White House	-3.15	1.4	.21	Virginia State Capitol	4.51	3.87	.14

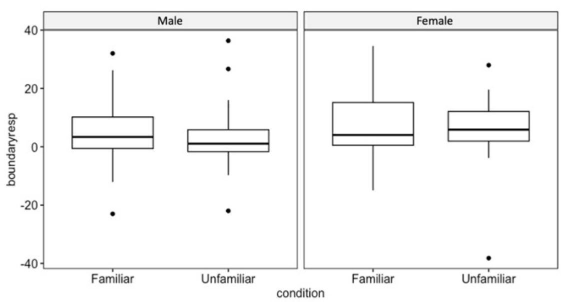
Note. n=187. Proportion of Participants Visited columns show the proportion of the number of participants that responded "yes" to the question "Have you visited this place before?" out of the total number of participants that responded to this landmark. If an image does not have a value in this table, that indicates that all the ratings for that image were removed from the analyses when the validation check was performed (removed familiar landmarks rated as unfamiliar and removed unfamiliar landmarks rated as familiar).

Appendix D

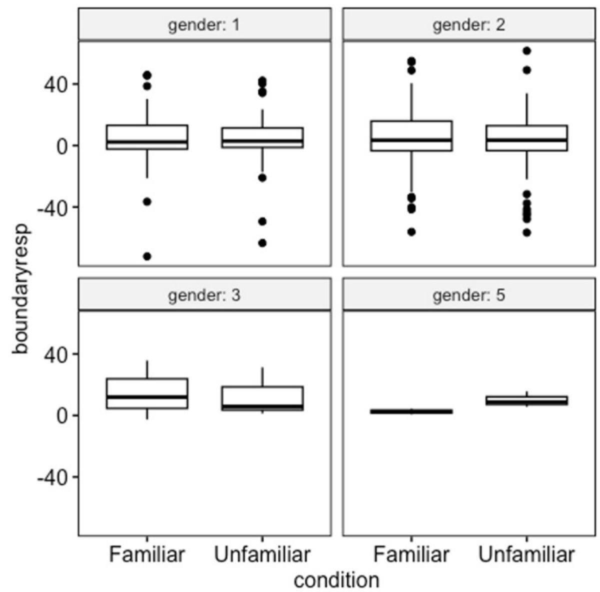
Gender-Differences

Figure D1

Boxplots of Boundary Responses by Gender



A



B

Note. (A) Bologna sample, (B) Toronto sample.

Table D1

Gender-Based Analysis of Variance

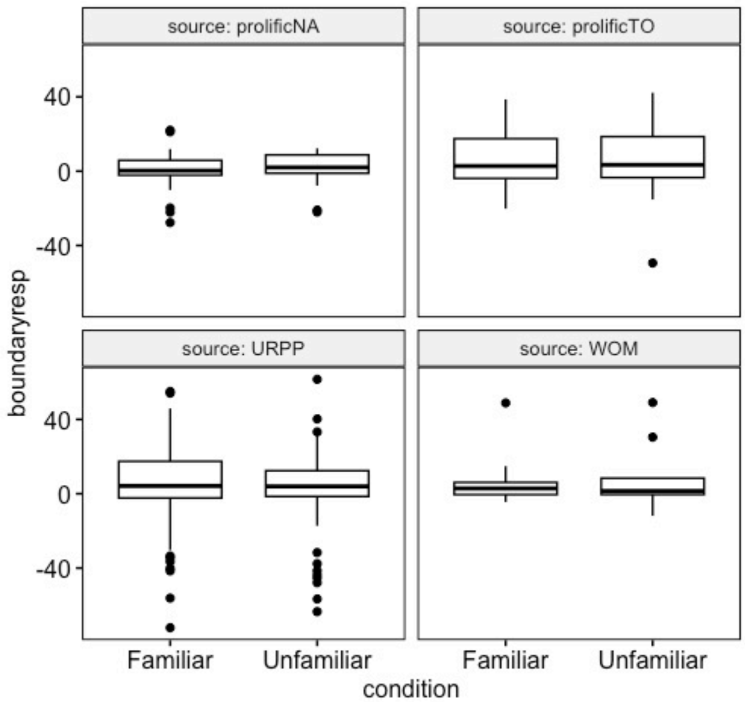
		F	df	p	η^2
Bologna	Gender	0.34	3, 180	.799	.005
	Condition (familiar, unfamiliar)	0.01	1, 180	.939	<.001
	Gender: Condition	0.17	3, 180	.916	<.001
Toronto	Gender	0.34	3, 180	.799	.005
	Condition (familiar, unfamiliar)	0.01	1, 180	.939	<.001
	Gender: Condition	0.17	3, 180	.916	<.001

Appendix E

Toronto Sample: Recruitment Source Analysis

Figure E1

Boxplots of Boundary Response in Toronto Sample by Source of Recruitment



Note. ProlificNA = Prolific 2, ProlificTO = Prolific 1, URPP = Undergraduate Participant Pool, WOM = Word of Mouth

Table E1

Toronto Sample Recruitment Source Analysis of Variance

	F	**df**	**p**	**η^2**
Source (URPP, WOM, ProlificTO, ProlificNA)	0.92	3, 180	.429	.013
Condition (Familiar, Unfamiliar)	1.85	1, 180	.919	<.001
Source: Condition	0.95	3, 180	.569	.002