THE INFLUENCE OF SPATIAL LATERAL BIASES AND NATIVE READING DIRECTION ON DRIVING AND AESTHETIC PREFERENCES

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ABSTRACT

The neglect of leftward space occurring after a right parietal lesion, known as hemispatial neglect, results in a rightward spatial bias. Neurotypical individuals display an opposite leftward spatial bias, known as pseudoneglect (Bowers & Heilman, 1980). The leftward lighting bias and the leftward aesthetic preference are hypothesized to be related to pseudoneglect (Smith & Elias, 2018). Leftward biases are attenuated, or even flipped to the right in certain circumstances, notably in participants whose native reading direction (NRD) moves from right-to-left (RTL) and when spatial tasks occur in extrapersonal space. Aesthetic preferences and spatial abilities were compared between RTL and left-to-right (LTR) groups in an image rating task using eye tracking (Chapter 2) and image lighting tasks of three-dimensional (3D) images of sculptures (Chapter 3) and two-dimensional (2D) images of abstract paintings (Chapter 4). Participants' basic spatial ability was assessed using the greyscales task (Mattingley, Bradshaw, Nettleton, & Bradshaw, 1994), a measure of perceptual asymmetries. LTR and RTL participants show clearly diverging trends of behaviour when making aesthetic judgments. When examining 2D images in Chapter 2 and illuminating 2D images in Chapter 4, preferences were leftward among LTRs and rightward among RTLs, however, both groups demonstrated a consistent leftward bias on the greyscales task. In Chapter 3, similar group differences between professionals in LTR and RTL regions were found for sculpture lighting, but participants illuminating 3D sculpture images did not show any light placement biases. In Chapter 4, a rudimentary version of a virtual mapping technique known as *Halos* (Baudisch & Rosenholtz, 2003) was carried out in a procedurally similar way to the artwork lighting task of the same chapter but measured spatial abilities rather than aesthetic preferences. Contrary to predictions, smaller errors were made when estimating the size of halos on the right, and as circle size increased estimation accuracy decreased. Studies in Chapter 5 examined navigation spatial abilities when driving, experimentally using a driving simulation, and through the analysis of naturalistic data from the Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS). Lane deviations were rightward, and collisions were more frequent and severe on the right side in the simulation and naturalistic data analysis revealed greater likelihoods of collisions from crossing over the right line or edge of the road and when making a right turn. Overall, findings suggest that an RTL NRD and task complexity modulate pseudoneglect and that lateral spatial biases when driving are in line with previous

lateral bumping when walking results. Across all studies, findings provide clarity about the occurrence leftward bias attenuation.

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LIST OF ABBREVIATIONS

Analysis of variance – ANOVA

Confidence interval – CI

Left hand – LH

Left-to-right – LTR

Native reading direction – NRD

Relative risk – RR

Right-to-left – RTL

Region of interest – ROI

Spatial agency bias – SAB

Spatial-numerical association of response codes – SNARC

Strategic Highway Research Program Naturalistic Driving Study – SHRP 2 NDS

Three dimensional – 3D

Two dimensional – 2D

CHAPTER 1

INTRODUCTION

The hallmark deficit of hemispatial neglect, often referred to as neglect, is the inattention to leftward space. Neglect results from damage to the network of structures critical for visuospatial processing within the right hemisphere such as the parietal lobe and the pathways that connect it to related neural areas (Corbetta & Shulman, 2011). Surprisingly, the unequal distribution of visual attention between the left and right visual fields results from an intact right hemisphere as well. Commonly referred to as neurotypical, these individuals display an opposite pattern of slightly attending more to the left visual field, known as pseudoneglect (Bowers & Heilman, 1980). An artistic bias to light a scene from the left has been identified across time periods and artistic styles (Mamassian, 2008; McManus, 1979; Sun & Perona, 1998) as well as with untrained research participants (McDine, Livingston, Thomas, Nicole, & Elias, 2011) leading Smith and Elias (2018) to suggest that aesthetic preferences and pseudoneglect may be related.

Although the leftward bias is hardwired, certain factors such as rightward cues and controlled right-to-left scan paths can effectively modulate the bias (Jewell & McCourt, 2000). Spatial biases shift rightward in groups whose native reading direction (NRD) moves from right-to-left (RTL; Chokron & Imbert, 1993). Moving laboratory tasks further away from the participant also shifts biases from left to right (Longo & Lourenco, 2006) and may help explain real-world phenomena such as increased right side bumping when walking (Nicholls, Loftus, Mayer, & Mattingley, 2007; Turnbull & McGeorge, 1998) and operating virtual or remote vehicles (Jang, Ku, Na, & Lee, 2009; Nicholls et al., 2010). Aesthetic preferences appear to follow a pattern parallel to spatial biases where the preferences of RTL participants are shifted rightward.

The research presented here explores how our perceptions of the world are shaped by innate lateral biases and how those perceptions influence our preferences and actions. Further, much of the focus of the research questions is on factors influencing these biases, which in turn guide perceptions that subsequently impact preferences and actions. This research program focuses on aesthetic preferences, measuring both perceptions and actions, and the actions required to navigate a motor vehicle.

The contralateral flow of visual information, from the left visual field to the right hemisphere and from the right visual field to the left hemisphere, is a fundamental component for understanding both the inattention of leftward space by neglect patients and the overestimation of leftward space by neurotypical individuals. Areas of the brain and associated networks that are dominant for visuospatial processing primarily lie in the right hemisphere, which mostly receives information from the left visual field (Corbetta & Shulman, 2011). Damage to the right hemisphere, especially the frontoparietal network of attention structures, results in neglect of the left visual field (Çiçek, Deoucell, & Knight, 2009). There is not necessarily any left visual field blindness in neglect patients, and they can, in certain circumstances (e.g. when attention is cued to the left), display levels of function in both the left and right visual fields comparable to neurotypicals, however several neuropsychological tasks highlight characteristic difficulties. For example, the inability to draw from memory or copy an image in its entirety, missing left targets in the cancellation task, and right of veridical centre bisections in the line bisection task when tasked with equally bisecting lines of varying lengths and spatial locations (Marshall & Halligan, 1994).

Research examining spatial biases flourished following Bowers and Heilman's (1980) initial report of the pseudoneglect of rightward space in neurotypical participants, leading to bisections left of true centre on the line bisection task. Spatial biases in neurotypical individuals are often measured with some of the same neuropsychological tests used in neglect assessment (Çiçek et al., 2009; Marshall & Halligan, 1994; Mattingley, Bradshaw, Nettleton, & Bradshaw, 1994). Observations of spatial biases on several measures that rely on vision have occurred including judgments of brightness, numerosity, size (Nicholls, Bradshaw, & Mattingley, 1999) and distance (Krupp, Robinson, & Elias, 2010).

Whereas the aforementioned spatial bias research has largely relied on visual tasks, Bowers and Heilman’s (1980) original finding of pseudoneglect came from a tactile line bisection task, where participants were blindfolded. Further, the leftward spatial bias does not appear to be bound to physical space or stimuli. Chatterjee (2002) proposed the spatial agency bias (SAB) where agents of action are conceptualized to be to the left of recipients of action. Using the abstract concept of stereotypes, Maass, Suitner, Favaretto, and Cignacchi (2009) report an association between males and leftward space, extending the SAB to include the belief that males have more agency than females. Mental number lines are conceptualized from left-to-right as numbers increase in what has come to be known as the Spatial-Numerical Association of Response Codes (SNARC) effect (Dehaene, Bossini, & Giraux, 1993). Like the pen and paper line bisection task, neurotypical participants' bisections of mental number lines are determined by a leftward overestimation that is reversed in neglect patients (Loftus, Nicholls, Mattingly, Chapman, & Bradshaw, 2009).

Kinsbourne (1970) theorized that spatial biases are a result of asymmetrical activation between the hemispheres, where spatially-oriented tasks activate the right hemisphere more than the left leading to a leftward spatial bias. However, when a spatial task moves from near space to far space, or when scanning stimuli occurs in a right-to-left direction, the typical leftward biases are modulated rightward. Neurotypical individuals have reliably displayed leftward biases on the line bisection task (Jewell & McCourt, 2000) and the greyscales task (Nicholls et al., 1999) but directing how the stimuli are visually explored has been found to impact the leftward bias in both tasks. Elias, Saucier, Sheerin, and Burton (2002) created a modified version of the greyscales task by rotating the rectangles 90 degrees so that scanning between the left and right hemispaces was no longer required, largely eliminating directional scanning. The attenuation of the leftward bias on the vertical greyscales task clearly illustrates the importance of scanning direction in perceptual asymmetries. Elias et al. found that implementing the same stimuli that typically elicit a leftward bias in such a way scanning across the midline was no longer required resulted in the disappearance of the leftward bias. A meta-analysis of the line bisection task reported significant variability between the studies examined but concluded that across different conditions and factors neurotypical individuals tended to make leftward bisections (Jewell & McCourt, 2000). Administering the task in the right hemispace, cueing attention right, and older adult participants were among the strongest factors attenuating the leftward bias, but the greatest modulator was scanning direction. Jewell and McCourt report that scanning from left-to-right results in leftward bisections whereas subjective centre estimates are rightward when scanning right-to-left.

Jewell and McCourt's (2000) finding that directional scanning is largely responsible for the commonly observed leftward biases on line bisection tasks is consistent with a growing body of research that examines the influence that NRD has on spatial attention. Native RTL readers (e.g. Farsi speakers) are among groups that have provided data leading to compelling theories regarding spatial biases. Mirroring Jewell and McCourt's findings when directional scanning is controlled during line bisection, Chokron and Imbert (1993) report leftward bisections by monolingual left-to-right (LTR) participants and rightward bisections by monolingual RTL participants in a free-viewing line bisection task. Rinaldi, Di Luca, Henik, and Girelli (2014) further examined the role that fluency in languages with opposite lateral directions had on standard and modified star cancellation tasks and the line bisection task with monolingual LTR, monolingual RTL, and bilingual RTL participants. Like Chokron and Imbert (1993) LTR monolinguals demonstrated leftward biases and RTL monolinguals demonstrated rightward biases, however bilinguals tended to show no spatial biases. Rinaldi et al. proposed the *interactive account of visuospatial asymmetries* which theorizes that the degree of modulation of leftward spatial biases depends on the interaction of cultural factors (NRD: monolingual LTR, bilingual, monolingual RTL) and biological factors (right hemisphere specialization for visuospatial processing). The effect that RTL NRD has on spatial ability does not appear to be bound to physical stimuli, in the same way that the leftward spatial bias influences the mental imagery of LTR individuals (Chatterjee, 2000; Dehaene et al., 1993; Loftus et al., 2009; Maass et al., 2009). RTL NRD appears to guide abstract thinking away from the left-to-right conceptualization of time (Ouellet, Santiago, Israeli, & Gabay, 2010) and numbers (Dehaene et al., 1993) while also flipping mental associations of agency from left to right (Maass et al., 2009).

Chokron and De Agostini (1995) and Fagard and Dahmen (2003) examined how the acquisition of reading and writing in opposite lateral directions may impact spatial ability in pre- and post-written language acquisition child participants. Chokron and De Agostini found that both French (LTR) and Israeli (RTL) pre-school children displayed rightward biases on the line bisection task, however LTR participants demonstrated a bias in the frequency of bisections to the left and by adulthood displayed a significant leftward deviation. In addition to the line bisection task, Fagard and Dahmen implemented a circle-drawing task and a dot-filling task with children participants at ages 5, 7, and 9. Participants were either French (LTR) or Tunisian (RTL), but Tunisian children also learned French at age 8. By age 9 differences emerged on the line bisection task as bisections by LTR participants became significantly leftward and bilingual RTL participants displayed no bias. By age 7 LTR children made more counter clockwise movements (LTR) on the circle-drawing task and filled in more dots when moving in a direction consistent with their NRD.

A shift to rightward biases on the line bisection task has been observed when task administration moves from intrapersonal to extrapersonal space (outside of arm's reach). Longo and Lourenco (2006) report that as the task moved from 30 cm to 60 cm to 90 cm to 120 cm, bisections using a laser pointer underwent a rightward shift. When making bisections at the same four distances with a pointing stick, however, the leftward bisection biases endured as the stick was treated like an extension of the arm, bringing the task back to within "arm's reach".

Spatial biases have also been observed in extrapersonal space during navigation. Like other aspects of the neglect/pseudoneglect dichotomy, an opposite pattern of biases is reported between individuals suffering from neglect and neurotypicals. Neglect patients bump the left sides of their bodies more often, whereas rightward bumping has been predominately reported in neurotypical individuals (Nicholls et al., 2007; Turnbull & McGeorge, 1998). The genesis for exploring extrapersonal space lateral biases in neurotypicals, termed "lateral bumping", was a study by Turnbull and McGeorge (1998) where participants' recollections of more rightward bumps were associated with leftward biases on a standard line bisection task. Studies following have used a host of propulsion methods including walking (Nicholls, Loftus, Orr, & Barre, 2008; Nicholls et al., 2007), wheelchairs (Nicholls et al., 2010), remote wheelchairs (Nicholls et al., 2010; Robertson, Forte, & Nicholls, 2015), electric scooters (Nicholls et al., 2010), and a small remote vehichle (Nicholls, Jones, & Robertson, 2016) and have come to the general consensus that rightward deviations occur when passing through a doorway (although there are exceptions, see Hatin, Sykes Tottenham, & Oriet, 2012).

Nicholls et al. (2010) connected the navigation and line bisection tasks of extrapersonal space in an experiment requiring participants to first bisect the doorway using a laser pointer and then navigate an electric scooter to the subjective middle of the same doorway. Replicating previous laser pointer findings (Longo & Lourenco, 2006) and doorway navigations (Nicholls et al. 2007; Nicholls et al., 2008) Nicholls et al. (2010) found laser pointer bisections and electric scooter bisections to be significantly rightward and suggest that scooter bisections occur in much the same way as laser pointer bisections. When required to navigate the scooter to the centre of the doorway, participants mentally mark the centre, to the right, and then proceed to drive to that point. Robertson et al. (2015) followed up on this line of thinking by pitting extinction-based and bisection bias theories against one another. They had participants navigate remote wheelchairs through doorways while eye movements were recorded. They hypothesized that an extinction-based theory would be supported by data showing rightward navigation errors resulting from leftward biased eye movements, indicating that participants deviated rightward because they were over-attending to the left side, whereas data supporting a bisection bias theory would show rightward deviations resulting from an initial rightward bisection and allocation of attention to match. Ultimately their findings supported the latter theory, confirming that persistent rightward bumping likely results from initial extrapersonal rightward bisections and moving towards the marks without updating the centre point (Berti et al., 2002).

Researchers have signalled their interest in the potential consistency between laboratory-based studies employing navigating non-automobiles and walking and the operation of automobiles in the real world (Nicholls et al., 2010; Robertson et al., 2015), however, there are thus far very few reports of taking the next step to investigate extrapersonal spatial biases while driving. A series of studies carried out by Robertshaw and Wilkie (2008) links the wheelchair and remote control studies together, and generally supports Robertson et al.'s (2015) findings. Using a driving simulator and eye-tracking Robertshaw and Wilkie (2008) report that the gaze of the driver determines the path of the vehicle, that is, drivers steer where they are looking. This study provides critical information about driving behaviour but does not examine lateral asymmetries. With two notable exceptions, few studies have investigated spatial asymmetries while operating a motor vehicle. Also utilizing a driving simulator, Jang et al. (2009) report a pattern of rightward deviations where participants consistently veered right regardless of road markings, the number of lanes, or instructions to drive on the correct or reverse side of the road. Similar to the results of studies investigating lateral bumping (Nicholls et al., 2008; Turnbull & McGeorge, 1998) Jang et al. (2009) found a leftward bias when administering pen and paper bisection tasks. The only study to use naturalistic driving data to examine spatial asymmetries when driving was conducted by Friedrich, Elias, and Hunter (2017). In contrast to findings from lateral bumping studies (Nicholls et al., 2008; Nicholls et al., 2016) and spatial asymmetries from a simulated driving environment (Jang et al., 2009) Friedrich et al. (2017) reported more left-sided incidents (collisions as well as near-collisions).

As mentioned above, when administered in the traditional horizontal orientation the luminance judgment in the greyscales task is considered a reliable measure of leftward perceptual asymmetries (Mattingley et al., 1994). Participants are presented with two rectangles, shaded from light to dark from left-to-right, and placed one on top of the other and mirrored so that dark and light extremes are at opposite ends to the other rectangle and asked to choose the rectangle with a certain feature, that is, either the one that appears to be overall lighter or darker. When forced to choose between the two equivalent but not identically shaded rectangles neurotypical participants will most often choose the rectangle with the feature (light or dark end) on the left side (Nicholls, Bradshaw, & Mattingley, 1999). As with other measures of pseudoneglect the greyscales task is also used in the clinical setting for assessing neglect patients, who show an opposite pattern of behaviour, choosing the rectangle with the feature on the right side more often (Mattingley et al.).

Pseudoneglect is widely reported outside the greyscales task, across the landmark task, the gratingscales task, and lateralized visual detection tasks (Learmonth, Gallagher, Gibson, Thut, & Harvey, 2015). However, pseudoneglect is also observed within the greyscales paradigm when luminance judgments are replaced with judgments of numerosity, size, or distance using stimuli made up of bars of unevenly distributed stars more concentrated to one side or the other, mirrored shapes that increase in height from one side to the other (Nicholls et al., 1999) or mirrored three dimensional (3D) boxes that appear closer at one end (Krupp, Robinson, & Elias, 2010). Perhaps related to spatial and luminance biases, pseudoneglect may also affect the perception of light. Tasks relying on the ability to perceive shape from shading (Elias & Robinson, 2005; Sun & Perona, 1998) and some aesthetic preference tasks (Hutchison, Thomas, & Elias, 2011) typically produce leftward biases. Using a shape from shading target finding paradigm Sun and Perona (1998) and McManus, Buckman, and Woolley (2004) found that light is assumed to come from above and to the left. Because natural and artificial light routinely come from a single overhead source it is not unexpected for the human visual system to assume that light comes from above (Ramachandran, 1988), however the suggestion of a more specific assumption of light from above and slightly to the left does not have an intuitive explanation.

Using ambiguously shaded two-dimensional (2D) stimuli that appeared 3D in certain orientations, Mamassian and Goutcher (2001) found the most stable percept of 3D shapes occurred when the light position was assumed above and to the left. Mamassian, Jentzsch, Bacon, and Schweinberger (2003) used the same stimuli and measured event-related potentials as participants determined if the stimulus appeared 3D or not. They found that the shape being disambiguated from shading was correlated with activation in early visual areas and suggest that higher cortical areas do not play a large role in the perception of shape from shading or in assumed light source position, rather both functions occur early on in the visual system.

In addition to the aforementioned automatic processing of directional light that occurs early on in the visual system, humans may also have a higher perceptual value for above-left lighting in more complicated tasks. Archival investigations by Mamassian (2008), McManus (1979), and Sun and Perona (1998) all report a bias by painters across time periods and artistic styles to place the light in the top left. Further, when artistically untrained participants are given the opportunity to illuminate paintings they also place the light in the top left (McDine et al., 2011) and choose the left lit image over the right lit as more aesthetically pleasing (Smith & Elias, 2013). Thomas, Burkitt, Patrick, and Elias (2008) report a higher prevalence of left lit images in advertising and further that left lit advertisements are more effective at influencing purchase intention (Hutchison et al., 2011).

The focus of research examining the relationship between NRD and aesthetics has primarily centred on manipulating the directionality and composition of images. The potential influence of lighting direction in stimuli has been reported on less relative to some of the more salient directional elements of stimuli. Both the composition of photographs (González, 2012) and aesthetic preferences of those photographs by non-artists (Chahboun, Flumini, González, McManus, & Santiago, 2016) have been found to align with the direction of NRD. Freimuth and Wapner (1979) and Christman and Pinger (1997) investigated the influence of image directionality on aesthetic preferences of participants with LTR NRD and found preferences for images with left-to-right directionality. Chokron and De Agostini (2000) also found left-to-right directionality preferences among LTR participants, but also report a right-to-left preference when examining RTL participants. An investigation by Maass, Pagani, and Berta (2007) used videos to highlight the robustness of the bias across different types of stimuli. Participants viewed and rated original and mirror reversed videos of goals scored in a soccer match. When the video clip followed a left-to-right direction LTR participants rated the performance of the soccer player as faster and stronger, and the goals more beautiful, whereas RTL participants gave higher scores for right-to-left trajectory videos.

Focussing on the aesthetics of lighting, Thomas et al. (2008) report a higher prevalence of left lit images in advertising. Further, Hutchison et al. (2011) found that ratings, overall, were higher for left lit advertisements by LTR participants when asked to rate left and right lit versions of the same advertisement across the three dimensions: feeling toward advertisement, feeling toward brand, and purchase intention. Using similar mirror reversed advertisement style images; Smith and Elias (2013) replicated the leftward lighting preference among LTR individuals but not with a group of bilingual RTL individuals. By conducting an analysis of eye movements that occurred while viewing the images, Smith and Elias proposed the possibility that the amount of time examining the left or right of an image depends on NRD, as time examining images was greater leftward in the LTR group and greater rightward in the RTL group (not significant, p = 0.09 & p = 0.07, respectively).

RTL participants, like LTR individuals, demonstrate coherence between aesthetic lighting preferences and biases on more rudimentary illumination tasks. Using simple shaded spheres in a target finding array, similar to that of McManus et al. (2004), Smith, Szelest, Friedrich, and Elias (2015) found that the LTR group identified targets quicker when lighting was from the upper left, whereas the RTL group found targets faster than the LTR group under upper right lighting. Bilingual RTL participants completing the greyscales task have produced mixed results. Nicholls and Roberts (2002) report a significant leftward bias among bilingual RTL participants, however, compared with LTR participants the bias of RTL participants is reduced and even absent (Friedrich & Elias, 2014). Measuring the assumed light source illuminating a group of 2D hexagon stimuli, Andrews, Aisenberg, D'Avossa, and Sapir (2013) report that both English (LTR) and Hebrew (RTL) participants display a leftward bias. However, the bias of Hebrew participants was significantly rightward of English participants, a pattern of results similar to findings examining aesthetic preferences and lighting (Smith & Elias, 2013).

Rationale and Research Questions

Researching the lateralization of function in the brain and its iterative relationship with the study of individuals with clinical neglect, leading to the inattention of leftward space, have been critical in beginning to understand pseudoneglect, the leftward shift of attention common to all neurotypical individuals. Under certain circumstances pseudoneglect can be attenuated or in some cases even flipped to a right bias. This phenomenon, at present, is understudied and surrounded by incongruent explanations. The aim of the research presented here is to make contributions to the disentangling of factors underlying the modulation of pseudoneglect by exploring three primary areas:

a) The effects that LTR and RTL NRD have on spatial biases and aesthetic preferences.

b) The dichotomy between spatial biases that result from tasks administered in intrapersonal and extrapersonal space.

c) The effects of increasing a task's complexity by incorporating aesthetic preference responses above and beyond only spatial ability.

The broad role of spatial attention is explored through aesthetic evaluations, driving, and basic spatial ability, with the effect of lateral biases on these aspects of everyday life pulling them together for study. However, it is the modulation of the leftward bias also occurring in each of these areas that is the motivation for the studies in this research program.

In Chapter 2 perceptual asymmetries were evaluated in both LTR and RTL participants using the greyscales task, and aesthetic preferences of LTR and RTL participants were assessed using eye tracking and a more complex image rating task. Perceptual asymmetries were again examined in Chapter 3 and the aesthetic preferences of LTR and RTL participants were assessed using a task of higher complexity requiring them to light 3D sculptures. Sculpture lighting preferences of LTR and RTL artistically trained professionals were also analyzed. A more direct comparison between aesthetic preferences and spatial ability was carried out in Chapter 4. Here LTR and RTL participants executed similar procedures using the computer mouse in two different tasks, either a 2D artwork lighting task or a rudimentary version of a virtual mapping technique. In Chapter 5 extrapersonal spatial biases were examined through the analysis of naturalistic driving data and through a driving simulation in the laboratory. The important underlying questions investigated in this research follow:

1. Is there congruency between spatial biases, i.e. on the greyscales tasks, and aesthetic preferences related to lighting?
2. Using eye tracking as a measure of overt attention, do the way images are visually explored differ between NRD groups?
    a. If differences in visual explorations exist, do they contribute in a meaningful way to understanding aesthetic preferences?
3. Do aesthetic preferences of LTR and RTL groups persist across artistic mediums? Specifically, is the leftward aesthetic preference observed with 2D stimuli also present when stimuli are 3D?
4. Are actions carried out related to aesthetic preferences, i.e. placing a light source, consistent with aesthetic judgments based on the perception of lateral lighting?

    a. Does NRD influence lateral lighting biases?
    b. Does artistic training influence lateral lighting biases?
5. Does the leftward spatial bias persist in a novel mapping task?
    a. Are spatial biases on this task influenced by NRD?
6. Do rightward biases of extrapersonal space, similar to those observed when walking or operating wheelchairs, scooters, and small vehicles, persist in real-world and/or simulated driving?
7. Do urban or rural landscapes affect lateral biases when driving?
8. Are lateral biases when driving influenced by types of obstacles on the road or their locations?
9. In both simulated and real-world driving: Do collisions occur more on the left or right side? Do collisions of greater severity occur more on either side?
    a. Does driving in the real world or in a simulation affect the frequency and/or severity of collisions?
    b. Do the frequency and/or severity of collisions vary when driving straight or turning left or right?

CHAPTER 2

NATIVE READING DIRECTION MODULATES EYE MOVEMENTS DURING AESTHETIC PREFERENCE AND BRIGHTNESS JUDGMENTS

A version of this chapter has been previously published:

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Introduction

Being drawn to a certain work of art may feel natural and unguided but neuroaesthetic research suggests our preferences are not free of biases, from the artist or ourselves. Ramachandran and Hirstein (1999) propose eight strategies that artists use to make artwork pleasing to us, knowingly or not, by tapping into the visual areas of the brain. Of these, some are well-known tactics in art such as Gestalt grouping, whereas others are ported from other domains, e.g. the peak shift effect. In 225 master paintings randomly selected from the Louvre, the Prado, and the Norton Simon Museum, Sun and Perona (1998) found artists across schools and periods systematically (knowingly or not) light their paintings from the top-left. The asymmetrical distribution of visuospatial attention, referred to as pseudoneglect, may help to explain why equal attention is not paid to all aspects of artwork. Pseudoneglect is the consistent over-attending to the left side of space that results in misperceptions like incorrectly identifying the centre of a line (Bowers & Heilman, 1980; Jewell & McCourt, 2000) or misjudging the brighter (or darker) of two equivalent stimuli (Nicholls, Bradshaw, & Mattingley, 1999). Pseudoneglect has been investigated throughout cognition and neuroscience research and may, in part, help explain aesthetic preferences.

Beaumont (1985) and Levy (1976) found an aesthetic preference for images with content weighted to the right. Possible explanations for this rightward bias in aesthetic judgments, which is seemingly opposite of pseudoneglect, posit that rightward content balances out the leftward bias (Levy, 1976) or that a rightward shift of eye gaze brings more of the image into the left visual field (LVF; Beaumont, 1985). The LVF sends more information to the contralateral right hemisphere, which is dominant for spatial processing and visual attention. Both accounts highlight the importance of the right hemisphere in making these judgements, which is consistent with pseudoneglect and the leftward bias of attention.

Aesthetic preferences may be modulated by Native Reading Direction (NRD) in the same way that attention seems to be. Rinaldi, Di Luca, Henik, and Girelli (2014) examined participants with monolingual left-to-right (LTR), monolingual right-to-left (RTL), and bilingual RTL NRDs on standard and modified star cancellation and line bisection tasks. These are canonical neuropsychological tests for hemispatial neglect that are also used with neurologically normal individuals to measure pseudoneglect. RTL individuals displayed a pattern of results that deviates from the leftward bias typically shown by LTR individuals. Rinaldi et al. propose an *interactive account* between biological and cultural factors modulated by the direction of the language system to account for performance differences. A pertinent finding from the line bisection review conducted by Jewell and McCourt (2000) may help explain these results. Jewell and McCourt report that scanning direction is a significant factor modulating bisection errors, that is, initiating a scan from the left leads to leftward errors whereas rightward errors occur when a scan starts on the right. Similar findings have been reported in comparisons of LTR and RTL groups completing aesthetic-based tasks, with LTR groups preferring LTR directionality or leftward lighting and RTL groups showing an attenuated leftward bias (Chokron & De Agostini, 2000; Friedrich, Harms, & Elias, 2014; Smith & Elias, 2013).

The leftward bias has been investigated in specific areas of the field of aesthetics. McDine, Livingston, Thomas, and Elias (2011) report behaviour among non-artistically trained students consistent with the leftward bias reported by Sun and Perona (1998). When given the opportunity to illuminate images of abstract paintings on a computer screen they found that the light source was most often placed at the top-left of the painting. McManus and Humphrey (1973) report the lateral presentation of the face (i.e. posing) as another commonly used method by portrait painters. McManus and Humphrey found that the left cheek was put forward more often across 1474 paintings. When investigating lighting and posing biases in magazine advertisements Thomas, Burkitt, Patrick, and Elias (2008) report consistent results with past studies. Of 2801 advertisements, models were overall more often leftward lit, with female models exhibiting an overall leftward posing bias and males displaying no bias. Examined together, lighting and posing interacted in a significant way with more left poses in leftward lighting and more right poses in rightward lighting. Further, Hutchison, Thomas, and Elias

(2011) found that leftward lit advertisements, compared to rightward lit advertisements, received higher ratings of purchase intention, feeling toward brand, and feeling toward the advertisement.

González (2012) compared several types of portrait photos from Iran and Spain (where the NRDs move in opposite directions: Iran RTL and Spain LTR) to determine if lateral biases found in artwork composition were tied to non-artistic visual training, that is NRD. They suggest composition is influenced by NRD as the directionality of the photos mirrored the origin of the sample, with Spanish photographers displaying a LTR directionality preference and RTL directionality more common among Iranian photographers. Whether perception is positively affected by laterally biased aspects of composition has been tested experimentally with different NRD groups as well. Chahboun, Flumini, González, McManus, and Santiago (2016) measured the ratings of individually presented images as well as preferences in a forced choice between the original and its mirror to both Spanish (LTR) and Moroccan (RTL) groups using images from González (2012). Each group preferred photos that aligned with their NRD. Maass, Pagani, and Berta (2007) presented Italian (LTR) and Arabic (RTL) individuals with video clips of soccer matches and found that NRD predicted preferences. Italians rated goals as more forceful when scored in a LTR direction whereas RTL direction goals received higher ratings from Arabic speakers.

Creating, critiquing, and valuing art require an appreciation of the aesthetically pleasing and beautiful elements of life. As Ramachandran and Hirstein (1999) and Leder, Belke, Oeberst, and Augustin (2004) point out, there are many factors contributing to our preferences and attempting to disentangle them is arduous. Using an image rating task with eye tracking, the greyscales task (Mattingley, Bradshaw, Nettleton, & Bradshaw, 1994; Nicholls et al., 1999), and a sample of RTL reader-writers, the study presented here focuses on the relationship between aesthetic preferences and the way an image is visually explored, and how both are potentially influenced by learned behaviours. The inclusion of a RTL NRD group follows from the argument that NRD, coupled with scan direction, is an important (and oft overlooked) variable in psychology and cognitive neuroscience research (Henrich, Heine, & Norenzayan, 2010; Jewell & McCourt, 2000; Rinaldi et al., 2014; Smith & Elias, 2013).

Based on our previous study (Smith & Elias, 2013), greater aesthetic preference scores are predicted to result from leftward lighting for LTR reader-writers and rightward lighting for RTL reader-writers. Similarly, opposite preference biases are predicted between groups when weighting of the image is examined, with LTRs preferring leftward weighting and RTLs preferring rightward weighting. Eye movements are predicted to differ on this task across 3 dimensions: scan time allocation to the left or right, frequency of leftward or rightward fixations, and durations of leftward and rightward fixations. NRD groups are predicted to make more frequent and longer duration fixations congruous with their NRD while spending more time examining the lateral side of space where scan paths originate (left for LTR, right for RTL). The LTR group is predicted to follow the established pattern of a leftward bias on the greyscales task whereas RTL reader-writers are not expected to display a leftward bias and may even show a rightward bias.

Method

Participants

Sixty-two students attending the University of Saskatchewan took part in the experiment. LTR participants were recruited though the psychology participant pool at the University of Saskatchewan and received course credit. RTL participants were compensated $10 and recruited through announcements posted to a University of Saskatchewan online bulletin board and paper posters throughout campus. Five participants' data were discarded due to problems during testing or experimenter error. Greyscales data were collected from twenty-two RTL participants (mean age = 26.7, SD = 5.5, 9 male, 3 left handed (LH)) and thirty-three LTR participants (mean age = 23.6, SD =8.6, 11 male, 3 LH). RTL participants spent an average of 27% of their lives living in a culture where a LTR language is dominant and an average of 51% of their lives speaking a LTR language. Responses to all ninety-six trials constituted a complete greyscales data set. Preference rating data of the one-hundred-and-sixty images were collected from nineteen RTL participants (mean age = 26.4, SD = 4.9, 8 male, 3 LH; average time in a LTR culture = 25%, average time speaking a LTR language = 49%) and thirty-three LTR participants (mean age = 23.7, SD = 8.6, 11 male, 2 LH). Valid eye tracking data were collected from twenty-two RTL participants (mean age = 26.8, SD = 4.7, 9 male, 3 LH; average time in a LTR culture = 28%, average time speaking a LTR language = 49%) and thirty-one LTR participants (mean age = 22.7, SD = 7.1, 10 male, 2 LH). Eye-tracking data from the preference rating task were discarded when hardware issues prevented proper recording or because of experimenter error.

Image preference stimuli

Eighty images were presented twice, once in their original orientation and once mirror reversed, for one-hundred-and-sixty test trials. Image presentation was centred on the screen. Half of the original eighty images were sourced from LTR cultures and half from RTL cultures. Of the original 80 images, half were illuminated from the upper-left and half from the upper-right, while 23 were weighted to the left, 24 were weighted to the right, and 33 were centrally weighted. Lighting direction and image weighting were rated independently by three individuals, with their ratings reaching an acceptable level of reliability. Images were collected online from websites such as www.adsoftheworld.com and www.coloribus.com.

Procedure

Ethics approval was granted from the University of Saskatchewan Behavioural Ethics Research Board. After giving informed consent and completing a demographic questionnaire addressing sex, age, visual or auditory impairments, handedness, footedness, and NRD (Elias, Bryden, & Bulman-Fleming, 1998; see appendix A) participants were seated at a desk to complete the computer based tasks. Participants were instructed to verbally report a rating for each image on a scale from one to seven (1 = "dislike" 7 = "like"). Ten practice trials were completed prior to one-hundred-and-sixty test trials occurring in two blocks. Image presentation was fixed at 2000 milliseconds (msec.), preceded by a fixation cross and followed by a blank grey screen. Fixation crosses were presented randomly in a location in one of the four quadrants of the screen (212x180; 212x840; 1064x180; 1064x840) to avoid systematic eye movements from a repeated central fixation and advanced to the test image when fixated on for 500 msec. The verbal rating was given during viewing of the blank grey screen, which remained until the space bar was pressed by the participant, invoking the next fixation cross.

The greyscales task (Mattingley et al., 1994) was administered following the preference rating task. Participants were instructed to choose the overall darker rectangle as quickly as possible, while remaining accurate, of two equivalent but not identical rectangular grey scales moving from black on the right to white on the left, or vice-versa, presented one on top of the other. Ninety-six free-viewing test trials were separated by central fixation crosses presented for 1000 msec. and preceded by five practice trials. Selections were made by pressing the up arrow ("8" on the number pad) to select the top rectangle or the down arrow ("2") for the bottom rectangle. Both tasks together were typically completed in less than thirty minutes.

Equipment

A Sensomotoric Instruments (SMI, Boston, USA, www.smivision.com) RED-4 eye tracking camera recorded at 60Hz during the image rating task. Stimuli for the image rating task were presented using Experiment Centre (SMI) on a 1280x1024 nineteen-inch display powered by a custom-built PC (SMI). Stimuli for the greyscales task were presented in E-Prime Version 1.2 (Psychology Software Tools, Inc., Pittsburgh, USA, www.pstnet.com/eprime) on the same display.

Scoring

Greyscales. Difference scores were calculated for each participant based on a right minus left scoring scheme. Responses made each time a darker on the left rectangle was chosen were subtracted from darker on the right rectangle responses, resulting in a leftward bias from a negative score.

Image rating. Each image was coded by lighting direction (left or right) and weighting of content (left, right, or neutral). Difference scores were calculated for lighting and weighting using a similar right minus left scoring scheme, averaging each participant's preference ratings for leftward lit and leftward weighted images and subtracting them from rightward lit and rightward weighted preference rating averages. Negative scores again indicating leftward biases.

Eye tracking.

ROI durations. Two regions of interest (ROI) were defined by dividing the display in half along the central vertical axis. Durations (msec.) of fixations occurring in each half were averaged for each trial.

Fixation analysis. A fixation with an x-axis coordinate smaller than the preceding fixation's coordinate, that is, moving from right-to-left, was classified as a *leftward fixation*. Opposite left-to-right movement constituted a *rightward fixation*. Fixations were analyzed in two ways, both by creating difference scores. First, the *number of fixations score* was calculated by subtracting the number of leftward fixations from the number of rightward fixations. Second, the *durations fixation score* was calculated by subtracting the leftward fixations duration average from the rightward fixations duration average (averages in msec.). As the first fixation landed in the space previously occupied by the central fixation cross, it was always excluded from analysis.

Results

Greyscales

Both LTR and RTL participants displayed a leftward bias on the greyscales task. When subjected to one-sample *t*-tests against zero RTL participants showed a just significant leftward bias, $t(21) = -2.08$, $p = .050$ (mean score = -23.55, SD = 53.06) while LTR participants displayed a highly significant leftward bias, $t(32) = -5.148$, $p < .001$ (mean score = -38.3, SD = 43.74). An independent-samples *t*-test found no significant difference between NRD groups, $t(53) = 1.14$, $p = .260$. Within the RTL group, the amount of time spent speaking a LTR language, living in a LTR culture, sex, or handedness were insignificant on greyscales scores. However, the small sample of LH participants exhibited a pattern of divergent behaviour. Within the LTR group, sex and handedness were not significant factors, but again the small sample of LH participants exhibited divergent behaviour. Within NRD groups right handed (RH) participants displayed leftward biases (RTL N = 19 mean = -31.47 SD = 51.97; LTR N = 30 mean = -40.27 SD = 44.17) but scores from LH trended towards a rightward bias, where LTR individuals' scores were halved (N = 3 mean = -18.67 SD = 17.45) and scores from RTL individuals were actually positive (N = 3 mean = 26.67 SD = 29.69). Collapsing across NRD group further illustrates this trend (RH N = 49 mean = -36.86 SD = 47.01; LH N = 6 mean = 4.00 SD = 33.03).

Image rating

Preferences for lighting and weighting were uniformly leftward in the LTR group and rightward in the RTL group (Figure 2-1). However, neither group displayed lateral biases for lighting or weighting as results from one-sample *t*-tests against zero did not reach significance. Further, lighting or weighting differences between NRD groups were not significant when compared with independent-samples *t*-tests (lighting $t(50) = .925$, $p = .360$; weighting $t(50) = 1.544$, $p = .130$). We conducted Pearson's product-moment correlations to investigate the strength of the relationships between preference scores and exposure to LTR language within the RTL group.

First, we investigated the relationship between the amount of time spent living in a LTR culture with lighting preference scores and then with weighting preference scores. A weak inverse relationship was discovered in both cases. Lighting preference scores were non-significantly negatively correlated with the time spent living in a LTR culture ($r = -.124$, n = 19, $p = .613$), as were weighting preference scores ($r = -.174$, n = 19, $p = .477$). As the amount of time living in a LTR culture increased, preference scores decreased (became more negative or leftward). Next, we examined the relationship between the amount of time spent speaking a LTR language with lighting preference scores and then with weighting preference scores. A weak inverse relationship was observed between speaking a LTR language and lighting preferences, indicating greater leftward preferences among those speaking a LTR language for a longer time ($r = -.119$, n = 19, $p = .628$). No correlation was found between speaking a LTR language and weighting preferences ($r = 0$, n = 19, $p = 1.0$).

Eye tracking

ROI durations. Durations (msec.) were examined using a repeated-measures analysis of variance (ANOVA) with a between subjects factor of NRD group (RTL or LTR) and within subjects factors of image lighting (left or right), image weighting (left, right, or neutral), and ROI (left or right). Significant interactions between lighting and ROI ($F(1,51) = 38.997$, $p < .001$, $\eta_p^2 = .433$), weighting and ROI ($F(2,102) = 1109.097$, $p < .001$, $\eta_p^2 = .956$), and lighting, weighting, and ROI ($F(2,102) = 96.893$, $p < .001$, $\eta_p^2 = .655$) were observed.

Post hoc paired-samples *t*-tests revealed that left lighting did not elicit greater scan times in either ROI, $t(52) = .427$, $p = .671$, whereas right lighting lead to longer scan durations in the right ROI, $t(52) = 3.058$, $p = .004$. Using paired-samples *t*-tests to compare left and right ROIs under left lighting revealed opposing biases between LTR and RTL groups leading to the null finding (LTR: $t(30) = .356$, $p = .725$; RTL: $t(21) = .961$, $p = .348$). However, scanning was significantly biased to the ROI with the majority of the image weight (left weight: left ROI > right ROI, $t(52) = 19.746$, $p < .001$; right weight: right ROI > left ROI, $t(52) = 24.522$, $p < .001$). Neither ROI was scanned more when the weighting of the image content was neutral, $t(52) = .171$, $p = .865$. There was a main effect of ROI, with a greater mean duration time in the right side ROI, that approached significance, $F(1,51) = 3.827$, $p = .056$, $\eta_p^2 = .070$.

Neutral weighted images, which on their own did not elicit any scanning biases, were broken down by left and right lit images and compared with Bonferroni corrected tests. Within the LTR group, left lighting biased scan durations to the left ROI, ($t(30) = 4.933$, $p < .001$) whereas right lighting increased duration times to the right ROI ($t(30) = 4.014$, $p < .001$). Within the RTL group, right lighting conditions led to more time examining the right ROI ($t(21) = 3.314$, $p = .003$) but left lighting did not elicit biases to either ROI ($t(21) = 1.689$, $p = .106$).

Independent-samples *t*-tests found the amount of time spent scanning the left or right ROI under left or right lighting did not differ significantly from each other in either NRD group.

Fixations. Although independent-samples *t*-tests did not find NRD groups to be significantly different from each other in the number of fixations made to the left or right ($t(51) = .366$. $p = .358$) or in leftward (right-to-left) or rightward (left-to-right) fixation durations ($t(51) = .823$, $p = .414$), one-sample *t*-tests compared to zero revealed significant biases within each group. A greater number of rightward (left-to-right) fixations were made by the LTR group ($t(30) = 2.278$, $p = .030$), and durations were greater for rightward (a fixation to the right of the previous fixation) fixations in the RTL group ($t(21) = 2.898$, $p = .009$).

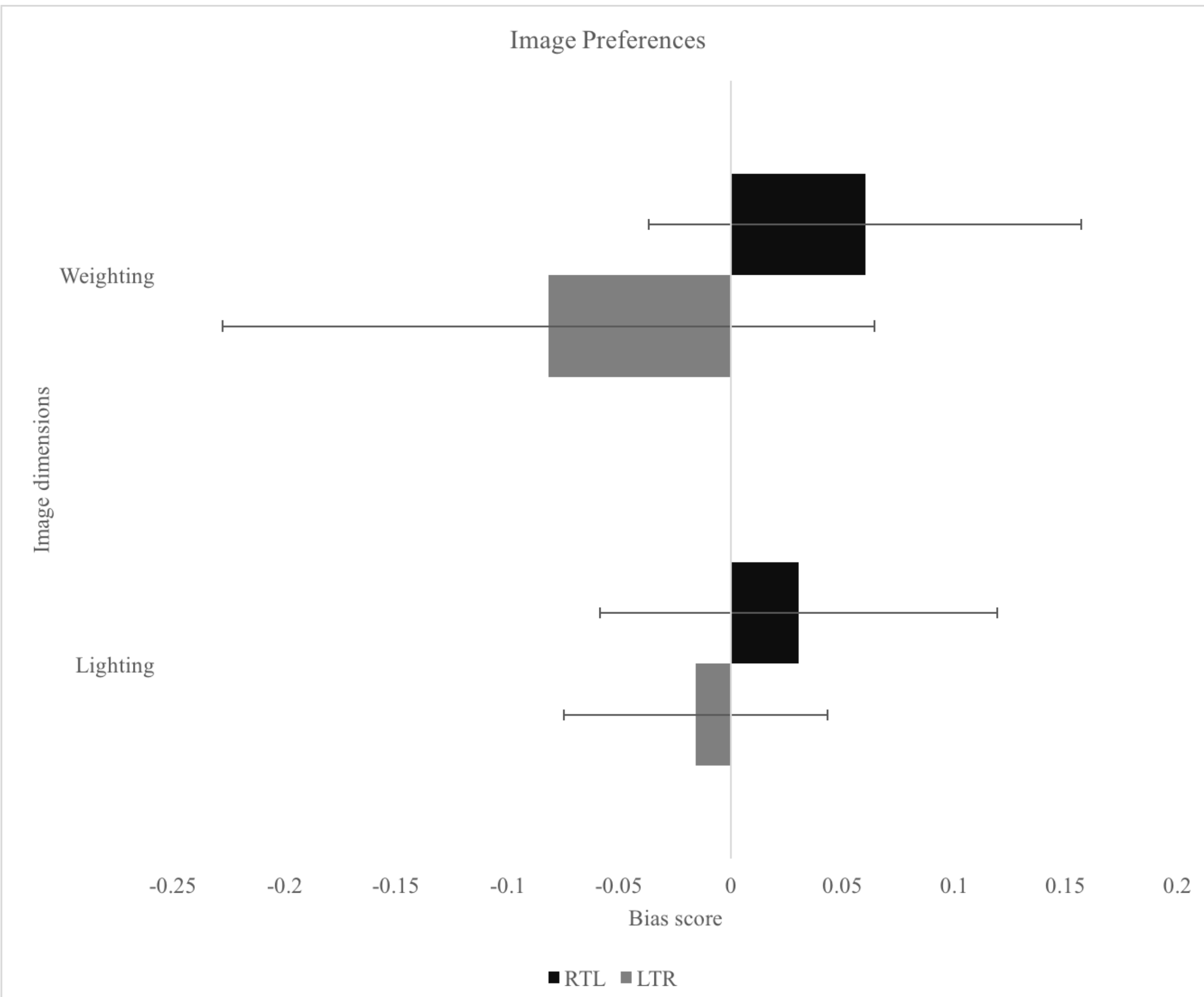

Figure 2-1. Image preferences uniformly leftward in the left-to-right (LTR) group and rightward in the right-to-left (RTL) group. Error bars represent 95% confidence intervals. Bias scores on the x-axis were calculated using a right minus left scoring scheme making leftward values negative.

Discussion

The results broadly support our predictions but differ in some important ways, further outlined below. Generally, we expected LTR reader-writers to display leftward biases on the perceptual asymmetries task as well as for aesthetic preference based on luminance and weighting, and eye-movements consistent with reading direction. Conversely, we expected eye movements in the RTL group to reflect NRD, and for image ratings and perceptual asymmetries to be biased rightward, or opposite from the LTR group.

Findings from the current study suggest that while neural areas involved in basic visuospatial processing are most likely shared between RTL and LTR groups, the process of learning a RTL primary language during the highly neural-plastic time of childhood attenuates leftward biases typically observed. We found LTR and RTL groups to show clearly diverging trends of behaviour when making aesthetic judgments and consistent leftward biases on the greyscales task. However, the perceptual asymmetries bias was much stronger in the LTR group. A consistent pattern of trends in predicted opposite directions for LTR and RTL groups across image lighting and weighting were found, despite lateral preference biases for either dimension in either group failing to reach significance. We theorize that the degree of leftward bias attenuation depends on the complexity of the task, which is outlined further toward the end of the discussion. The greyscales task is a simple visuospatial exercise and subsequently elicits leftward biases in each group. Although completing the aesthetics task shares the basic visuospatial elements that underpin the greyscales comparison, it also relies on many other processes because of the complexity of the judgement. The added complexity and computations appear to reduce biases.

Eye tracking ROI data from the current study provides support for the theory that a rightward attentional shift occurs when making aesthetic judgments to more completely view an image, compensating for the dominance of the right hemisphere in visuospatial processing (Beaumont, 1985). Mean gaze times were greater for the right side of space across lighting conditions and in the right weighted condition, enabling more of the image to be explored and processed, regardless of cultural differences like learning to read and write. The design of the current study allowed for more in-depth analyses of eye-movements and image conditions, with the ability to explore the influence of lateral weighting and lighting. Weighting content is an effective manipulation in biasing visual attention as both groups spent more time scanning the side of the image that was more heavily weighted. In neutral weighted images, lateral lighting also effectively biases attention. NRD may also play an important role in attention allocation as in some analyses null effects were found to result from opposite effects in each group.

Fixation data supports the hypothesis that images are visually explored in a similar manner as reading. Just as reading a LTR language involves more rightward (left-to-right) eye movements, LTR individuals make more rightward fixations when visually exploring images. Consistent with Rinaldi et al.'s (2014) findings that bilingual RTL groups and LTR groups do not necessarily exhibit an opposite pattern of behaviour, the bilingual RTL group in the current study did not make a greater number of leftward (right-to-left) fixations. However, longer rightward fixation (a fixation to the right of the previous fixation) durations made by the RTL group may indicate greater information extraction from fixations that are congruous with where scans are initiated.

In the present study, where images were rated one at a time, preference scores were of smaller magnitude compared to preference scores recorded in a forced choice paradigm. Both Chahboun et al. (2016) and Smith and Elias (2013) have experimentally demonstrated that directly comparing mirror images elicits a stronger aesthetic preference. Findings from the current study replicate lighting biases observed by Smith and Elias (2013) and extend them to include information about image weighting and more detailed eye movements. Smith and Elias highlight the necessary trade-off between eye tracking data accuracy and the stronger biases elicited by forced choice. Following from that, using an image rating paradigm in the present experiment yielded additional eye tracking data and sacrificed magnitude, but not reliability, of preference biases. Taken together, findings from the current study design and the forced choice paradigm present a more comprehensive picture than before of human aesthetic preferences. Additionally, the allocation of visuospatial attention and how artistic elements like lighting and image weighting can be influential in different ways for each NRD group.

The attenuation of the leftward bias is demonstrated across tasks in the present study. On the greyscales task the LTR group displayed a strong leftward bias compared with the weaker leftward bias of the RTL group. The leftward bias of RTL reader-writers is reduced to an even greater degree on the aesthetic preference task. Our post-hoc examination of the greyscales task results revealed a rightward shift among a small group of left-handed RTL reader-writer participants. While a reduced leftward bias among left-handed LTR reader-writers is to be expected, the trend toward a rightward bias among RTL LH participants further highlights potential interactions between learning to read and write, hemispheric dominance, and handedness. These findings support the continued inclusion of non-western participants in psychological science and further challenge the established leftward bias. Others may be encouraged by these findings and intentionally test these differences by designing experiments for RTL participants with equal samples of LH and RH individuals.

Based on preference ratings from the current study by LTR and RTL groups (as well as within the RTL group) and also considering the results from the forced choice experiment from our previous study (Smith & Elias, 2013) that used the same stimuli, we present some conclusions and summarize our theory below. Despite relatively minor differences in image exploration strategies between NRD groups, RTL and LTR individuals make different decisions that suggest distinct aesthetic preferences. Lateral bias strength differs in the same way, to a lesser degree, on the greyscales task. This suggests that aesthetic preference may be informed by the allocation of visuospatial attention. We propose the following: Aesthetic preference is dependent on the rudimentary elements of lighting and shading, which are foundational to luminance judgments of the greyscales task. The allocation of visuospatial attention in the greyscales task is arguably more stable and operating at a more basic neurological level than aesthetic preference, but it is also malleable and dependent on factors such as handedness and NRD, as well as the interactions between them.

As we have demonstrated, extensive analyses are required when working with rich eye tracking data. Further studies are needed to build on the results presented here to establish baseline measures of eye movements when making aesthetic judgments. For this theory to progress, future studies must make additional comparisons between basic and complex judgment tasks using different stimuli and measures. A limitation of the theory, at present, is that it is based on very specific data. Future studies must be designed to examine other possible factors at work between aesthetic preferences and visuospatial tasks to determine the validity of the *attenuation increases with complexity* theory. The research presented here, and the resulting theory, are also limited by the sample of RTL NRD individuals. Admittedly, we would ideally have a more balanced sample of LTR and RTL NRD groups. Future research should aim for larger samples of RTL NRD individuals, as well as the recruitment of monolingual RTL NRD individuals. Administering neuropsychological tests used for understanding neglect to RTL NRD individuals with typical and atypical language dominance may be valuable, as questions remain about spatial attention based (and further, aesthetic preference) decision making of native RTL reader-writers.

CHAPTER 3

IS THERE AN ARTISTRY TO LIGHTING? THE COMPLEXITY OF ILLUMINATING THREE-DIMENSIONAL ARTWORKS

A version of this chapter has been previously published:

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Introduction

The aesthetic experience and evaluation of a piece of art is complex, influenced by the interplay of emotions, knowledge, and perception (Chatterjee & Vartanian, 2014). Elements such as composition, grouping, colour, and lighting are perceived both independently and in combination with each other, helping to form aesthetic preferences. Vision scientists are particularly interested in the artistic element of value, the contrast between light and shadow, which is critical in determining the *where* and *what* of the light source, which helps resolve ambiguities of object *shape* and *colour*, respectively (Mamassian, 2008).

It is no surprise that the human visual system makes the assumption that light comes from above (Ramachandran, 1988). Somewhat surprisingly, the human visual system also makes the assumption that light comes from above and to the left (Sun & Perona, 1998). Our experience in the world, with natural or artificial light routinely coming from a single overhead source, is thought to guide the light-from-above assumption. Kleffner and Ramachandran (1992) and Ramachandran (1988) discovered that when ambiguously shaded two-dimensional (2D) stimuli were illuminated from above a layer of dimensionality was added, such that a circle then appeared as a sphere. However, shifting the light source ninety degrees, illuminating the circle laterally, the perception of three-dimensions (3D) disappeared. Studies using various other simple stimuli report consistent results, suggesting that these biases may be rooted in neural organization (Mamassian & Goutcher, 2001; Mamassian, Jentzsch, Bacon, & Schweinberger, 2003).

The above-left lighting preference does not appear to have an intuitive explanation, but researchers have gained insight through the use of simple 2D stimuli and real-world investigations. Target detection tasks using arrays of shaded spheres reveal that above-left lighting facilitates quicker target finding than lighting from other orientations (McManus, Buckman, & Woolley, 2004; Sun & Perona, 1998); this lateral lighting bias also translates to individually-presented shaded spheres (Elias & Robinson, 2005). Whereas the light-from-above bias may have been born out of necessity, it could be that humans have higher perceptual value for above-left lighting. Archival investigations by Mamassian (2008), McManus (1979), and Sun and Perona (1998) all report a bias by painters across time periods and artistic styles to place the light in the upper left, indicating the importance of examining more complex, real-world, images. Findings from studies examining the contemporary medium of advertisements support the robustness of the above-left lighting bias. Thomas, Burkitt, Patrick, and Elias (2008) found full-page magazine ads were more likely to be lit from the upper left. Further, left lit advertisements were also found to be more effective at influencing future purchase intentions and preferences than right lit advertisements (Hutchison, Thomas, & Elias, 2011).

With these investigations in mind, questions arise about the intentionality behind lighting biases. Is this bias produced by artists? Do artists possess an innate ability to hold, arrange, and manipulate aesthetic elements in a unique way? Or, is the leftward lighting bias a product of selection by the masses? Has the higher perceptual value of left lit paintings lead to their proliferation? Does the higher perceptual value of left lit versions of advertisements result in those being what is mostly viewed the public? There are indications that the higher perceptual value of leftward lighting is not exclusive to artists and the artistically trained. McDine, Livingston, Thomas, and Elias (2011) report that non-artists will more often choose to place the light in the upper left of artworks when given control over lighting images of abstract paintings. The argument that a common network of structures within the brain are at the core of the leftward lighting bias is supported by the coherence of results from assumptions about luminance made by the visual system with basic stimuli, lighting preferences of non-artists in the laboratory, and examining artists in the real-world.

Sedgewick, Weiers, Stewart, and Elias (2015) implemented a paradigm in which participants were given control of artwork lighting, similar to that of McDine et al. (2011). As much of aesthetics research examines 2D artistic media, Sedgewick et al. used 3D sculptures to investigate lighting biases outside of two-dimensions. Sedgewick et al. report that the move from 2D to 3D stimuli results in a rightward lighting bias and no interaction between lighting direction and posing direction, two atypical findings. As previously outlined, artwork lighting is consistently biased to the left. Further to this, lighting has been found to interact with posing direction. A bias to present the left cheek, known as the leftward posing bias, has been identified in archival examinations of 2D images like portrait painting (McManus & Humphrey, 1973) and photography (Labar, 1973). Grüsser, Selke, and Zynda (1988) and Thomas et al. (2008) examined posing direction in conjunction with lighting direction in portraits and advertisements, respectively. Findings from the two studies were consistent in reporting a congruency between the direction of lighting and the direction of the pose. In an effort to complement aesthetic detail and not over-expose the sculpture, a rightward lighting bias may have emerged, as Sedgewick et al. propose that lighting from the left may have appeared more intense on 3D sculptures. This rationale comes from a study by McCourt, Blakeslee, and Padmanabhan (2013) in which the theory of subjective lighting equality is posited. McCourt et al. reported perceptual lighting inequalities of more basic 3D stimuli, as 3D cube arrays were perceived as significantly more intensely illuminated when lit from the left.

Atypical lighting biases have also been reported from participants with a native reading direction (NRD) other than left-to-right (LTR), with right-to-left (RTL) NRD participants showing attenuated leftward biases on tasks of both perception and action. RTL participants tend to display a stable trend of preferences significantly different from LTR individuals, however mean scores indicating rightward lighting preferences are typically small and non-significant. This has been demonstrated when forced to indicate a preference between mirror-reversed images, left lit and right lit versions, either presented at the same time one on top of the other (Smith & Elias, 2013) or when rating images one at a time (Smith & Elias, 2018). Additionally, in a study replicating and extending McDine et al.'s (2011) study, Smith, Duerksen, Gutwin, and Elias (2019) found that average light placements of RTL participants illuminating paintings were slightly right of centre, significantly rightward of LTR participants' placements but not a significant rightward bias.

RTL participants, like LTR individuals, demonstrate coherence between aesthetic lighting preferences and biases on more rudimentary illumination tasks. Measuring the assumed light source illuminating a group of hexagons Andrews, Aisenberg, D'Avossa, and Sapir (2013) report that both English (LTR) and Hebrew (RTL) participants display a leftward bias. However, a similar pattern of results to the aforementioned aesthetics studies is observed as the bias of Hebrew participants is significantly rightward of English participants. Using simple shaded spheres in a target finding array, similar to that of McManus et al. (2004), Smith, Szelest, Friedrich, and Elias (2015) found that the LTR group identified targets quicker when lighting was from the upper left, whereas the RTL group found targets faster than the LTR group under upper right lighting.

The pattern of leftward bias attenuation by RTL participants seen on basic illumination and aesthetics tasks has also been observed on basic spatial attention tasks like line bisection, star cancellation (Rinaldi, Di Luca, Henik, & Girelli, 2014), and greyscales (Friedrich & Elias, 2014; Smith & Elias, 2018). Leftward biases typically observed on these tasks have been explained by *pseudoneglect* (Bowers & Heilman, 1980). Pseudoneglect is the leftward spatial bias common to all humans, driven by specialization of the parietal lobe of the right hemisphere for spatial processing. Rinaldi et al. (2014) have proposed the *Interactive Account of visuospatial asymmetries* that posits the degree of pseudoneglect depends on the interaction of cultural factors (NRD: from monolingual LTR, to bilingual, to monolingual RTL) and biological factors (right hemisphere specialization for visuospatial processing). Smith and Elias suggest that illumination is foundational to aesthetic preference and hypothesize that leftward biases observed on basic illumination tasks (falling under the umbrella of pseudoneglect) and aesthetics tasks are related. To complement the Interactive Account, Smith and Elias conceived the *attenuation increases with complexity theory*, which suggests pseudoneglect (importantly, including judgements of illumination) is on a shared spectrum with aesthetic biases. Although the strength of the leftward bias depends on the interaction of culture and biology, it is further contingent on task complexity. Higher task complexity appears to attenuate pseudoneglect, and move biases rightward, regardless of NRD. The nature of the task seems to dictate the degree of leftward attenuation, with NRD dictating baseline biases, as starting points for RTL individuals are typically rightward of LTR individuals.

The attenuation increases with complexity theory offers an alternate explanation for Sedgewick et al.'s (2015) results with 3D sculptures. For the following reasons it could be argued that Sedgewick et al.'s task was of *high* complexity: (a) at the most basic level, aesthetics tasks are more complex than basic spatial or simple illumination tasks; (b) within aesthetics tasks, lighting a sculpture in a pleasing way is more complex than illuminating 2D stimuli; (c) with several lights to toggle and the ability to move around sculptures, Sedgewick et al.'s experimental design was realistic but also added significant complexity (compared with other artwork lighting paradigms, e.g. McDine et al., 2011). The current study considered these points and implemented a simplified experimental design. In an attempt to test the theory behind the Interactive Account and the attenuation increases with complexity theory, bilingual RTL participants were recruited in addition to LTR participants to complete the sculpture lighting task. The same sculpture stimuli used by Sedgewick et al. (2015) were employed in the current study, however they were depicted in a greyscale format on a black background, and light came from only a single source and was simply manipulated by clicking and dragging the computer mouse. Lighting intensity was held constant throughout so that the only manipulation was the location of illumination. Following the sculpture lighting task, participants completed the greyscales task as a measure of perceptual asymmetries (Nicholls, Bradshaw, & Mattingley, 1999). A content analysis examining sculpture lighting in galleries in predominately LTR and RTL regions was also conducted.

We outline three hypotheses:

1) From the content analysis, lighting biases in LTR and RTL regions are predicted to diverge, with sculpture lighting biased leftward in LTR region galleries and either show no significant bias or a rightward bias in RTL region galleries.

2) Light placements of the LTR group compared with those of the bilingual RTL group in the laboratory may not result in significant differences between groups, however, the LTR group is predicted to show a bias leftward of the RTL group.

3) On the greyscales task both groups are predicted to show leftward biases; however, the magnitude of the bias for the LTR group should be greater than the RTL group.

Method

Sculpture Content Analysis

Images. Of 1930 images of sculptures, only images with a clear light source were coded and included for analysis. This resulted in the exclusion of 241 images for a final sample of 1689 images. Images were collected and scored by JRS and LJE from online archives of twenty-two galleries from either LTR or RTL regions. Table 3-1 outlines which gallery archives were used.

LTR Galleries	RTL Galleries	
Museum of Modern Art New York, NY	Israel Museum Jerusalem, Israel	Safarkhan Art Gallery Cairo, Egypt
Metropolitan Museum of Art New York, NY	Mayanot Gallery Jerusalem, Israel	Karim Francis Gallery Cairo, Egypt
Los Angeles County Museum of Modern Art Los Angeles, CA	Jewish Quarter Reconstruction[a] Jerusalem, Israel	Adam Henein Cairo, Egypt
Art Institute of Chicago Chicago, IL	Tel Aviv Museum of Art Tel Aviv, Israel	Picasso Art Gallery Egypt Cairo, Egypt
Museum of Fine Arts Boston Boston, MA	Musa Eretz Israel Museum Tel Aviv, Israel	Zamalek Art Gallery Cairo, Egypt
Montreal Museum of Fine Arts Montreal, Canada	The Negev Museum of Art Negev, Israel	Almasar Gallery Cairo, Egypt
	Design Museum Holon Holon, Israel	The Grand Egyptian Museum Giza, Egypt
	Mishkan Museum of Art Ein Harod, Israel	ATHR Jeddah, Saudi Arabia

Table 3-1. Sculpture Image Gallery Locations
Note. LTR = left-to-right; RTL = right-to-left
[a]The Company for the Reconstruction and Development of the Jewish Quarter in the Old City of Jerusalem LTD.

Coding and scoring. Of the 1689 final images, 900 were from LTR galleries and 789 were from RTL galleries. These final images were coded for pose and lighting direction. From LTR galleries there were 317 images with a central pose, 261 with a left pose, and 322 with a right pose and 174 images with central lighting, 400 with leftward lighting, and 326 with rightward lighting. From the RTL galleries there were 271 centre posed images, 239 left posed images, and 279 right posed images and 85 images with central lighting, 316 with leftward lighting, and 388 with rightward lighting. The pose of the sculpture and lighting direction in the image were scored by assigning *+1* for rightward, *-1* for leftward, and *0* for central. Averages were calculated for each region, resulting in an overall negative score indicating a leftward lighting bias and an overall positive score indicating a rightward lighting bias.

Sculpture Lighting Paradigm

Participants. Forty-nine participants with a mean age of 20.3 years (*SD* = 2.9) reported having a LTR direction native language. Eight participants were left-handed, 42 were female, and all were undergraduate students recruited through the University of Saskatchewan Psychology Participant Pool, receiving course credit as remuneration.

Thirty participants with a mean age of 29.2 years (*SD* = 5.8) reported a RTL direction native language. Two participants were left-handed, 17 were female, and were either an undergraduate or graduate student recruited through posters on campus or digitally on the university website, receiving $10 as remuneration.

Native language was determined through self-report using a pen and paper demographic questionnaire which also addressed sex, age, visual or auditory impairments, handedness, and footedness (Elias, Bryden, & Bulman-Fleming, 1998; see appendix A). Farsi was the most common RTL native language at 20 participants, with 6 Arabic, and 4 Urdu participants following. The majority of RTL participants indicated that their native language remained their current primary language with only 7 participants disclosing that English was now their primary language. RTL participants reported an average time speaking a LTR language of 13.4 years with an average time spent in a primarily LTR culture of 5.4 years.

Equipment. Computer programs were presented using a Windows 10 PC with 8 GB of ram and a 3.3 GHz Intel Core i5 processor mated to a 1920 x 1080 pixel display with 32-bit RGB colour, 60 Hz refresh rate, and powered by an NVIDIA GeForce GTX 750 Ti graphics card. The sculpture lighting task was designed in the Unity editor (Unity Technologies, San Francisco, USA, www.unity.com). All interactions were developed in C#, the scripting language used in Unity.

Procedure. Ethics approval for this research was granted by the University of Saskatchewan Behavioural Research Ethics Board (Beh-REB #15-31). Participants were seated at a desk for the computer-based tasks after giving informed consent and completing a pen and paper demographic questionnaire addressing sex, age, visual or auditory impairments, handedness, footedness, and NRD (Elias et al., 1998). There were no windows in the room and the overhead lights were turned off. Participants first completed the sculpture lighting task followed by the greyscales task. The sculpture lighting task consisted of twenty-two original sculpture orientations and twenty-two mirror-reversed orientations for a total of forty-four trials to balance for posing direction (10 central posed, 17 left posed, 17 right posed). Sculptures were depicted in greyscale on a black background. Five practice trials preceded the test trials and a centrally located fixation cross was presented for 1000 msec. prior to each sculpture. Aural instructions were given to the participant to click and drag the computer mouse around the sculpture and place the light in the location that made the sculpture most aesthetically pleasing to them. Lighting intensity was held constant throughout so that the only manipulation available to participants was the location of the unidirectional light source. The light placement decision was finalized by pressing the return key on the computer keyboard. There were no time constraints, but participants were encouraged to make their decision in a timely manner.

Coding and scoring. Final light placement in each trial was coded as left or right, and the pose of the sculpture was coded as centre, left, or right. The pose of the sculpture and final decision about light placement were scored by assigning *+1* for rightward, *-1* for leftward, and *0* for central. Averages were calculated for participants in each NRD group, resulting in an overall negative score indicating a leftward lighting bias and an overall positive score indicating a rightward lighting bias. The time taken to make the final decision about light placement was also recorded as *response time*.

Greyscales task. Participants viewed ninety-six pairs of equivalent but not identical greyscales, presented one on top of the other. A greyscale is a rectangular bar, referred to as a luminance gradient, that is black and white at the extremes. The length of the greyscales and amounts of black and white pixels varied between trials. A visual example is provided in Nicholls et al. (1999). Participants were instructed to choose the overall darker rectangle as quickly as possible, while remaining accurate, by pressing the *t* or *b* keys for the top or bottom rectangle. Left and right finger placement was counterbalanced between participants. Stimuli were presented for a maximum of 5000 msec. and were separated by a central fixation cross remaining for 1000 msec. Lateral bias scores on the greyscales task were computed by subtracting the number of times the darker on the left rectangle was chosen from the number of times the darker on the right rectangle was chosen, resulting in a negative score for more leftward choices and a positive score for more rightward choices.

Completion of both tasks typically did not take longer than thirty minutes. After finishing both tasks participants were given a debriefing form and a brief explanation of the aims of the experiments.

Results

Sculpture Content Analysis

One-sample *t*-tests against a midpoint of zero were used to determine if lighting was biased in a certain direction when applied to sculptures. In LTR galleries, leftward lighting was used significantly more, $t(899) = -2.76$, $p = .006$, whereas in RTL galleries an opposite rightward lighting bias was found, $t(788) = 2.73$, $p = .007$. As the Levene's test for equality of variances was violated a *t*-statistic not assuming homogeneity found the difference in lighting biases between galleries in LTR and RTL regions to be significantly different from each other, $t(1633.19) = -3.868$, $p < .001$.

Congruency between pose and lighting direction was revealed using follow up one-sample *t*-tests against a midpoint of zero, with $p = .001$ to correct for multiple comparisons. In LTR and RTL regions lighting direction was significantly biased leftward for left poses (LTR: $t(260) = -26.95$, $p < .001$; RTL: $t(238) = -7.04$, $p < .001$) and biased rightward for right poses (LTR: $t(321) = 14.47$, $p < .001$; RTL: $t(278) = 11.07$, $p < .001$). In LTR regions lighting was also biased leftward for centre poses, $t(313) = -3.61$, $p < .001$, whereas no significant lighting bias for centre pose sculptures in RTL region galleries was revealed, despite a mean positive score, $t(270) = 1.16$, $p = .245$ (see Figure 3-1).

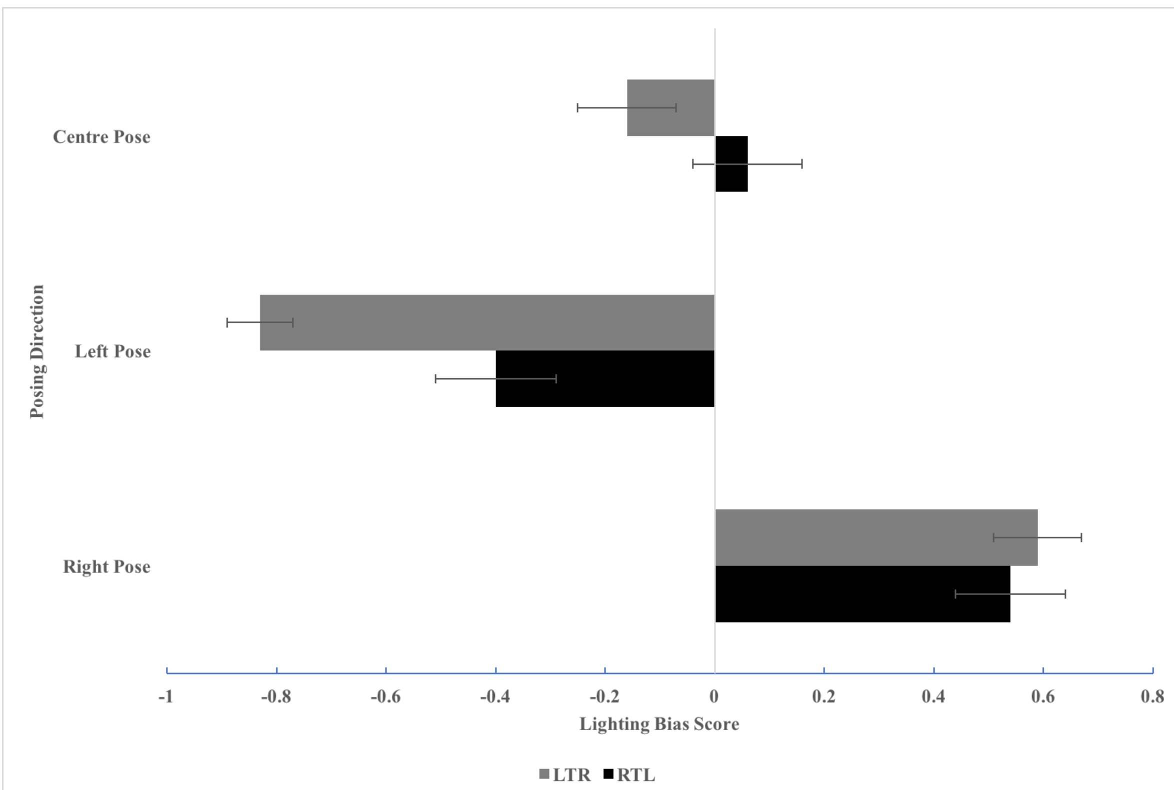

Figure 3-1. Lighting bias association with posing bias in LTR and RTL region galleries. Error bars represent 95% confidence intervals. Lighting bias scores created by coding rightward light placements as +1 and leftward placements as -1; overall negative score indicates a leftward lighting bias. LTR = left-to-right; RTL = right-to-left.

Sculpture Lighting Paradigm

No significant light placement biases were observed for the LTR or RTL group when mean scores were compared against a midpoint of zero with one-sample *t*-tests (LTR: $t(49) = .11$, $p = .910$, $M = .002$, $SD = .13$; RTL: $t(29) = -.89$, $p = .380$, $M = -.04$, $SD = .22$). An independent-samples *t*-test revealed that the mean scores between groups were not different from each other, $t(77) = .96$, $p = .339$.

Grouping trials by posing direction and analyzing light placements against the midpoint of zero with one-sample *t*-tests for each pose revealed congruency between lighting bias and posing direction. In the LTR group, the mean score of -.56 ($SD = .24$) for left posed sculptures was significant, $t(48) = -16.41$, $p < .001$, the mean score of .57 ($SD = .21$) for right posed sculptures was significant, $t(48) = 18.52$, $p < .001$, and there was no significant lighting bias for centre posed sculptures, $t(48) = .1$, $p = .920$ ($M = .004$, $SD = .28$). Although there was a leftward lighting bias for left posed sculptures, ($M = -.55$, $SD = .25$) $t(29) = -12.07$, $p < .001$, and a rightward lighting bias for right posed sculptures ($M = .47$, $SD = .35$) $t(29) = 7.26$, $p < .001$, there was again no significant lighting bias for centre posed sculptures ($M = -.03$, $SD = .36$) $t(29) = -0.41$, $p = .684$, in the RTL group. Results are presented graphically in Figure 3-2.

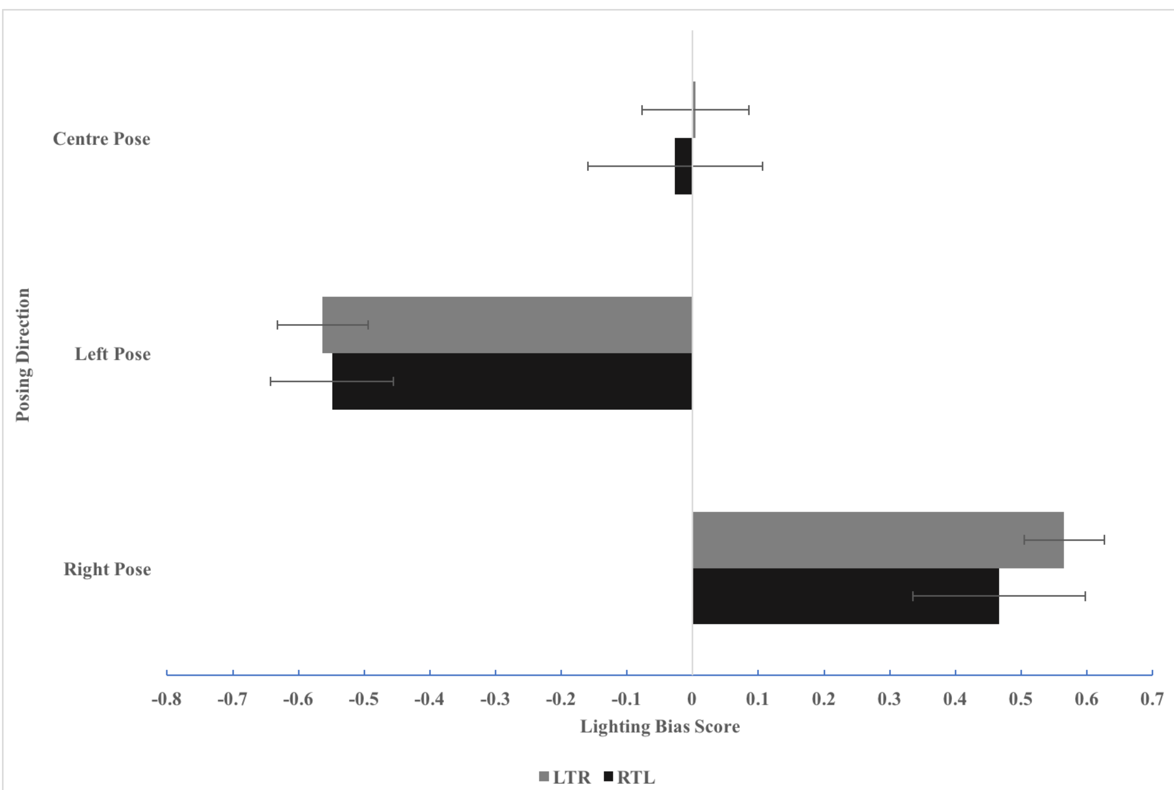

Figure 3-2. Lighting bias association with posing bias in the experimental lighting paradigm. Error bars represent 95% confidence intervals. Lighting bias scores created by coding rightward light placements as +1 and leftward placements as -1; overall negative score indicates leftward lighting bias. LTR = left-to-right; RTL = right-to-left.

A 2 x 2 repeated-measures analysis of variance (ANOVA) was used to determine if response times differed between groups for left or right lit sculptures. The within subjects variable was response time (left light, right light) and the between subjects variable was NRD (LTR, RTL). The interaction between response time and NRD approached significance, $F(1,77) = 3.86$, $p = .053$, $\eta_p^2 = .048$. Post hoc pairwise comparisons revealed that the effect was driven by differences in response times in the LTR group. Bonferroni corrected pairwise comparisons revealed that the LTR group applied light to sculptures from the left (M = 9.5s, SD = 3.5) quicker than from the right (M = 10.1s, SD = 3.5) with this difference approaching significance (p = .071), whereas mean response times for left (M = 9.6s, SD = 5.1) or right (M = 9.1s, SD = 4.9) lighting placements of the RTL group were not different ($p = .291$).

Greyscales Task

Bias scores from one RTL and two LTR individuals were more than two standard deviations greater than the mean score of their group and excluded from the analysis as outliers.

The bias score of the LTR group (M = -34.8 SD = 35.93) was significantly leftward when compared with no bias using a one-sample *t*-test with a midpoint of zero, $t(46) = -6.63$ $p < .001$. The RTL group also made more leftward choices, and when compared with a midpoint of zero in a one-sample *t*-test, the group bias score (M = -27.0 SD = 40.60) was significantly leftward, $t(28) = -3.58$ $p = .001$. Although the bias score of the RTL group was of slightly less magnitude, results from an independent-samples *t*-test show that scores between groups were not significantly different from each other, $t(74) = -.88$, $p = .719$.

Discussion

Sedgewick et al.'s (2015) study examining lighting of 3D stimuli revealed new information about individuals' aesthetic preferences when given control of the lighting. Results from that investigation differ from trends in the related 2D artwork lighting literature in some key ways, first that lighting was biased to the right, and second that lighting direction did not interact with posing direction. In the current study, we attempted to replicate Sedgewick et al.'s (2015) findings using the same stimuli within a simplified experimental design, and including a sample of participants whose NRD was from RTL. Participants also completed the greyscales task as a measure of perceptual asymmetries. Additionally, we carried out a content analysis with images of illuminated sculptures from galleries in LTR and RTL regions in an attempt to examine aesthetic preferences of monolinguals. Contrary to our predictions, average light placements of the LTR and RTL groups were not different from each other and no lateral lighting biases emerged for either group in the sculpture lighting paradigm. As predicted, both groups displayed a leftward bias on the greyscales task; however, even though the bias of the RTL group was weaker than the LTR group, the difference between groups was not significantly different. Our prediction that lighting of sculptures in LTR region galleries would be leftward and significantly different from RTL region galleries was confirmed. Further, sculptures in RTL region galleries were more often illuminated from the right.

Results from RTL participants on both laboratory tasks, as well as the accompanying content analysis from galleries in RTL regions, support the idea that spatial and aesthetic biases are on the same spectrum and allow for the Interactive Account to be extended to cover aesthetics as well. Full support for extending the model, even to the specific area of the aesthetics of lighting, will require rigorous examination using varied stimuli in different paradigms. Within aesthetics, however, the strong rightward lighting bias exhibited by RTL monolinguals revealed through the content analysis contrasted against the lack of bias exhibited by RTL bilinguals in the laboratory follows what would be expected from the Interactive Account. Although the Interactive Account may predict more attenuation of pseudoneglect on the greyscales task than we observed, our results reflect the dominance of the right hemisphere on this task and could reflect a variable bilingual sample. Further, the smaller magnitude of the bilingual RTL group's bias score on the greyscales task, in the context of the scores of the LTR group, is in line with theory predictions.

Although overall group means for light placements on the sculpture lighting task did show small variations, each group essentially placed the light nearly directly overhead of the sculptures. This overall lack of lateral lighting bias did not replicate Sedgewick et al.'s (2015) findings, nor did it confirm our hypothesis. However, comparing the overall light placements of the LTR group from the current experiment to Sedgewick et al.'s (2015) findings (LTR participants) in the context of the attenuation increases with complexity theory (Smith & Elias, 2018) does raise an interesting possibility. Although we predicted that simplifying Sedgewick et al.'s paradigm would shift the bias from right to left, the lack of bias with the simplified design does suggest that the leftward bias was in fact inhibited less. Further support for this idea is found in our examination of trial time differences between left and right light placements as there was increased fluency when applying light from the left. Why light placements by non-artistically trained LTR individuals are not consistent between 2D and 3D stimuli is at this point unknown. The fact that the leftward lighting bias typically exhibited by LTR individuals has not been replicated in the current experiment, nor in that carried out by Sedgewick et al. (2015), raises the possibility that our 3D stimuli are in some way remarkable. The lack of biases also exhibited by RTL individuals could be representative but may also support the idea that the exercise of lighting a 3D sculpture does not elicit lateral biases in the same way that 2D artwork lighting does.

Examining differences in the details between stimuli used in 2D and 3D paradigms, in addition to the broad difference of dimensionality, reveal two important considerations about composition. First, 2D abstract artworks do not contain any faces whereas many of the sculptures in the current experiment do. Thomas et al. (2008) suggest that the congruency between lighting and posing serves to highlight the face, and as an interaction between posing and lighting direction occurred in the current experiment, any potential lateral lighting biases may have been masked by the interaction. Second, 2D abstract artwork images used by McDine et al. (2011) and Smith et al. (2018, under review) were free from a discernable top, bottom, or sides whereas top, bottom, and sides of sculptures were obvious in the current study. If lateral lighting biases observed by McDine et al. (2011) are a true representation of attentional asymmetries, rooted in hemispheric inequalities, and biases observed by Smith et al. (2018, under review) are also an accurate depiction of hemispheric dominance, in conjunction with the environmental impact of learning to read and write, and emerged because of confound-free stimuli, future experiments evaluating aesthetics, lighting, 3D stimuli, and monolingual and bilingual RTL individuals may take the following steps to draw more certain conclusions. First, stimuli could be simplified by using sculptures with no defined sides or orientations. If taking away predefined poses and orientations of 3D stimuli elicits leftward lighting biases among LTR participants, then perhaps an endorsement of the attenuation increases with complexity theory can be made with more certainty. Second, if bilingual RTL participants display a leftward bias that is significantly weaker or rightward of LTR participants or continue to show a lack of lateral bias with the same stimuli, the suggestion that the Interactive Account applies to aesthetic lighting and not just spatial stimuli can be more confidently made. Lastly, research groups with access to RTL monolinguals could experimentally demonstrate this group's lighting preferences, potentially bolstering the Interactive Account if a rightward bias is confirmed.

Between the laboratory experiment and the content analysis, our study highlights the preferred congruency between lighting direction and posing direction. Our findings are the first to experimentally demonstrate this phenomenon as support for this theory has come previously only come from archival and content analyses (Grüsser, et al.,1988; Thomas et al., 2008). Although results from our content analysis confirm that this phenomenon occurs among art experts, our experimental findings from non-experts suggest that congruity between lighting and posing is preferred regardless of art expertise. Further, our study is the first to show that the preference for congruity between lighting and posing endures across NRDs. The persistence of lighting biases across poses appears to also be related to the expertise of the lighting agent. Non-experts do not show overall lighting biases with posed 3D stimuli whereas the attenuation of lateral lighting biases (left for LTR, right for RTL) is overcome if the lighting agent is artistically trained. Our earlier discussion concerned with the possible uniqueness of 3D stimuli and lighting biases may also relate to the separation between experts and non-experts. It could be that lighting a 3D object, even in a relatively simple experiment like the one presented here, is fundamentally more difficult than 2D stimuli. Non-experts with less experience might be making the obvious choice and lighting sculptures to highlight posing direction whereas the experience of experts enables them to recognize the higher perceptual value of lateral light (depending on their culture: left for LTR, right for RTL) and deviate from light placements in line with posing when it is aesthetically pleasing.

As others have shown, lighting is an important tool used by artists to enhance the aesthetic value of their artwork. Consistent lateral lighting biases have yet to be observed with 3D stimuli and it is at this point unknown if that results from the complexity of the stimuli or the individual variation of participants tested thus far, pointing to the importance and necessity of future research in this area. Typically, light is biased leftward, but there is evidence to suggest that lateral lighting preferences vary with NRD. Our archival analysis of sculpture lighting in galleries confirms that lateral lighting biases persist among the artistically trained (photographers, curators) when lighting is disconnected from art production and examined in isolation, as left lighting is more prevalent in LTR region galleries and right lighting in RTL region galleries. These lateral lighting biases also persist in isolation among the non-artistically trained when 2D stimuli are used, however the perseverance of these biases is less clear when stimuli are 3D.

CHAPTER 4

LATERAL BIASES IN AESTHETIC AND SPATIAL LOCATION JUDGMENTS: DIFFERENCES BETWEEN TASKS AND NATIVE READING DIRECTIONS

A version of this chapter has been previously published:

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Introduction

Both the inattention of leftward space by neglect patients and the overestimation of leftward space, known as pseudoneglect in neurotypical individuals, rely on neural networks of attention rooted in the parietal lobe of the right hemisphere (Corbetta & Shulman, 2011). These behaviours manifest themselves on neuropsychological assessments, like the line bisection task, where neglect patients err rightward and neurotypical individuals produce leftward errors (Bowers & Heilman, 1980). There may be an underlying mechanism connecting aesthetics and pseudoneglect, as elements of aesthetic preference (e.g. lighting) appear to follow a similar pattern of leftward space over-representation. Thomas, Burkitt, Patrick, and Elias (2008) report a higher prevalence of left lit images in advertising and further that left lit advertisements are more effective at influencing purchase intention (Hutchison, Thomas, & Elias, 2011). In conjunction with hemispheric asymmetries, pseudoneglect is believed to result from, or is conversely attenuated by, native reading direction (NRD). Neurotypical participants with a right-to-left (RTL) NRD display an opposite rightward bias on the line bisection task (Chokron & Imbert, 1993) and attenuated leftward lighting preferences (Smith & Elias, 2013). We present a spatial location task and an aesthetic task executed in a functionally similar way by both left-to-right (LTR) and RTL reading participants. Our aim in comparing the performance of both groups on a straightforward spatial task and an elaborate aesthetic task is to evaluate the efficacy of the attenuation increases with complexity theory (Smith & Elias, 2018) and the generalizability of the interactive account (Rinaldi, Di Luca, Henik, & Girelli, 2014).

Evidence suggests the leftward spatial bias, resulting from hemispheric asymmetries, is widespread and not bound to physical space and stimuli. The spatial agency bias (SAB; Chatterjee, 2002) proposes that agents of action are conceptualized to be to the left of recipients of action. Maass, Suitner, Favaretto, and Cignacchi (2009) extend the SAB to include the stereotypic belief that males are more agentic, finding an association between males and leftward space. Dehaene, Bossini, and Giraux (1993) highlight the spatial-numerical association of left with small numbers and right with large numbers, in what has come to be known as the Spatial-Numerical Association of Response Codes (SNARC) effect. Like pen and paper line bisections, a leftward overestimation determines the bisection of mental number lines by neurotypical participants and is reversed in neglect patients (Loftus, Nicholls, Mattingly, Chapman, & Bradshaw, 2009). The effect that NRD has on spatial ability appears to be pervasive, as horizontal differences exist between RTL and LTR individuals' mental associations of agency (Maass et al., 2009), mental representations of number lines (Dehaene et al., 1993), and mental representations of time lines (Ouellet, Santiago, Israeli, & Gabay, 2010).

Generalizing results from the laboratory to the broader population and applying theories to real-world situations are important for better understanding some phenomenon. A map-based visualization technique called Halos (Baudisch & Rosenholtz, 2003) may be one such real-world application for the leftward spatial bias. Halos are particularly useful when working with search results in a mapping application, as off-screen locations in a map viewer are represented by a circle that *just* intrudes into the visible region of the display. For example, searching a conventional virtual map for 'donuts' returns a list of all locations associated with donuts and a snapshot of the map marked by pins within the search area. Zooming out or panning around is required to bring donut locations outside of your search area into view. One major advantage of Halo mapping is that search results previously only accessible by zooming or panning are now more fully integrated into the initial search results.

As described above, in the Halo technique the same donut search highlights *all* locations with circles. This implementation of search results is particularly useful when viewing a virtual map on a device with a smaller screen, such as a mobile phone. Comprehensive and accurate mapping of search results on mobile devices has never been more important, as web analytics company StatCounter reported that internet usage on mobile devices surpassed desktops worldwide in October of 2016 for the first-time (http://gs.statcounter.com/platform-market-share/desktop-mobile-tablet/worldwide/2016), with this trend continuing to present day. In brief, by using the location and size of the circles one is able to estimate the number, location, and relative distance of off-screen search results. The size of the arc indicates the distance (i.e., smaller arcs indicate closer locations and larger arcs indicate more distant locations) and the circles' positions along the edges of the map indicate the direction of each off-screen donut location. Just as spatial biases result in pseudoneglect and lateralized mental imagery, Halo mapping may be susceptible to pseudoneglect, a potential problem in making Halo mapping a more accurate alternative to conventional virtual mapping. Because the success of Halo mapping relies on the user's ability to make size and distance judgments, spatial biases may hinder the reliability of the Halo technique.

Spatial navigation is one area of research examining the application of pseudoneglect in the real world, and framing Halo mapping in this context may be beneficial. Pseudoneglect may influence different aspects of navigation and bumping to the left or right when walking has thus far received the most attention. Based on a bumping self-report and line bisection task, Turnbull and McGeorge (1998) theorize that pseudoneglect contributes to navigation biases. Reports of more rightward bumping and an association with leftward line bisections are believed to result from reduced attention to rightward space on account of the salience of leftward space. Confirmation of the relationship between rightward bumping and pseudoneglect comes from replications of this finding using doorways of various sizes in the laboratory (Nicholls, Loftus, Mayer, & Mattingley, 2007; Nicholls, Loftus, Orr, & Barre, 2008) although there have been exceptions using this method (Hatin, Sykes Tottenham, & Oriet, 2012).

As outlined above, the robust *pseudoneglect* effect is a persuasive account for explaining systematic leftward errors outside of the field of aesthetics (Learmonth, Gallagher, Gibson, Thut, & Harvey, 2015), and the same may be true within aesthetics. Studies examining lighting in paintings across schools and periods find light placements consistently in the upper left (McManus, Buckman, & Woolley, 2004; Sun & Perona, 1998). Thomas, Burkitt, Patrick, and Elias (2008) report the same persistence of leftward lighting in present day magazine advertisements, adding to the reliability of the effect. Ramachandran and Hirstein (1999) suggest that artists, knowingly or not, employ several techniques that successfully capture the viewer's attention by targeting visual areas of the brain. The deliberateness of leftward lighting by artists is also not known, but evidence from McDine, Livingston, Thomas, and Elias (2011) suggests that preferences for leftward illumination may stem more from common neural organization than artistic training, as non-artists also consistently light artwork from the top left. Several studies have isolated lighting preferences by using basic shape stimuli, shaded in such a way to imply a directional light source, and have come to the general consensus that a preference for leftward lighting is rooted in the human brain (Elias & Robinson, 2005; Mamassian & Goutcher, 2001; McCourt, Blakeslee, & Padmanabhan, 2013; McManus et al., 2004; Sun & Perona, 1998).

Just as leftward aesthetic preferences and pseudoneglect may be related, RTL NRD may attenuate leftward aesthetic preference in the same way seen in pseudoneglect (Chokron & Imbert, 1993; Fagard & Dahmen, 2003; Rinaldi et al., 2014). In one of the clearest examples of the influence of NRD, Rinaldi et al. report leftward biases among LTR monolinguals, rightward biases by RTL monolinguals, and no spatial biases by bilinguals on the line bisection and star cancellation tasks. Rinaldi et al. suggest that this pattern of results is best explained by the *Interactive Account of visuospatial asymmetries*, which they explain as the interaction of biology with culture. In this theory pseudoneglect, driven by the right hemisphere's dominance for spatial processing, is modulated by scanning direction.

Freimuth and Wapner (1979) and Christman and Pinger (1997) investigated the influence of directionality of an image on aesthetic preferences in participants with LTR NRD and found a preference for images with left-to-right directionality. Chokron and De Agostini (2000) also found left-to-right directionality preferences among LTR participants, but they found a right-to-left preference when examining RTL participants. Attenuation of the leftward bias by NRD has been replicated with a range of stimuli, from still photographs to videos. Chahboun, Flumini, González, McManus, and Santiago (2016) examined directionality in photos and found that when presented with the original and mirror images in a forced choice paradigm LTR participants preferred photos with left-to-right directionality and RTL participants preferred photos with right-to-left directionality. An investigation by Maass, Pagani, and Berta (2007) had participants view original and mirror reversed videos of goals scored in a soccer match. LTR participants rated the performance of the soccer player as faster and stronger, and the goals more beautiful, when the video clip followed a left-to-right direction, and conversely, RTL participants gave higher scores for right-to-left trajectory videos.

Focussing on the aesthetics of lighting, Hutchison, Thomas, and Elias (2011) found that ratings, overall, were higher for left lit advertisements by LTR participants when asked to rate left and right lit versions of the same advertisement across the three dimensions: feeling toward advertisement, feeling toward brand, and purchase intention. Using similar mirror reversed advertisement style images, Smith and Elias (2013) confirmed the leftward lighting preference among LTR individuals but did not replicate the finding with a group of bilingual RTL individuals. By conducting an analysis of eye movements while viewing the images, Smith and Elias propose the possibility that the amount of time examining the left or right of an image depends on NRD as time examining images was leftward in the LTR group and rightward in the RTL group (not significant, $p = .09$ & $p = .07$, respectively). Further evidence suggesting that scanning direction is largely responsible for visuospatial leftward bias attenuation comes from Jewell and McCourt's (2000) meta-analysis of the line bisection task that shows the lateral bias of subjective centre is modulated by controlling where visual scanning of a line begins (i.e. leftward bias results from beginning left and rightward bias when beginning right). Important discrepancies between NRD groups in visual explorations have been documented in a variety of other tasks, from simple dot patterns (Abed, 1991) to reading tasks (Pollatsek, Bolozky, Well, & Rayner, 1981) and may also be largely responsible for the attenuation of leftward lighting and aesthetic preferences in RTL individuals.

The aesthetic task is described in further detail below, but briefly, it replicates the artwork lighting task implemented by McDine et al. (2011). A single image of an abstract painting is presented, and participants control the lighting with the computer mouse, clicking when optimal illumination is achieved. Our rudimentary version of the Halos task (Figure 4-1) presents participants with a grey rectangle centred on a white background and a white circle overlapping a portion of the rectangle (representing the map space on a mobile device and the halo from a destination, respectively). Participants make different judgments in the two tasks but manipulate the computer mouse in the same way to estimate the circle's centre or find the optimal illumination location. Visuospatial attention is foundational to both tasks, and we argue that basic spatial ability is sufficient for the Halos task but that there are additional computations required for aesthetic evaluations. Manipulating the complexity while controlling the procedures of the tasks and manipulating the NRD of participants allows for the evaluation of the efficacy of the attenuation increases with complexity theory, and the robustness of the Interactive Account, that is, its generalizability to aesthetic preferences. In this study we operationalize complexity as the higher cognitive processes, those over and above spatial ability, required to complete the aesthetics task.

Manipulating both task complexity and NRD requires our predictions to rely on the converging of the Interactive Account and the attenuation increases with complexity theory. In the current study we hypothesize that a strong leftward bias will emerge from the LTR group on the less complex spatial location task, while the bilingual RTL group bias will be rightward relative to the LTR group, perhaps attenuated to the point of no bias. Both LTR and RTL participants should be more accurate when estimating the centre of a left sided circle, but leftward biases in the LTR group will be of greater magnitude. We predict a similar pattern of results, shifting rightward in both groups, in the more complex aesthetic task by applying the same logic. LTR participants should place the light source left of centre, whereas light placements by the RTL group should be rightward relative to the LTR group and perhaps right biased. Eye tracking data are hypothesized to corroborate light placements by revealing greater amounts of time examining leftward space in the LTR group and, conversely, greater time exploring rightward space in the RTL group.

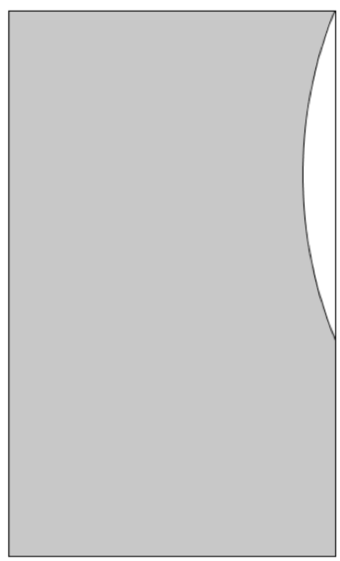

Figure 4-1. An example *Halo* from the spatial location task. A grey rectangle is centred on a white background (representing the mapping space on a mobile device) and a white circle occludes a portion of the rectangle (representing the halo from a destination). Participants estimated the centre of the circle in similar fashion to the aesthetics task, manipulating the mouse with a single click to indicate their choice.

Method

Participants

Spatial location task. Twenty-one LTR individuals (8 males, 1 left handed (LH)) with a mean age of 20.95 years (SD = 2.82) participated. Twenty-one bilingual RTL individuals (9 males, 2 LH) with a mean age of 28.57 years (SD = 5.29) and an average of 3.33 years (SD = 2.53) spent in Canada ranging from 6 months to 10 years (N = 10 living in Canada 2 years or less) participated in the spatial location task.

Artwork lighting task. Twenty-three LTR individuals (10 male, 4 LH) with a mean age of 19.65 years (SD = 2.72) participated. Twenty bilingual RTL individuals (9 male, 1 LH) with a mean age of 29.30 years (SD = 4.64) and an average of 2.99 years (SD = 2.62) spent in Canada ranging from 2 months to 10 years (N = 11 living in Canada 2 years or less) completed the artwork lighting task.

Stimuli

Both experiments were created in the Human Computer Interaction Lab at the University of Saskatchewan and used custom software, written in the Processing/Java language, to display all visuals and record all performance data.

Spatial location task. Each trial consisted of a white circle overlapping a grey rectangle on the right or left side against a white background, resulting in only part of the circle (that overlapped the rectangle) and part of the rectangle (not overlapped) being visible to the participant. The rectangle was unchanged trial to trial but the amount of circle visible and lateral location of the circle varied. There were fifteen possible circle sizes that were classified as *large* if the centre was in one of the outer rows, *medium* for circles with centres in the middle rows, and *small* when the centre was in a row closes to the rectangle. All possible circle centre locations are shown in Figure 4-2. One block consisted of the presentation of every circle twice, for a total of 60 trials.

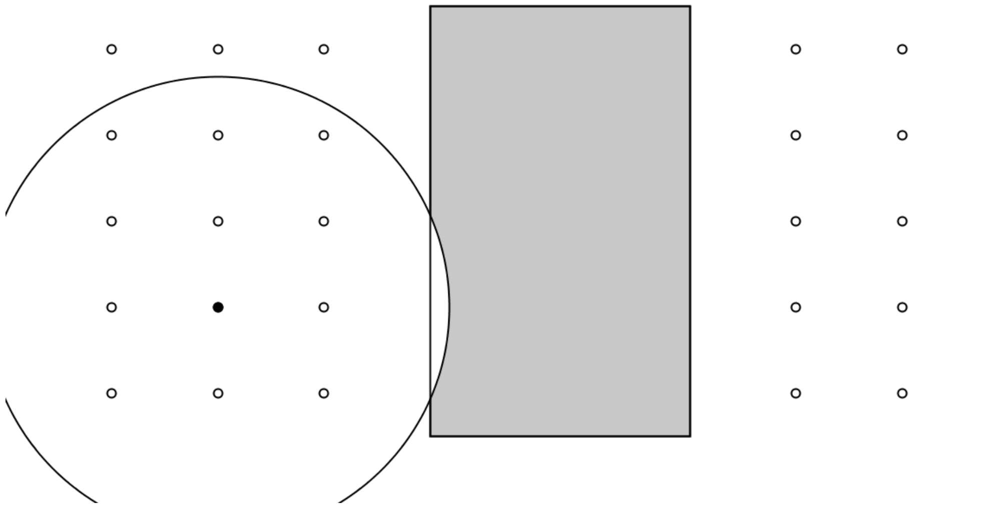

Figure 4-2. An example stimulus of a left side medium halo from the spatial location task. Centres of all other possible circles are provided shown but were not visible to participants.

Artwork lighting task. The same 20 images used by McDine et al. (2011) were used as stimuli in the present task. Further details about the stimuli, along with visual examples, are found in the aforementioned paper. All images were coloured, abstract, and showed no indication of proper orientation or where a light source should be positioned (that is, no confounding elements like shadows or ground lines). Each image was viewed twice for a total of 40 trials.

Procedure

Ethics approval for this research was granted by the University of Saskatchewan Behavioural Ethics Research Board. After giving informed consent and completing a demographic questionnaire addressing sex, age, visual or auditory impairments, handedness, footedness, and NRD (Elias, Bryden, & Bulman-Fleming, 1998; see appendix A) participants were seated at a desk for the computer-based tasks. Both the spatial location task and the artwork lighting task were typically completed in thirty minutes or less. LTR participants received course credit and RTL participants received $10 at the completion of the experiment.

Spatial location task. The implementation of Halos in the current study follows the basic design principles set out in the original work by Baudisch and Rosenholtz (2003) although no map images or multiple location comparisons were used. Participants were presented with a grey rectangle (centred on a white background) with a white circle overlapping a portion of the rectangle, meant to represent the map space on a mobile device and the halo from a destination, respectively. Participants began by completing 5 practice trials followed by 2 blocks of trials (60 trials = 1 block, resulting in 120 counterbalanced trials), with a break in between the blocks. Using the information provided to them by the partially occluded rectangle and incomplete circle on the screen, participants were instructed to estimate the centre of the circle with a single mouse click. Participants were instructed to extrapolate the missing information and as quickly and as accurately as possible make their judgment about the centre of the circle. Upon clicking, the image was replaced with a central fixation cross for 1000 msec. and followed by the next image.

Artwork lighting task. Participants were presented with the 20 abstract painting images twice, once in their original orientation and once mirrored, for a total of 40 trials. Participants controlled a 'virtual flashlight' with the computer mouse. The size, shape, and brightness of the light did not vary when moved and the light did not cast shadows. Participants were instructed to light the painting in a way that was most aesthetically pleasing to them, clicking when satisfied. A central fixation cross presented for 1000 msec. appeared between each trial.

Scoring

Spatial location task. The accuracy of each estimation of the centre of a circle was calculated using the Euclidean distance, measured in pixels, between the X coordinate of the centre of the circle and the click estimation. The veridical X coordinate was subtracted from the participant's estimation click, creating a negative error score if the click was left of true centre and a positive error score if the click was right of true centre. As aggregated error scores for both LTR and RTL groups were positive in left circles and negative in right circles, indicating that estimations were always towards the rectangle side of the circle, lateral location of the circle (left or right of the rectangle) was accounted for and associated with click location when analyzed. Circle size was also accounted for by dividing up trials as either left side large, left side medium, left side small, right side large, right side medium, or right side small.

Artwork lighting task. X and Y coordinates were recorded for clicks indicating final light placements measured in pixels. The viewable area (1280 x 1024) of the computer screen was divided for analysis in two ways: left/right and top/bottom. The mid-point of the X-axis, 640, divided left and right, and the mid-point of the Y-axis, 512, divided top and bottom.

Results

Spatial Location Task

A 2 x 2 x 2 repeated-measures Analysis of Variance (ANOVA) was carried out to determine the conditions of the most accurate estimations of the centre of the circle. Within subjects variables were the lateral location of the circle (left/right side of the rectangle), block (1, 2), and the between subjects variable was NRD (LTR/RTL). None of the interactions were significant. There were no main effects of NRD or block, indicating that performance was consistent between groups and across testing sessions. The main effect of lateral location of the circle was significant, $F(1,40) = 4.8$, $p = .034$, $\eta_p^2 = .107$. A means comparisons of unsigned error scores for left and right circles revealed that estimations of centre were closer to veridical centre in right circles ($M = 100.59$) than in left circles ($M = 104.11$). This finding suggests that estimations made left of veridical centre were more accurate than estimations right of true centre, as per the aforementioned association between lateral circle location and click location error scores. Pairwise comparisons examining the non-significant interaction between NRD and circle location were carried out to better understand trends between the NRD groups. Across all conditions mean error scores of LTR participants were smaller than those of RTL participants. Means in both groups indicated smaller errors for right circles (leftward error clicks).

Collapsing across all circle sizes, paired-samples *t*-tests comparing error scores between groups revealed that within right circles the LTR group was more accurate than the RTL group $t(14) = 2.45$, $p = .026$. Further, error scores were smaller in the LTR group compared with the RTL group on right side large circles, $t(4) = 2.95$, $p = .042$, and right side medium circles, $t(4) = 2.9$, $p = .044$. Independent-samples *t*-tests examining the effect of circle size on error scores revealed that in both LTR and RTL groups accuracy progressively declined as circle size increased. Within the RTL group, error score comparisons between left and right circles did not differ significantly from each other within large, medium, and small circles, however, error scores were significantly smaller for right circles compared with left circles within the medium sized circles range in the LTR group, $t(8) = 3.18$, $p = .013$.

Artwork Lighting Task

An independent-samples *t*-test found that light placements for each NRD group were significantly different from each other based on the average X-axis coordinates, $t(41) = -2.45$, $p = .019$. One-sample *t*-tests were carried out for each group, comparing the mean to the mid-point of 640. The LTR average (576.17, SD = 101.91) was significantly leftward of the mid-point, $t(22) = -3.0$, $p = .007$, whereas the RTL average (647.53, SD = 87.15) was rightward but not significant, $t(19) = 0.39$ $p = .703$. An independent-samples *t*-test comparing light placements on the Y-axis did not find significant difference between NRD groups, $t(41) = -1.75$, $p = .088$. Each group's average light placement Y-axis coordinates were compared to a mid-point of 512 in one-sample *t*-tests. LTR average light placement (399.97, SD = 132.05) was significantly upward of the mid-point, $t(22) = -4.07$, $p = .001$, whereas the RTL average light placement (479.06, SD = 164.64) was upward, but did not reach significance, $t(19) = -0.9$ $p = .382$. Figure 4-3 provides a visual representation of average light placements by both groups.

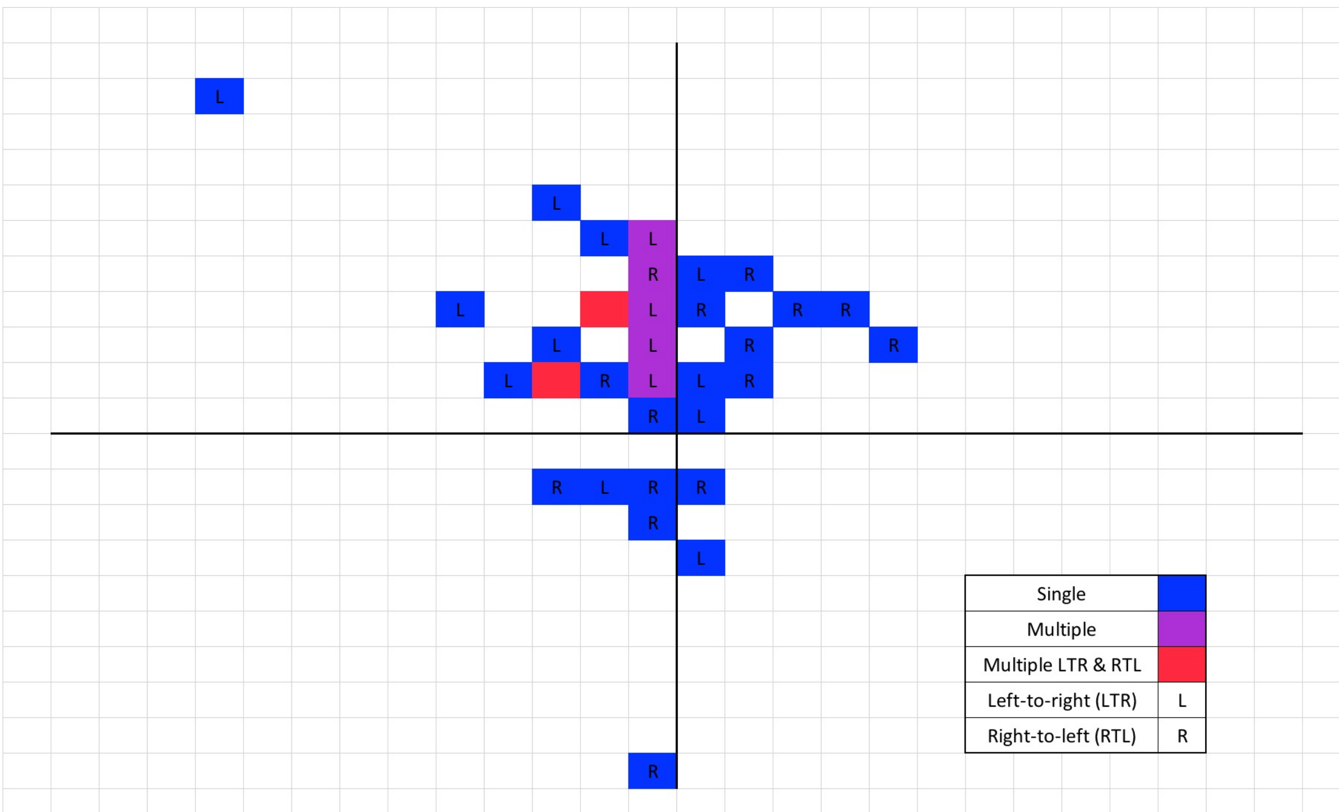

Figure 4-3. Heat map showing each participants' average light placements. An 'L' denotes a LTR participant whereas an 'R' denotes an RTL participant. Blue represents the average placement of a single participant whereas multiple participants' averages in the same space are represented by purple. Red indicates spaces occupied by multiple LTR *and* RTL participants. Grid squares represent 50 pixels x 50 pixels.
Note: LTR = left-to-right; RTL = right-to-left.

Eye tracking. Data collection from all participants was not possible during the artwork lighting task due to eye tracking camera calibration difficulties. Data were collected from eighteen LTR participants (9 male, 4 LH) with a mean age of 19.61 (SD = 3.03) and fourteen bilingual RTL participants (6 male, 1 LH) with a mean age of 29.29 (SD = 4.94). RTL participants had spent an average of 2.83 years in Canada (SD = 2.82) ranging from 2 months to 10 years (N = 8 living in Canada 2 years or less).

A 2 X 2 repeated-measures ANOVA was performed to examine the possibility that differences existed between NRD groups in the amount of time spent examining the left or right side of the screen while placing the light. The within subjects variable was Region of Interest (ROI) (left and right sides of screen) and the between subjects variable was NRD (LTR and RTL). The interaction between ROI and NRD was significant, $F(1,30) = 4.36$, $p = .045$, $\eta_p^2 = .127$, and is illustrated graphically in Figure 4-4. Examining the means confirmed our predictions as in the LTR group scan time was greater for left ROI (compared to right) and in the RTL group more time was spent scanning the right ROI (compared to left). Bonferroni corrected post-hoc pairwise comparisons revealed that the greater examination of the right side by RTL group was significant ($p = .011$).

Potential differences between NRD groups in the amount of time spent examining the upper or lower portions of the screen while placing the light were examined with a 2 X 2 repeated-measures ANOVA. The within subjects variable was ROI (upper and lower portions of screen), while the between subjects variable was NRD, (LTR and RTL). The interaction between ROI and NRD was significant, $F(1,30) = 6.68$, $p = .015$, $\eta_p^2 = .182$. Bonferroni corrected post-hoc pairwise comparisons revealed that within the LTR group, significantly more time was spent examining the upper half of the screen ($p = .009$). Between groups, the greater amount of time spent exploring lower visual space by RTL participants was significantly different from LTR participants ($p = .049$).

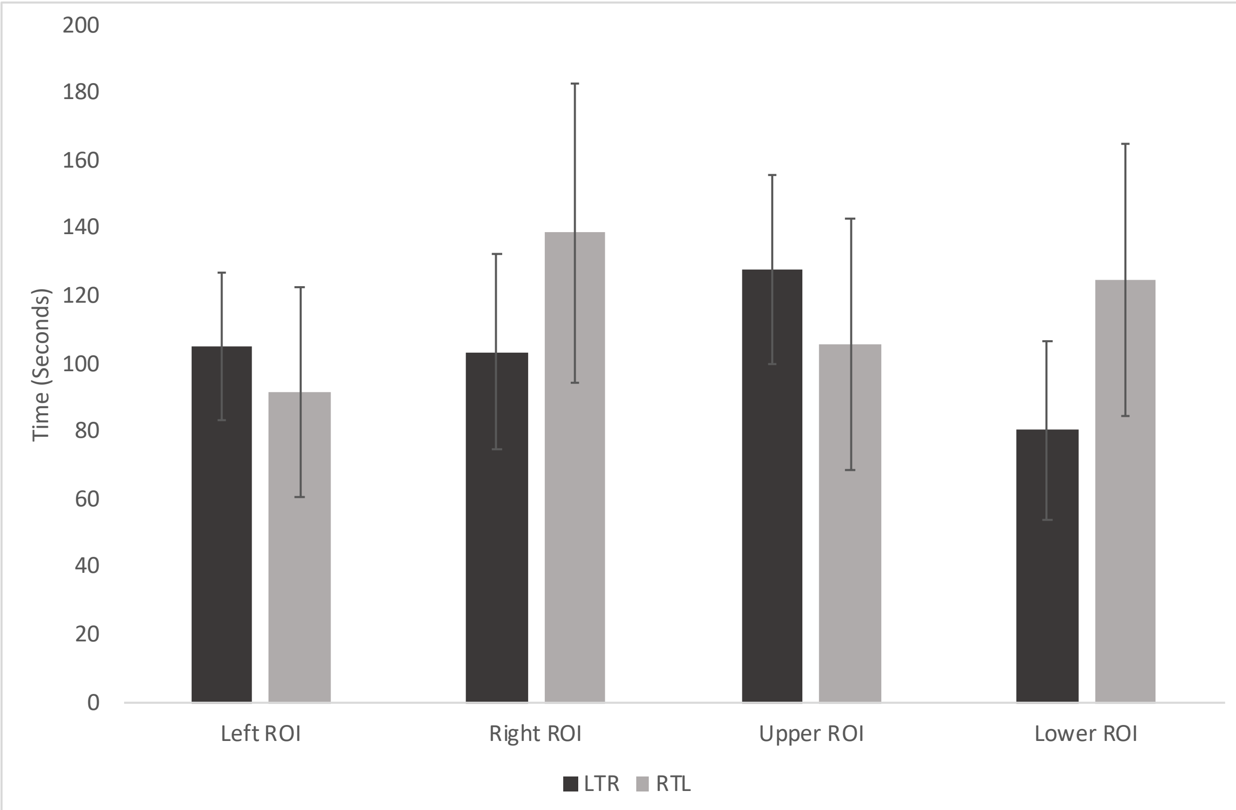

Figure 4-4. Graph comparing average time, in seconds, spent examining each region of interest (ROI) during the artwork lighting task between LTR and RTL native reading direction groups. Averages represent inspection of all 40 images. Error bars represent 95% confidence intervals. *Note:* LTR = left-to-right; RTL = right-to-left.

Discussion

In an attempt to extrapolate the general principles of the Interactive Account (Rinaldi et al., 2014) to aesthetics and further scrutinize our proposed supplementary theory, that *attenuation increases with complexity* (Smith & Elias, 2018) we carried out two tasks measuring different aspects of visuospatial attention but carried out in a nearly identical fashion. Following Rinaldi et al.'s theory, on the spatial location task we predicted an additive interaction between the cultural factor of LTR NRD and the biological factor of right hemisphere specialization for spatial processing in the LTR group, resulting in a strong leftward bias. On the same task, again as per Rinaldi et al.'s logic, we predicted a weaker left or lack of spatial bias in the bilingual RTL group as the cultural and biological factors negate each other to a certain degree. Following the attenuation increases with complexity theory, on the artwork lighting task we predicted a similar pattern of behaviour between NRD groups with the bias shifting rightward as a consequence of the increased computations needed to carry out the aesthetics task.

We did not find direct support for our predictions between tasks or within the spatial location task, however the results within the artwork lighting task support our predictions. Within the spatial location task LTR and RTL groups did not demonstrate widespread marked differences, with both groups displaying greater accuracy for circles on the right. The rightward biased spatial location task then positioned the findings from the aesthetics task to be overall more leftward, contrary to predictions. Within the artwork lighting task, the LTR group replicated previous findings by McDine et al. (2011), displaying a leftward lighting aesthetic bias. The lack of lateral aesthetic bias from the RTL group in conjunction with eye movement data suggesting differences in the distribution of scan time between NRD groups extends McDine et al.'s findings and falls in line with Rinaldi et al.'s Interactive Account.

The effect of circle size on estimation accuracy was not predicted but may have had unintended consequences in adding to the complexity of the task. The task was employed, initially, as it was believed to represent a basic test of spatial ability. However, as the circle size analysis reveals, both NRD groups showed significant performance decreases as the size of the circle increased. The consequences of increasing circle size, which perhaps increases the complexity of the task, do not appear to selectively affect one side or the other. When treated as one group, or by NRD groups, error scores increased with circle size but were consistently smaller for circles on the right.

Through careful examination of our initial implementation of the Halo mapping task we highlight some areas that may have masked the predicted effects, effects typically observed in a representative pseudoneglect task. First, smaller error scores when estimating the centre of circles on the right could result from a feeling of fluency that arises when circles are ipsilateral to the mouse hand. The accuracy of the estimation may have suffered when the participant felt forced to 'cross over' and mark the centre of a circle on the left. Second, the grey rectangle occupying much of the viewable area may have played a more prominent role than predicted. Although visualizing more than just what was presented on screen, i.e. the rest of the circle, was critical to the task, in actuality the rectangle is the dominant visual stimulus. With this in mind, estimations of the centre of imagined circles may have depended on the amount of uncovered rectangle (dependant on circle size). This position is perhaps supported by click location errors from our data set that show centre estimations were towards, rather than away from, the rectangle.

Our initial hypothesis that pseudoneglect would affect centre estimations by facilitating circles in leftward space, a result of right hemisphere dominance for spatial processing, may have been slightly misguided. Future iterations of the Halo mapping paradigm using a forced choice situation, comparing multiple halos simultaneously, may yield different results than unitary spatial estimation provided in the current study. This may be valuable in clearing up questions raised from the current study as different methods assessing pseudoneglect provide unique insights into spatial biases. Alternatively, there is the possibility that the results from the Halo mapping task, that circles on the right are more precisely estimated, are correct. This could imply that completing the task, as it is presented, relies on more than just basic spatial ability.

Comparing the results from the artwork lighting task with previous studies leads us to believe that our findings are an accurate representation of human behaviour. Light placements of LTR participants from the current study replicate McDine et al.'s (2011) findings of more upper-left light placements in LTR participants. Additionally, average light placement differences between LTR and bilingual RTL participants follow the proposed Interactive Account by Rinaldi et al. (2014), although it was not formulated around aesthetics. Results from the present study, in conjunction with findings from Smith and Elias (2018), provide preliminary support to generalize the Interactive Account to cover aspects of aesthetic preferences. And although the task comparison in the present study did not follow the predicted pattern set out by the *attenuation increases with complexity theory* (Smith & Elias, 2018), a different basic task of spatial ability could be used to compare against the artwork lighting task to further test the theory.

Eye tracking data and lighting preferences of LTR and RTL participants in the current study are consistent with our past aesthetic studies (Smith & Elias, 2013; 2018). Complementing past studies focussing on the perception of aesthetic elements, findings from the current study were elicited through motor output, increasing the robustness of the phenomenon. Previously, in a forced choice aesthetic preference task Smith and Elias (2013) report a leftward lighting preference by LTR participants and non-significant preference for right lit images by RTL participants, with leftward mean scan times for the LTR group and rightward mean scan times for the RTL group. Additionally, using single image presentation in an aesthetic rating task

Smith and Elias (2018) reported preferences for lighting and weighting that were uniformly leftward for LTR and rightward for RTL participants. When examining images, LTR participants made more fixations in a left-to-right direction while durations for rightward fixations were longer for RTL participants.

Results from the current study provide further evidence to support the theory that directional scanning and NRD are important in the formation of lateral biases in aesthetic preferences. The data confirms that a leftward lighting aesthetic preference is specific to LTR groups and not replicable among bilingual RTL groups. The finding of a lack of bias from the RTL group further supports the theory that years of learning to read and write in a right-to-left direction effects scanning in other visual domains, which eventually interacts with right hemisphere spatial specialization. This claim is supported by eye tracking data showing LTR and RTL groups differ in allocations of overt visual attention.

Further assessing of Rinaldi et al.'s Interactive Account specific to aesthetics could use other aesthetic tasks, such as those dependent on composition, to compare bilingual and monolingual RTL individuals. Recruiting a group of monolingual RTL individuals to complete the artwork lighting task is a next step in determining how NRD influences lighting preferences. To know if the results from the current study are representative of LTR and RTL individuals, further testing of the Halo mapping paradigm is required. Using the aforementioned manipulation of comparing multiple Halos at once in a forced choice experiment may be the first step in determining if Halo stimuli are susceptible to pseudoneglect.

CHAPTER 5

LEFTWARD SPATIAL BIASES DURING NATURALISTIC AND SIMULATED DRIVING: DOES PSEUDONEGLECT INFLUENCE PERFORMANCE?

A version of this chapter has been submitted for publication and is under review:

Smith, A.K., Vicencio-Moreira, R., Friedrich, T.E., Flath, M.E., Gutwin, C., & Elias, L.J. (2019). Leftward spatial biases during naturalistic and simulated driving: Does pseudoneglect influence performance? Submitted to *Transportation Research Part F: Psychology and Behaviour (TRF_2019_243)*.

Introduction

Safety and collision analysis are priorities when investigating navigation. Distracted driving has received much attention, in large part because of rapid advances in mobile technology and the increasing tendency to never fully disconnect. Several meta-analyses have been produced from the vast amounts of data from studies examining the adverse effects of cell phone use and texting while driving, as well as the effectiveness of vehicle systems that integrate with mobile phones (Caird, Johnston, Willness, Asbridge, & Steel, 2014; Caird, Willness, Steel, & Scialfa, 2008; Simmons, Caird, & Steel, 2017; Simmons, Hicks, & Caird, 2016). The effects of drugs and alcohol while driving continue to be heavily researched (Elvik, 2013; Irwin, Iudakhina, Desbrow, & McCartney, 2017; Li, Brady, & Chen, 2013) and current events such as the opioid crisis and legalization of marijuana have spawned more in-depth analyses (Asbridge, Hayden, & Cartwright, 2012; Chihuri & Li, 2017; Rogeberg & Elvik, 2016; Sevigny, 2018).

Research examining external factors that influence driver attention and impairment are no doubt critical for a more comprehensive understanding of collisions and improving safety on roadways. However, even the most basic driving situations, devoid of significant external distractions, are complex and demand multitasking. Human tendencies to display lateral biases of spatial attention have been the focus in other areas of navigation research and have the potential to influence road safety and collisions but have as of yet to be investigated when driving a motor vehicle. Pseudoneglect is a leftward spatial bias common to all humans, resulting from the right parietal lobe's dominance for spatial information processing (Bowers & Heilman, 1980). Relatedly, neurotypical humans consistently bump their right side more often (Turnbull & McGeorge, 1998). This small but growing area of research has been referred to as *unilateral* *bumping*. While interest in the potential role that pseudoneglect may have when driving a car has been expressed (Nicholls et al., 2010; Robertson, Forte, & Nicholls, 2015), insight into lateral navigation errors has thus far come primarily from laboratory studies requiring participants to walk or guide electric wheelchairs through door posts.

Turnbull and McGeorge (1998) found that healthy neurotypical participants recalled bumping slightly more to the right than to the left, and Nicholls, Loftus, Mayer, and Mattingley (2007) experimentally demonstrated the greater occurrence of right side collisions. When Turnbull and McGeorge (1998) asked participants to recall recent bumps they also measured responses on the line bisection task and found that right bumpers' bisections were further to the left than left bumpers. Nicholls, Loftus, Orr, and Barre (2008) experimentally confirmed this association, suggesting that right bumping may be associated with pseudoneglect. However, the reliability of greater rightward bumping and its association with line bisection biases has been questioned (Hatin, Sykes Tottenham, & Oriet, 2012; Nicholls et al., 2007). Pseudoneglect may be a useful framework for understanding spatial asymmetries when driving as it has been with unilateral bumping.

Pseudoneglect is most often measured with neuropsychological tools that assess clinical neglect, such as the aforementioned line bisection task. When presented with lines of varying lengths and spatial locations, attempts by neglect patients to equally bisect the lines (by marking the centre) result in marks right of veridical centre. The inattention to leftward space is a hallmark deficit of clinical neglect and is a consequence of damage to areas which are important for spatial and attention processes such as the right parietal lobe, related neural areas and pathways connecting them (Corbetta & Shulman, 2011). Conversely, healthy participants show a small but consistent overestimation of leftward space, resulting in bisections left of veridical centre (Jewell & McCourt, 2000). Leftward biases have also been reported when judging brightness, numerosity, size (Nicholls, Bradshaw, & Mattingley, 1999) and distance (Krupp, Robinson, & Elias, 2010). Krupp et al. (2010) suggest pseudoneglect results in both left biased object distance estimations and right biased collisions in healthy participants, consistent with an opposite pattern of left hemispace neglect in clinical neglect patients resulting in leftward collisions and rightward biases on pen and paper assessments.

Healthy participants deviating to the right when passing through a doorway is a stable trend, whether through self propulsion by walking (Nicholls et al., 2007; Nicholls et al., 2008) or by wheelchair (Nicholls et al., 2010), or remotely navigating a wheelchair (Nicholls et al., 2010; Robertson et al., 2015) or small vehicle (Nicholls, Jones, & Robertson, 2016). Using eye-tracking data, Robertson et al. (2015) suggest the rightward bias occurs because of a persistent bisection bias, or that participants treat the space between two door posts as a faraway line to bisect. Participants mentally mark the centre of the doorway to the right and without updating the centre mark (Berti et al., 2002) move towards that point. Given past line bisection investigations there may be an expectation that healthy participants bisect the line to the left (Bowers & Heilman, 1980), however Longo and Lourenco (2006) point out that the bias flips from left to right as the bisection task moves from peripersonal to extrapersonal space.

A series of studies carried out by Robertshaw and Wilkie (2008) links the wheelchair and remote control studies together, and generally supports Robertson et al.'s (2015) findings. Using a driving simulator and eye-tracking Robertshaw and Wilkie (2008) report that the gaze of the driver determines the path of the vehicle, that is, drivers steer where they are looking. This study provides critical information about driving behaviour but did not examine lateral asymmetries. With two notable exceptions few studies have investigated spatial asymmetries while operating a motor vehicle. Jang, Ku, Na, and Lee (2009) report a pattern of rightward deviations in a driving simulator and a leftward bias using pen and paper bisection tasks. Participants consistently veered right regardless of road markings, the number of lanes, or instructions to drive on the correct or reverse side of the road. In contrast to lateral bumping (Nicholls et al., 2008; Nicholls et al., 2010; Nicholls et al., 2016) and spatial asymmetries in simulated driving (Jang et al., 2009) Friedrich, Elias, and Hunter (2017) reported more left-sided incidents (collisions as well as near-collisions) when investigating spatial asymmetries when driving. Friedrich et al. (2017) used observational data from the Strategic Highway Research Program Naturalistic Driving Study (SHRP 2 NDS) and is the only study to use naturalistic data to examine spatial asymmetries when driving.

Research examining lateral spatial asymmetries when driving is mixed, however, the lateral bumping literature suggests that humans tend to veer to the right and bump the right side more often. By investigating baseline lateral errors when driving the studies presented here address this gap in driving literature. Additionally, these studies examine the robustness of unilateral bumping in other modalities, an area in the pseudoneglect literature where more research is needed. Investigating these questions was done through a simulated driving experiment in the laboratory and an analysis of naturalistic driving data from the SHRP 2 NDS. In the simulated driving experiment university-aged students demonstrated a pattern of handedness consistent with the general population, as determined by the Waterloo Handedness/Footedness Questionnaire – Revised (Elias, Bryden, & Bulman-Fleming, 1998; see appendix A). The much larger sample of naturalistic driving data had a greater age range but continued to display a pattern of handedness consistent with the general population. Despite differences in methodology and samples, our expectation was to be able to make meaningful comparisons between studies.

In the simulated driving environment average lateral lane position of the vehicle and collisions were measured and analyzed. Specifically, urban and rural locations, left and right turns, straightaways, moving and stationary obstacles were investigated for the potential influence they may have on spatial asymmetries. We predicted greater rightward average lane deviations across both urban and rural conditions, and greater rightward deviations in the urban condition because of lane markings. Deviations in lane position were predicted to follow the direction of a turn, and to be rightward on straightaways. Moving obstacles were predicted to be involved in more collisions and those collisions were predicted to be more severe. Collisions, overall, were predicted to occur more on the right with greater severity. Similar to average lateral lane positioning, collision frequency was predicted to follow the direction of the turn, with more collisions occurring with obstacles on the right on straightaways. Severity and frequency of collisions were predicted to be laterally congruous.

In the naturalistic driving data, the frequency and severity of collisions were measured and analyzed across the following dimensions: collisions resulting from crossing over the left or right edge of the road; collisions occurring on straight sections of road or when making a left or right turn; and collisions with lateral obstacles. Furthermore, lateral evasive maneuvers to avoid collisions were examined. Predictions for the naturalistic driving data analyses generally reflected those in the simulated driving study. Overall, collisions with obstacles on the right were predicted to occur more frequently and with greater severity. We predicted a higher frequency of collisions, and greater collision severity, when crossing the right edge of the road and also when making a right turn. More collisions, and greater collision severity, were predicted for obstacles on the right when driving straight. Rightward evasive maneuvers were predicted to be more effective for avoiding collisions as a rightward maneuver may feel safer (moving away from oncoming traffic, regardless of the threat of an actual head on collision).

Simulated Driving Experiment

Method

Participants. All participants were students at the University of Saskatchewan and were remunerated either $10 or 1 course credit, depending on the method by which they were recruited. Complete data sets were analyzed from fifty-three participants. Participants were almost two thirds female (32 female, 21 male) with an average age of 23.7 years (SD = 6.6) and primarily right-handed (five left-handed). All participants spoke English, but native languages varied and also included Arabic, Bengali, Farsi, Korean, Punjabi, Tagalog, and Urdu.

Procedure. Experimental procedures were approved by the Behavioural Research Ethics Board at the University of Saskatchewan. After providing informed consent, completing a pen and paper demographic questionnaire (Elias et al., 1998) and a video game experience questionnaire (see appendix B) the participant was seated at the driving simulator (described in detail below). The experimenter gave verbal instructions to drive in a way consistent with everyday driving. Further instructions were to continue only in one direction and attempt to keep the car on the road the entire time, vary speed as required but maintain control of the car (no speed limits were posted but there was an on-screen speedometer), follow the general rules of the road and take whatever measures necessary to avoid a crash when obstacles are encountered. After the instructions were given there was an opportunity to ask questions. The door was closed, and the lights were dimmed while the participant was left alone to complete the task. Participants drove in both a rural and an urban setting. Track layouts in each location were exactly the same with the only differences being scenes of fields, trees, and mountains in the rural setting and scenes of apartments and buildings and roads with lane markings in the urban setting. The participant made five circuits of the track, although there were no indicators for when a lap had started or finished giving the impression that driving was continuous rather than circular. Following the completion of one location, participants took a break while the second part of the experiment was set up by the experimenter. Several counterbalancing measures were implemented to ensure a laterally equal experience, including equal amounts of left and right turns (with straightaways of varying lengths making up the remainder of the course), and obstacle placements to the left and the right sides of the road. The amounts of stationary and moving obstacles were also counterbalanced. Further, between participants, the order that urban and rural locations were completed was counterbalanced.

Equipment. The participant navigated the virtual environment by way of the Logitech G27 driving kit, which consisted of brake and accelerator pedals and a 270mm leather wrapped steering wheel. The virtual environment was displayed on a 1920x1080 monitor. The steering wheel (using a USB interface) and display (connected by HDMI) were routed through a Windows 10 PC (8GB ram, 3.3GHz Intel Core i5 processor) with an upgraded graphics card (NVIDIA GeForce GTX 750 Ti) to ensure a seamless visual presentation while operating the virtual vehicle. The virtual driving environment was a custom software application developed in collaboration with the Human-Computer Interaction lab at the University of Saskatchewan. The driving system was developed using the Unreal 4 game engine and the Unreal Development Kit (Epic Games, Inc., Maryland, USA, www.unrealengine.com) and was written in the C++ language. All visuals and logging of performance data were built into the system.

Scoring. Two main dependent variables were examined: average lateral lane position and collisions. Average lateral lane position was constantly recorded in virtual-world units specific to the virtual environment, measuring the distance of deviations left and right from centre. Collisions were analyzed by frequency and severity. Collision frequency was calculated by coding collisions with left obstacles as negative one (*-1*) and collisions with right obstacles with a positive one (*1*) and then creating a collision score by averaging the total number of incidents, resulting in an overall negative score for more leftward collisions. A gap score, based on the absolute horizontal spatial locations of the vehicle and obstacle at the time of the incident, was used to measure the directness of a collision. We acknowledge that the gap score does not necessarily correspond to severity in real-world collisions but suggest that it acts a reasonable estimation for severity in most collisions. Within this framework, a higher gap score indicated a less severe collision and a more severe collision was represented by a lower gap score, which is visually presented in Figure 5-1.

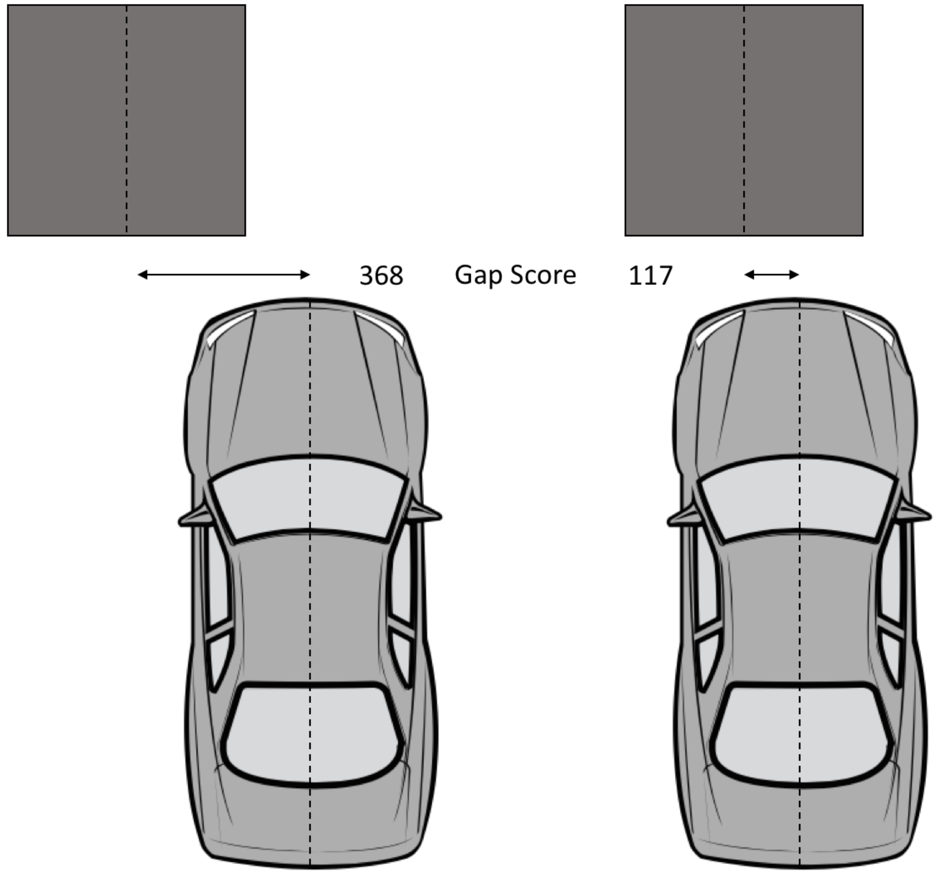

Figure 5-1. Gap score calculation. The distance between the lateral midline of the vehicle and the lateral midline of the obstacle are illustrated. The vehicle on the left shows a less direct collisions, resulting in a less severe collision compared to the vehicle on the right involved in a more severe collision resulting from a more direct collision.

Results

Average lateral lane position. Collapsing across track sections, we used a 2 (location: urban, rural) x 2 (deviation: left, right) repeated-measures analysis of variance (ANOVA) to determine the average left or right distance deviating from the centre of the road in both locations. The interaction between location and lateral deviation was significant, $F(1, 52) = 18.2$, $p < .001$, $\eta_p^2 = .259$, as well as main effects of location, $F(1, 52) = 203.5$, $p < .001$, $\eta_p^2 = .796$, and deviation, $F(1, 52) = 69.7$, $p < .001$, $\eta_p^2 = .573$. A means analysis revealed that deviations to the right were greater and deviations were greater in the urban setting. Post-hoc paired samples *t*-tests corrected to $p = .001$ revealed rightward deviations (vs. leftward) were significantly greater in urban, $t(52) = 7.4$, $p < .001$, and rural, $t(52) = 5.1$, $p < .001$ locations. Further, rightward deviations in the urban location were significantly greater than those in the rural condition, $t(52) = 11.8, p < .001$.

Collapsing across locations, we used a 3 (track section: left, right, straightaway) x 2 (deviation: left, right) repeated-measures ANOVA to determine the average left or right distance deviating from the centre of the road when turning or going straight. The interaction between track section and deviation was significant, $F(2, 104) = 412.4, p < .001, \eta_p^2 = .888$. Post-hoc paired-samples *t*-tests corrected to $p = .001$ found greater leftward deviations during left turns, $t(52) = 7.9, p < .001$, greater rightward deviations during right turns, $t(52) = 21.9$ $p < .001$, and greater rightward deviations on straightaways, $t(52) = 6.7, p < .001$. Further paired-samples *t*-tests examining deviation differences between track section revealed deviations to the right during right turns were greater than leftward deviations during left turns, $t(52) = 7.7, p < .001$ and that rightward deviations on straightaways were significantly less than leftward deviations during left turns, $t(52) = 6.1, p < .001$, and rightward deviations during right turns, $t(52) = 25.1, p < .001$. Results from the *t*-tests were congruent with a means analysis of the significant main effects from the ANOVA: track section, $F(2, 104) = 190.9, p < .001, \eta_p^2 = .786$, with greatest deviations occurring in right turns, and deviation, $F(1, 52) = 69.7, p < .001, \eta_p^2 = .573$, with rightward deviations on average greater than leftward.

Collisions. Of the 812 collision incidents, 464 occurred with obstacles on the right and 348 occurred with obstacles on the left. A one-sample *t*-test comparing the collision score of .14 (*SD* = .990) to a midpoint of zero was significant, $t(811) = 4.1, p < .001$, indicating that more collisions occurred with objects on the right across conditions and locations. An independent-samples *t*-test used gap scores to compare the severity for left and right obstacle collisions and revealed that the smaller gap score (indicating greater severity) for collisions with obstacles on the right (267.8, S*D* = 188.4) was significantly different from the leftward collisions gap score (330.2, S*D* = 207.3), $t(706.7) = 4.4, p < .001$.

There were more collisions with obstacles on the right in both the urban (right N = 220; left N = 141) and rural (right N = 244; left N = 207) locations, resulting in positive collision scores (urban .22, *SD* = .977; rural .08, *SD* = .998) across all conditions and between locations. Further, gap scores in both urban and rural locations were lower for collisions on the right than on the left. Because collision scores and gap scores were all biased in the same direction between locations, further analyses were carried out by collapsing across urban and rural locations.

Collisions were examined by occurrences in the three sections of track: left turns, right turns, and straightaways. Straightaway collisions had a score of .18 (S*D* = .986), which was found to be significantly different from zero by a one-sample *t*-test, $t(233) = 2.8$, $p = .006$. Despite the greater occurrence of rightward collisions there was no significant difference in left and right gap scores, $t(232) = 1.1$, $p = .265$, indicating that collision severity was not greater on the right or left. Whereas a one-sample *t*-test found a collision score of -.43 (S*D* = .906) in left turn sections to be significantly different from zero, $t(261) = 7.6$, $p < .001$ (indicating that more collisions occurred with obstacles on the left), a comparison between left and right collision gap scores revealed more severe collisions with obstacles on the right, $t(173.2) = 3.2$, $p = .002$. A collision score of .59 (S*D* = .810) in right turn sections was found to be significantly different from zero through a one-sample *t*-test, $t(315) = 12.9$, $p < .001$. Further, collisions with right obstacles in right turns were more severe than left obstacle collisions, $t(314) = 4.5$, $p < .001$.

Further, there were more collisions with moving (N = 700) than with static (N =112) obstacles. Comparing collision scores against zero with one-sample *t*-tests, moving obstacle collisions ($M = .15$, $SD = .99$) were biased significantly rightward, $t(699) = 3.97$, $p < .001$, and static obstacle collisions ($M = .11$, $SD = 0.999$) showed no significant bias, $t(111) = 1.1$, $p = .259$. The two rightward collision scores were not different from each other when compared with an independent-samples *t*-test, $t(810) = .4$, $p = .681$. Collisions with static obstacles (gap score = 190.1, S*D* = 97.3) were found to be more severe than collisions with moving obstacles (gap score = 311.3, S*D* = 206) when gap scores were compared in an independent-samples *t*-test, $t(302.5) = 10.1$, $p < .001$.

Naturalistic Driving Analyses

Method

Ethics Statement. The SHRP 2 NDS was sponsored by the Transportation Research Board (TRB) of the National Academy of Sciences. All subjects gave written informed consent. The Behavioural Research Ethics Board of the University of Saskatchewan approved the requested variables from the SHRP 2 NDS.

SHRP 2 NDS participants. Data was analyzed by aggregating events rather than by participants, and so, participant demographics were not examined in each analysis. However, an overview of participant handedness provided here shows that the sample generally displayed a pattern of handedness consistent with the general population. Of 1758 participants there were no data for 80, 1476 were right handed, 138 were left handed, and 64 were ambidextrous.

Procedure. The variables analyzed, and additional aggregations made in the current study are outlined below. Variable definitions and descriptions come from the SHRP 2 Researcher Dictionary for Video Reduction Data (Version 3.4; Virginia Tech Transportation Institute, 2015). The first variable examined was *Precipitating Event*, defined as the state of environment or action that began the sequence under analysis. This is not a driver behaviour, this is a vehicle kinematic measure based on what the vehicle does. This is the critical event which made the crash or near-crash possible. Some examples of coded events include subject vehicle lane change: left, other vehicle: backing, and subject vehicle lost control: excessive speed. Most collisions occurred in the precipitating events of subject vehicle over the right line or edge of the road and subject vehicle over the left line or edge of the road and, thus, were isolated and focussed on in analyses. Occurring just before the precipitating event is the *Pre-incident Maneuver*. This is the last type of action or driving maneuver just prior to or at the time of the precipitating event and cannot be determined until the precipitating event is defined. This is also a vehicle kinematic measure based on what the vehicle does and not the driver behaviour. Examples of these maneuvers include merging, decelerating in traffic lane, and maneuvering to avoid an object. The most collisions occurred when turning right, going straight at a constant speed, and turning left, resulting in focus of the analyses on these three pre-incident maneuvers.

Next, we investigated the variable *Evasive Maneuver*, which is the reaction or avoidance maneuver (if any) in response to event nature, event severity, incident type, and crash severity by the subject driver. This is independent of maneuvers associated with or caused by the resulting crash or near-crash. Examples of these maneuvers include braked (lock up), accelerated and steered left, and steered right. We created the dichotomous variables of left evasive maneuvers and right evasive maneuvers by consolidating events coded as braked and steered left, accelerated and steered left, and steered left, and doing the same with respective maneuvers occurring on the right. We used the variable *Motorist 2 Location* to create the dichotomous variables left obstacles and right obstacles. *Motorist 2* Location is the position of other vehicles, animals, or objects involved in the event or restricting the subject vehicle's ability to maneuver at the time of the start of the precipitating event. While all possible impact locations are shown in Figure 5-2, only the four lateral impact locations were consolidated on both sides to create left obstacle and right obstacle. Examples of the types of objects coded in this variable include various types of automobiles (pick-up truck, mini-van, etc.), pedestrians, cyclists, and animals and will be simply be referred to as obstacles from here on. The *Crash severity* variable is a ranking of crash severity based on the magnitude of vehicle dynamics, the presumed amount of property damage, knowledge of human injuries (often unknown in this dataset) and the level of risk posed to the drivers and other road users. This variable is coded only for events that include a crash and encompassed most severe crash, police-reportable crash, minor crash, and low-risk tire strike. Most severe crash and police-reportable crash were combined to a new group labelled *severe crashes*, and minor crash and low-risk tire strike were combined as *minor crashes*.

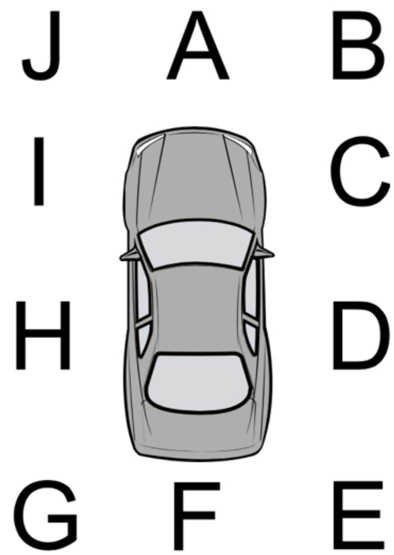

Figure 5-2. Possible impact locations on the subject vehicle. Location of obstacle, *Motorist 2*, is coded A – J in relation to the subject vehicle. Impact locations B, C, D, & E were coded as right and locations G, H, I, & J were coded as left.

Relative risk analyses. Relative risk (RR) is calculated by comparing the probability of one event occurring to the probability of another event occurring, with a resulting value being greater than or equal to zero. A value greater or less than one, opposed to an exact value of 1, indicates that one of the outcomes is more or less likely to occur. This likelihood is statistically significant if it falls within a 95% confidence interval (CI), and that the confidence interval does not include the exact value of 1. Additionally, the increase or reduction in risk is presented in each case, calculated by using the formula:

Relative Risk = |1 - RR| * 100

Results

Precipitating event: crossing road line or edge. Comparing the frequencies of collisions occurring from the subject vehicle crossing the left line or edge of the road with right line or edge crossings revealed that crossing right resulted in 1.17 times the risk of a collision occurring compared to crossing left (CI: 1.098 – 1.247, $p < .001$), or a 17% increase in collision risk over and above crossing left. Although, collisions resulting from crossing left had 2.17 times the risk of a severe collision, the difference was not significant with crossing right (CI: .403 – 11.811, $p = .365$).

Pre-incident maneuvers: turning. Making a right turn had 1.51 times the risk of a collision occurring compared with turning left (CI: 1.349 – 1.691, $p < .001$), or a 51% increase in collision risk over and above turning left. Making a left turn had 3.40 times the risk of a severe collision (CI: 1.394 – 8.619, $p = .008$), or a 240% increase in severe collision risk over and above turning right. We compared the frequency and severity of collisions with left and right obstacles when going straight at a constant speed. The collision risk with a left obstacle was 1.04 times that of a collision risk with a right obstacle, however this difference was not significant (CI: .626 – 1.724, $p = .883$). A collision with an obstacle on the left had 1.9 times the risk of resulting in a severe collision compared with a collision on the right (CI: 1.068 – 3.368, $p = .029$), or a 90% increase in severe collision risk over and above a severe collision on the right. Collisions occurred at either the front or rear of the subject vehicle 94% of the time when making a left turn and 97% of the time when making a right turn. However, when we examined the frequency of collisions with left and right obstacles during left and right turns it was revealed that there was 1.17 times the risk of a collision to the left during a left turn than during a right turn (CI: 1.268 – 5.528, $p = .010$), or a 167% increase in risk to have a leftward collision when turning left and there was 5.65 times the risk of a rightward collision during a right turn compared with making a left turn (CI: 1.469 – 21.862, $p = .012$), or a 466% increase in risk in having a rightward collision while turning right.

Evasive maneuvers avoiding collisions. Making an evasive maneuver to the right to avoid a collision had .49 times the collision risk compared with a left evasive maneuver (CI: .413 – .594, $p < .001$), or a 51% reduction in collision risk with a right evasive maneuver.

Lateral obstacle location: avoided. The likelihood of steering right when encountering an obstacle on the left was 3.9 times that of steering right when encountering an obstacle on the right (CI: 3.363 – 5.070, $p < .001$), or a 295% increase to steer right for left obstacles over and above steering right for right obstacles. Conversely, the likelihood of steering left for an obstacle on the right was 6.34 times that of steering left when encountering an obstacle on the left (CI: 4.579 – 8.029, $p < .001$), or a 534% increase to steer left when encountering a right obstacle over and above steering left for a left obstacle.

Lateral obstacle location: collisions. Despite obstacles on the right having 0.9 times the risk of a collision compared to left obstacles (CI: .7013 – 1.150 $p = .393$), or a 10% decrease in collision risk for right obstacles, no significant difference was found between frequencies of collisions with obstacles on the left and right. However, collisions with left obstacles had 1.4 times the risk of being a severe collision compared with obstacles on the right (CI: 1.048 – 1.869, $p = .023$), or a 40% increase in severe collision risk with an obstacle on the left over and above an obstacle on the right.

General Discussion

To date, there have been few reports of spatial asymmetries when driving a motor vehicle in a simulated or naturalistic setting. Therefore, when making predictions about driving our theoretical orientation was based on what has become known as unilateral bumping, which has focussed on walking (Nicholls et al., 2008) or navigating a motorized scooter (Robertson et al., 2015) or remote-controlled car (Nicholls et al., 2016). It has been proposed within this growing body of literature that lateral deviations, veering, bumping, and collisions are best understood within the context of hemispheric asymmetries leading to unequal spatial processing commonly referred to as pseudoneglect (Bowers & Heilman, 1980). We dichotomized road incidents to the left and right of the vehicle and made predictions by extrapolating previously observed lateral bumping behaviours to driving situations. Consistent with much of the lateral bumping literature, our findings point to a rightward bias that persists in both studies.

In the driving simulation experiment we studied lane positioning and collisions, examining the potential impact of turns, locations, and obstacles. For the most part, differences between the types of obstacles and the locations did not contribute to the interpretation of results. Rightward lane position deviations were greater across all conditions, notably in the lane-marked urban location, as was predicted. Collisions on the right occurred more often across all conditions and obstacle types, also as expected. Deviations and collisions tended to follow the direction of a turn, but a key finding came from investigating driving on straight sections of road.

We had few opportunities to make direct comparisons to past lateral bumping studies as one of the aims of the current study was to simulate a natural driving experience, thereby not restraining driving to a straight line. The most direct comparisons that could be made with previous lateral bumping studies, where participants move in a straight line, were made by analyses of behaviour when driving on straightaways. Our predictions that drivers would exhibit rightward road position deviations and more collisions on the right were supported and suggest that rightward deviations while navigating is indeed a stable tendency among healthy neurotypical participants. These findings suggest that spatial biases previously observed in a controlled driving simulator (Jang et al., 2009), when walking (Nicholls et al., 2007), in a wheelchair (Nicholls et al., 2010), and when remotely controlling a wheelchair (Nicholls et al., 2010; Robertson, et al., 2015) or small vehicle (Nicholls et al., 2016) are present when navigating a motor vehicle in a naturalistic virtual driving setting.

Collision data was the primary method of ascertaining measures of spatial asymmetries from naturalistic driving data, however, asymmetrical driver behaviour in the absence of other objects or collisions was examined by analyzing the variable describing line or road edge crossings. There was no additional coding specifically for veering to the left or right, however those incidents would be captured in this variable, which could be comparable to veering in the laboratory (Nicholls et al., 2016; Robertson et al., 2015). Consistent with past lateral bumping and veering findings we report that crossing over the right line or edge results in a greater risk of a collision.

A general trend was found for collisions to occur on the side of the vehicle congruent with the direction of the turn, on the right for a right turn and on the left for a left turn, in the driving simulation and the naturalistic driving data. The increase in the risk of a severe collision when making a left turn in the real-world may be attributable to the presence of oncoming traffic. This is in contrast to the experimental driving simulation where more severe collisions occurred on the right in both left and right turns.

When driving straight a similar pattern is found between the driving simulation and the naturalistic driving data when examining collisions with obstacles. The frequency of collisions was greater for obstacles on the right in the simulation and the risk of a severe collision increased with obstacles on the left in naturalistic driving data. The presence of oncoming traffic may again help explain the disparity between the findings as the risk of a head-on-collision, a severe collision, will almost exclusively occur when making left turns and with left obstacles, increasing the risk for these types of collisions. The absence of external factors like oncoming traffic (or any traffic at all) in the driving simulation may give a clearer indication of spatial biases when presented with lateral obstacles when driving but may not accurately represent some real-world conditions.

While the data sets of each study describe behaviours that are theoretically similar, there was no standardization of the measurements and any attempt to compare them statistically could be misleading. We have presented the findings from each study, which are focussed on lateral differences within each variable, and made comparisons between the studies pertaining to the direction and degree of deviations and collisions. The data presented here supports the suggestion that a shared underlying mechanism is responsible for increased collision risk when crossing over the right line or edge in the real-world, rightward lane deviations and increased rightward collisions in the driving simulation, and rightward bumping and veering in the laboratory.

Our analyses and comparisons of basic spatial asymmetries occurring in a motor vehicle in both a laboratory simulation and in the real-world using a subset of naturalistic data from the SHRP 2 NDS is, to our knowledge, the first of its kind. The richness of the naturalistic driving data set enabled us to carry out unique analyses from those of a typical laboratory-based study, but also contained some restrictions. Conversely, our laboratory-based driving simulation experiment produced very precise data while being limited in other ways. The tension between highly controlled laboratory-based studies that sacrifice real-world validity and real-world observational studies with no experimenter control and high external validity is common in psychology, and present in the current research.

Continuing to investigate spatial asymmetries while driving will require future studies to examine participants who have learned to drive on the left side of the road in right-side-drive cars. In future investigations of both left side and right side driving behaviour, eye-tracking may be useful in more accurately determining where overt attention is guided when driving, particularly when avoiding obstacles. This information would be helpful in establishing if either obstacle avoidance judgements or simply pointing the vehicle in a given direction involves any eye movement indicating behaviours seen in line bisection tasks.

The research presented here stands alone in many ways, but these findings open the door for future examinations of lateral biases when driving in a naturalistic setting. Our findings contribute to bridging the gap between real-world behaviour and that occurring in the laboratory, and give a more comprehensive understanding than ever before of spatial asymmetries when driving.

CHAPTER 6

DISCUSSION AND FUTURE DIRECTIONS

The overarching goal of this research program was to examine the ways in which biases of attention direct our interactions with the world in everyday activities like driving and evaluating artwork. There is a complex relationship between the way that the world is perceived, the interpretation of that information, and resulting actions. This relationship is further complicated by the fact that actions are guided not only by new, up-to-date information but also information acquired from past experiences. The research presented here focussed on two areas with wide reaching influence, primarily through the visual modality, art and driving. Despite the fact that an individual's experience with any piece of art (and aesthetic appreciation in general) is subjective, the focus of this research was to identify how asymmetry in the brains of neurologically normal individuals contributes to some consistent lateralized aesthetic preferences. Relatedly, in spite of the subjective capabilities of every driver, research questions were structured throughout in search of objective, reliable, lateralized patterns of behaviour, also guided by asymmetries in the brain. Participants with RTL NRD and the consideration of near and far space contributed to exploring how innate biases might be modulated. Broadly, the aim of this research was to extend our collective knowledge about pseudoneglect by considering potential attenuating factors and more precisely examining how susceptible certain stimuli are to the phenomenon.

The research in Chapters 2, 3, and 4 evaluated the effects of lateral biases of attention on spatial ability while taking into consideration the NRD of participants, more complicated stimuli, and the added complexity of arriving at an aesthetic preference. Lateral collisions and veering when driving were explored in the simulated driving experiment and the analysis of naturalistic driving data in Chapter 5 by adopting a theoretical orientation based on human biases of attention, aiming to extend the existing lateral bumping literature to motor vehicle operation. All the investigations addressed the circumstances leading to the attenuation of pseudoneglect and the shift to a right bias through at least one of the previously outlined primary areas:

a) The effects that LTR and RTL NRD have on spatial biases and aesthetic preferences.

b) The dichotomy between spatial biases that result from tasks administered in intrapersonal and extrapersonal space.
c) The effects of increasing a task's complexity by incorporating aesthetic preference responses above and beyond only spatial ability.

In Chapter 2 clearly diverging trends between LTR and RTL groups were identified for aesthetic preferences, while at the same time mean gaze times were generally consistent between groups. The greater amount of time spent exploring the right side of space, regardless of lateral reading and writing directions, in conjunction with the LTR group displaying leftward preferences and the RTL group demonstrating rightward preferences suggests that learning a non-LTR primary language during the highly neural-plastic time of childhood attenuates the typical leftward bias. Attenuation of leftward biases on both the aesthetic and perceptual asymmetries tasks by the RTL group were hypothesized based on past investigations of the influence of NRD on aesthetics (Smith & Elias, 2013), spatial ability (Rinaldi et al., 2014), and perceptual asymmetries (Friedrich & Elias, 2014). In Chapter 2, however, this trend was only observed for aesthetic preferences.

As aesthetic preference was theorized to depend on the rudimentary elements of lighting and shading, which are foundational to luminance judgments in the greyscales task, it was puzzling for RTL participants to display opposite biases between the two tasks and for there to be such a disparity between the magnitude of leftward bias of LTR participants between tasks. One might expect more congruency within groups and between tasks given the aforementioned theory and that the aesthetic task images could be considered more complex analogues to greyscales images. In particular, an aesthetic preference required evaluating the image as whole while depending on the factors of lateral lighting and weighting, and likewise the luminance judgment in the greyscales task depended on considering both rectangles in the scene as a whole while weighing the brightness at the extremes of each rectangle. Although the pattern of results did not confirm predictions, it proved to be more important than first thought when further examined in the context of eye movement data from the aesthetics task.

Distinct aesthetic preferences coupled with similar eye movements between NRD groups suggest that differences in preferences may result from factors other than the way visual information is acquired. In particular, the allocation of covert attention and the distribution of attention between competing aspects of visual information may depend on habits and learning specific to a certain culture. This learning would be especially important for aesthetic preference deliberation as complexity, in the context of the research presented here, is defined as the higher cognitive processes over and above spatial ability required in making an aesthetic judgment. The dependence of aesthetic preference on the aforementioned rudimentary elements of lateral luminance and weighting has been suggested by Smith and Elias (2018), but the judgment is also undoubtedly guided by the personal history of the viewer, including their memories and contextualization of art. In contrast, it could be argued that luminance judgments in the greyscales task are comparatively less complex and leave less room for the influence of culture. More research is needed, however, as perceptual asymmetries appear to show interactions with factors like handedness and NRD.

Findings from the studies in Chapter 3, especially from the behaviour of RTL participants, further support the possibility that there is a common underlying mechanism for spatial ability and aesthetic preferences, plotting them as points on the same continuum (Smith & Elias, 2018; Smith et al. 2019a). Biases progressing from left to right in bilingual RTL to monolingual RTL individuals provides compelling evidence to extend Rinaldi et al.'s (2014) interactive account to cover some aspects of aesthetic preference and to continue pursuing the development of the attenuation increases with complexity theory. Bilingual RTL participants displayed leftward biased perceptual asymmetries on the greyscales task, neutral light placement biases on the sculpture lighting task, and monolingual RTL art experts showed right biased light placements. Greater context for these results comes from comparisons with LTR participants and between tasks as the bias of RTL participants on the greyscales task was a notably smaller magnitude left bias than that of LTR participants, light placements lacking lateral bias were shifted rightward relative to greyscales bias, and right biased light placements of monolingual RTL art experts were a further shift to the right and opposite to those of LTR art experts. With the outstanding exception that both LTR and RTL participants lacked lateral biases on the sculpture lighting task, the succession of biases outlined above follows what would be predicted by Rinaldi et al.'s model even with the inclusion of more complicated images that cannot be evaluated by spatial ability alone.

Focussing on the behaviour of LTR participants, the simplified sculpture lighting task, compared with Sedgewick et al.'s (2015) earlier version, resulted in a leftward shift of the lighting bias in the Chapter 3 version of the task. The LTR group's behaviour supports the attenuation increases with complexity theory in two ways: first, the decrease in attenuation of the leftward bias from the previously reported rightward lighting bias (Sedgewick et al.) indicates that perhaps the simplified stimuli and procedures guided lighting biases leftward, and second, relative to the greyscales the greater complexity of the sculpture stimuli resulted in the attenuation of the leftward bias.

As there is curiously very little research using 3D stimuli to study aesthetics, conclusions must be cautiously drawn from the limited information available. As participants in the Chapter 3 sculpture lighting paradigm and in Sedgewick et al.'s (2015) sculpture lighting task did not display the expected leftward lighting bias, one such tentative conclusion may be that 3D stimuli are in some way remarkable. The uniqueness of 3D stimuli and lighting biases may also relate to the separation between experts and non-experts. It could be that lighting a 3D object is more difficult than illuminating 2D stimuli. The choice of the non-expert may be the more the obvious one, lighting the sculpture in a way that highlights posing direction. The experience of experts, on the other hand, might facilitate the recognition of instances when the more aesthetically pleasing choice is to deviate from lighting in line with posing direction.

Not all initial predictions for Chapter 3 experiments were supported but the findings reported are ground breaking. The sculpture lighting task is the first experimental evidence of congruency between lighting direction and posing direction, a theory previously only supported by archival and content analyses (Grüsser, et al., 1988; Thomas et al., 2008). Further innovation comes from the results showing that the preference for congruity between lighting and posing directions is stable across NRDs and levels of art expertise.

Participants made distinct judgments in the two experiments in Chapter 4 but manipulated the computer mouse in the same way to either estimate the centre of the circle or find the optimal illumination location. The manipulation of the complexity of the stimuli and the NRD of the participants allowed for further evaluation of the efficacy of the attenuation increases with complexity theory and the robustness of the interactive account when generalizing the theory outside of basic spatial ability. The theory that spatial ability and aesthetic preference have some common underlying mechanism and are potentially points on the same continuum, was at the forefront of experimental design and formulation of predictions. With LTR participants showing a leftward lighting bias, and the light placements of RTL participants significantly rightward of the LTR group, the results from the artwork lighting task further support the theory that the interactive account (Rinaldi et al., 2014) may be generalized to aesthetics.

The light placements of LTR and RTL participants on the 2D artwork lighting task in Chapter 4 are consistent with aesthetic preferences previously displayed by both groups on the image rating task of Chapter 2 (Smith & Elias, 2018) as well as a forced choice version of the task (Smith & Elias, 2013). Further, focusing on the light placements of LTR participants, results replicate findings from McDine et al. (2011) and fit into a larger pattern of upper left light placements in artworks, observed across artistic style and time periods (Mamassian, 2008; McManus, 1979; McManus et al., 2004; Sun & Perona, 1998; Thomas et al., 2008). This continuity of the leftward bias in aesthetic preference across studies supports the idea that aesthetic preferences may be built upon more rudimentary elements such as lighting and shading and suggests that aesthetic preference and spatial ability exist on a shared continuum of lateral biases, making aesthetic preference susceptible to pseudoneglect. The convergence of these observations across studies as well as the uniformity between the perception and production of what is beautiful supports the notion that humans have a higher aesthetic value for leftward lighting.

The leftward bias was expected in the Chapter 4 Halos task given that spatial ability was critical for completing the novel task. However, the assumption that the impact of factors other than spatial ability would not be significant, and that is was a *simple* task, may have been misguided. In addition to some potential sources of error highlighted in Chapter 4, it is possible that participants in the Halo task became fatigued by the difficulty of the task. Being given very little information, the process of visualizing an entire circle and then making a centre estimation might have been a *complex* task, which reduced alertness and shifted the bias to the right. Manly, Dobler, Dodds, and George (2005) observed a rightward shift in lateral biases among neurotypical participants during the landmark task that they suggest resulted from decreased alertness. Manly et al.'s theory points to clinical neglect patients' trouble maintaining attention (Howes & Bowler, 1975) and the attenuation of persistent left neglect though increased arousal by auditory tones (Robertson, Mattingley, Rorden, & Driver, 1998). Oppositely, Manly et al. propose that decreased alertness in neurotypical participants induces the rightward shift of spatial biases. At this time, it is unknown if the finding that individuals (regardless of NRD) are more accurate when identifying the centre of circles on the right (regardless of size) is indeed representative of the Halos task, given the lack of use of the Halos task to examine lateral spatial biases.

Rightward spatial biases have also been demonstrated by shifting a basic spatial task from intrapersonal space to extrapersonal space (Longo & Lourenco, 2006; Nicholls et al., 2010). Further, the rightward spatial bias has also been reliably reproduced in spatial tasks with participants with a RTL NRD, at varying levels of reading and writing capability (Fagard & Dahmen, 2003) and LTR bilingualism (Rinaldi et al., 2014). Perhaps the most extensively investigated occurrence of the rightward spatial bias comes from lateral bumping tasks (Nicholls et al., 2007; 2008; 2010; 2016; Robertson et al., 2015; Turnbull & McGeorge 1998). Many lateral bumping studies directly or indirectly imply that navigation asymmetries may have consequences when driving, but few studies have reported, or even examined, lateral biases when driving (save Jang et al., 2009 & Friedrich et al., 2017). The theoretical orientation adopted in Chapter 5 was based on what has become known as lateral bumping, which relies on the theory of pseudoneglect, in the same way that Jang et al. and Friedrich et al., as well as studies exploring navigation asymmetries using methods other than driving (Nicholls et al., 2007), have done. The observation of the rightward bias in our tightly controlled simulated driving environment in Chapter 5 was consistent with previous lateral bumping studies also reporting the rightward biases.

Perhaps the best indicator of consistency between our simulated driving task and previous lateral bumping studies were the behaviours observed when driving on only straight sections of road. Like previous laboratory studies where participants walk (Nicholls et al., 2008), operate a wheelchair (Nicholls et al., 2010) or remotely control a small car (Nicholls et al., 2016) in a straight line, more rightward collisions occurred when driving in a straight line in the driving simulation. Further, rightward deviations of lane position on straight sections were consistent with similar past findings from Jang et al. (2009). As previously reviewed, Robertson et al. (2015) have suggested that collisions and veering are asymmetrically right because of a persistent rightward bisection bias. It is difficult to know if the bisection bias theory is the best fit to explain similar lateral biases observed when driving at this early stage of new research. Acquiring precise eye tracking data while driving (in a simulation or through naturalistic observation) would help determine if collisions and lane position biased to the right occur in a similar way to navigating through doorposts.

Encountering a single obstacle on either the left or the right, or lane deviations on empty roads, may not intuitively map onto a bisection task. Eye tracking data would help determine if, perhaps, the driver uses lane markings in the distance as the left and right ends of a line. According to the bisection theory, bisecting the faraway endpoints results in a rightward biased judgement and as the vehicle progressed it would veer right, similar to veering behaviour observed by Robertson et al. (2015). As eye tracking data is not available from either study one cannot be confident that any type of bisection is occurring. However, more rightward line or edge crossings in the naturalistic observation data and the rightward lane deviations in the driving simulation certainly support this hypothesis.

A rightward bisection bias when encountering an obstacle also explains the greater incidence of rightward collisions in the driving simulation. If an imaginary line is created between the end points of the innermost point of an obstacle closest to the subject's car on the right side and the innermost point of the centre line or oncoming vehicle, whichever is closest to the car, on the left side, according to the bisection theory bisecting the space outlined above will result in a rightward bisection and subsequently more rightward collisions. The counter argument could be made that individuals learning to drive on the right side of the road make a rightward lateral error when estimating the distance between the two points because that is the safer direction to deviate, resulting in more rightward collisions. However, Jang et al. (2009) looked for this very phenomenon in their driving simulation and did not find any evidence to support this theory.

It is difficult to determine the role that oncoming traffic, or any traffic at all, have in lateral lane position and collisions because of the lack of studies that compare driver behaviour in simulations and naturalistic observations. Conclusions drawn from the comparison presented in Chapter 5 should be viewed cautiously for a few reasons. First, the data exists almost in isolation and more research is needed to contextualize the two studies. Second, although the data sets from each study describe behaviours that are theoretically similar, there is no standardization of the measurements and any attempt to compare them statistically could be misleading. However, there does appear to be a general trend of attenuation of the rightward biases in the naturalistic observations compared with the simulation. In the simulation, the frequency and severity of collisions was greater on the right, as were lane deviations. During naturalistic observations there were indicators of rightward biased spatial judgements, such as greater risk of collision from crossing the right line or edge of the road and increased frequency of collisions from right turns, but no significant difference between the frequency of collisions on the right or left was found. Further, leftward collisions were found to be more severe in the naturalistic data, perhaps due to the presence of oncoming vehicles.

Future Directions

In light of the summaries and explanations of the current research reasonable next steps are outlined below that focus on further examining the use of pseudoneglect theory as an approach for understanding spatial biases when driving, continuing to work with bilingual and monolingual RTL NRD individuals to understand spatial ability, and to more accurately understand behaviours that occur in three-dimensional space by moving beyond the use of 2D stimuli. These areas relate directly to outstanding issues raised by the current research relating to the theories relied on throughout, the interactive account and attenuation increases with complexity theory. Future studies centred on these issues will further disentangle the factors contributing to spatial and aesthetic biases.

A study analyzing data from left-side driving regions with the same focus on lateral spatial attention would be an ideal foil for the Chapter 5 studies and provide the opportunity to disentangle the association between lateral location of the vehicle on the road (right) and lateral spatial biases when driving (also right). Is the frequency and severity of collisions and overall lane positioning biased rightward regardless of regional driving laws? Naturalistic data could certainly provide clarity to this issue but researchers may find that the rightward spatial bias when driving endures, given Jang et al.'s (2009) findings from the simulation that had participants drive on both sides of the road.

Acquiring naturalistic driving data from regions of the world where RTL is the primary NRD, as well as regions where driving occurs on the left-side of the road, would complement the analyses of North American naturalistic driving data in Chapter 5 and further contribute to our understanding of spatial ability and lateral biases in intra- and extrapersonal space. At this time large-scale naturalistic driving data collection is not known to be occurring in either left-side driving or RTL NRD regions. The findings from the work in Chapter 5 may demonstrate some of the opportunities available to researchers and incite action.

An investigation into collisions and lane positioning in RTL NRD regions where drivers are primarily monolingual RTL readers would be equally as compelling, furthering research on the influence that reading habits have on spatial abilities. A study of RTL NRD drivers may also make contributions about extrapersonal spatial biases to Rinaldi et al.'s (2014) interactive account, which explores intrapersonal spatial biases. Given the findings from the current research, in conjunction with what is known about extrapersonal spatial biases, one might expect an additive effect between the right bias in extrapersonal space and RTL NRD.

A pressing area to be further explored when examining spatial biases and driving depends on the presence of other vehicles on the roadway, particularly those heading in the opposite direction. The development of driving simulations with additional traffic will help determine if vehicles heading in the other direction skew lateral biases, particularly those related to collision severity, and what conditions enable the addition of traffic to increase task complexity. These new developments would also allow for novel comparisons to be made with existing naturalistic driving data.

Collecting eye tracking data from participants operating a vehicle in driving simulations will provide critical updates to claims made by Robertson et al. (2015), Berti et al. (2002), and Robertshaw and Wilkie (2008). Experiments analyzing eye tracking data while driving will help determine if an extrapersonal line bisection type of computation occurs when avoiding obstacles or during unobstructed driving. Further, insight may be gained into if that bisection is indeed right of veridical centre, if (or when) the bisection mark is updated, and if the gaze of the driver determines the path of the vehicle. Eye tracking data from LTR and RTL participants may also be critical in understanding how NRD influences spatial navigation and extrapersonal spatial biases, which to this point has received particularly little attention. Differences in driving behaviour between NRD groups using variables measuring lateral biases from Chapter 5 could be examined in conjunction with analysis of eye tracking data in an effort to gain new insights that help explain potential navigation differences.

Further exploration of the degree that aesthetic preference depends on culture may benefit from qualitative analysis, as preferences have been found to be distinct between groups, but eye tracking has not revealed reliable differences. At this time, solely measuring overt attention through eye tracking when examining and judging visual art does not necessarily provide a satisfactory explanation for preference differences that clearly exist between NRD groups. It could be that cultural practices result in the lateral distribution of covert attention, and subsequent information extraction, resulting in the variations of aesthetic preference between

NRD groups. One method to potentially gain additional insight into this situation would be to elicit commentary from participants about where attention is first drawn to when making an aesthetic preference judgment. This qualitative data would complement eye tracking data and contribute to a more complete understanding of the factors comprising aesthetic preferences.

As research exploring the Halo visualization is limited and the experiment in Chapter 4 appears to be the first use of the Halos task to explore pseudoneglect, continued implementation of the Halos task will provide the data needed to assess whether the pattern of results reported in Chapter 4 are representative of neurotypical participants. Future iterations of the Halo task can reduce the risk of participant fatigue by making simple procedural changes and limiting the number of trials. Altering the stimuli to present two halos simultaneously in a forced choice paradigm may yield a different pattern of results and provide unique insights from the current implementation.

Finally, I offer some suggestions for increasing the robustness and validity of future work. The attenuation of pseudoneglect has been theorized to occur with aging in the hemispheric asymmetry reduction in older adults model (HAROLD; Cabeza, 2002) and further examination of this segment of the general population may make important contributions to understanding atypical lateral biases while responding to the persistent criticism that research is too often solely conducted with young adults. Also, the use of virtual reality and augmented reality are now beginning to become widespread. The proliferation of these technologies that are increasingly more user friendly opens up possibilities to researchers to create highly realistic experimental paradigms. Participants interacting with immersive experiments in 3D may provide the data needed for more accurate measurements and subsequently better understanding of human behaviour.

The theory of attenuation increases with complexity seeks to explain patterns of results that do not conform to expected biases and provide some unity to our understanding of atypical biases of spatial ability, and lighting and aesthetic preferences, which may rely on basic spatial ability. Foundational to the theory of attenuation increases with complexity is research exploring pseudoneglect (Bowers & Heilman, 1980; Jewell & McCourt, 2000; Learmonth et al., 2015) atypical spatial biases in extrapersonal space (Longo & Lourenco, 2006; Nicholls et al., 2010) and participants with RTL NRD (e.g., Chokron & Imbert, 1993; Fagard & Dahmen, 2003; Rinaldi et al., 2014).

The theory of attenuation increases with complexity complements interactive account. Just as the interactive account theorizes that spatial biases move rightward as reading direction moves from LTR to bilingual RTL to monolingual RTL (Rinaldi et al., 2014), the attenuation increases with complexity suggests that the same trend of increased leftward bias attenuation occurs as more high-level processes become involved in completing a judgment task. Examining these theories in tandem plots the spatial abilities and aesthetic preferences of LTR and RTL individuals on the same continuum, with the theories working together in harmony while both explaining variations of leftward biases independently. Between NRD groups this information suggests that the interactive account be extended to cover some aspects of aesthetics, with aesthetic preference bias baselines rightward to those of spatial ability.

Our perceptions of the world are guided by a host of various factors, knowingly and unknowingly perceived, and the overviewed studies explore only some of these. The research presented here was carried out with the aim to better understand several factors that interact with imperceptible biases that occur because of asymmetries in the brain. First, the complexity of a task: is there a relationship between lower complexity basic spatial abilities and higher complexity aesthetic preferences? Second, the cultural lens the world is viewed through: does NRD interact with asymmetries in your brain? Third, the spatial location of a task: does the distance at which a spatial judgement is made modulate lateral biases? Findings from the analyses of experiments and naturalist observations presented here make some suggestions for greater insights to these three points. First, the innate leftward spatial bias influences aesthetic preferences, displaying a similar but attenuated pattern to spatial biases. Second, the innate leftward spatial bias interacts with the horizontal direction of NRD. And lastly, the previously reported flip to an innate rightward spatial bias in extrapersonal space may endure when driving.

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APPENDIX A

Waterloo Handedness and Footedness Questionnaire-Revised

(LTR)

PARTICIPANT QUESTIONNAIRE

Age: ________

Sex (circle one): **M** **F**

If you are a student, what is your major? _________________ Year of study? ____________

What was the **first** language you learned as a child? **English** **French** **Chinese** **Other: __________**

Do you have any hearing impairments? **Yes** **No**

Do you have any visual impairments (including colorblindness)? **Yes** **No**
If yes to either question, please specify:

What colour are your eyes? **Blue** **Brown** **Green** **Hazel** **Violet** **Other:_____**

What is your natural hair colour? **Blond** **Brown** **Black** **Red** **Auburn** **Other:_____**

Do you have any primary **biological** relatives (i.e., mother, father, brother, or sister) who are left-handed?
Yes **No** **Don't Know**

Do you have any **biological** extended family members (i.e., grandparents, ***biologically*** related aunts and uncles) who are left-handed? **Yes** **No** **Don't Know**

Please list any medications (including oral contraceptives) that you are currently taking:

Instructions: Please indicate your hand preference for the following activities by circling the appropriate response. If you **always** (i.e., 95% or more of the time) use one hand to perform the described activity, circle **Ra** or **La** (for **right always** or **left always**). If you **usually** (i.e., about 75% of the time) use one hand circle **Ru** or **Lu,** as appropriate. If you use both hands **equally often** (i.e., you use each hand about 50% of the time), circle **Eq.**

1. With which hand would you use a pair of tweezers?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
2. With which hand would you use a paintbrush to paint a wall?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
3. Which hand would you use to pick up a book?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
4. With which hand would you use to eat a bowl of soup?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
5. With which hand would you use the eraser on the end of a pencil?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
6. Which hand would you use to pick up a piece of paper?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
7. Which hand would you use to draw a picture?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
8. Which hand would you use to hammer a nail?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
9. Which hand would you use to insert a plug into an electrical outlet?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
10. Which hand would you use to throw a ball?	**La**	**Lu**	**Eq**	**Ru**	**Ra**

11. In which hand would you hold a needle while sewing?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
12. In which hand would you use to turn on a light switch?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
13. Which hand do you use for writing?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
14. Which hand would you use to saw a piece of wood with a hand saw?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
15. Which hand would you use to open a drawer?	**La**	**Lu**	**Eq**	**Ru**	**Ra**

16. Is there any reason (e.g., injury) why you have changed your hand preference for any of the above activities? **YES** **NO**

17. Have you been given special training or encouragement to use a particular hand for certain activities? **YES** **NO**

18. If you have answered YES to either Questions 16 or 17, please explain.

Instructions: Please indicate your foot preference for the following activities by circling the appropriate response. If you **always** (i.e., 95% or more of the time) use one foot to perform the described activity, circle **Ra** or **La** (for **right always** or **left always**). If you **usually** (i.e., about 75% of the time) use one foot circle **Ru** or **Lu** (for **right usually** or **left usually**). If you use both feet **equally often** (i.e., you use each hand about 50% of the time), circle **Eq**. Please do not simply circle for all questions, but imagine yourself performing each activity in turn, and then mark the appropriate answer.

19. Which foot would you use to kick a stationary ball at a target straight ahead?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
20. If you had to stand on one foot, which foot would it be?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
21. Which foot would you use to smooth sand on a beach?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
22. If you had to step up onto a chair, which foot would you place on the chair first?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
23. Which foot would you use to stomp on a fast moving bug?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
24. If you were to balance on one foot on a railway track, which foot would you use?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
25. If you wanted to pick up a marble with your toes, which foot would you use?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
26. If you had to hop on one foot, which foot would you use?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
27. Which foot would you use to help push a shovel into the ground?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
28. During relaxed standing, most people have one leg fully extended for support and the other slightly bent. Which leg do you have fully extended first?	**La**	**Lu**	**Eq**	**Ru**	**Ra**

29. Is there any reason (i.e. injury) why you have changed your foot preference for any of the above activities? **YES** **NO**

30. Have you ever been given special training or encouragement to use a particular foot for certain activities? **YES** **NO**

31. If you have answered YES for either question 29 or 30, please explain:

The experimenter will complete question 32:

32. Eyedness **Left** **Right**

Waterloo Handedness and Footedness Questionnaire-Revised

(RTL)

PARTICIPANT QUESTIONNAIRE

Age: ________

Sex (circle one): **M** **F**

If you are a student, what is your major? _________________ Year of study? ____________

What was the **first** language you learned as a child? __________ What is your primary language? __________

How long have you spoken a language that reads left-to-right? __________

How long have you lived in a culture where the primary language reads left-to-right? __________

Do you have any hearing impairments? **Yes** **No**

Do you have any visual impairments (including colorblindness)? **Yes** **No**
If yes to either question, please specify:

What colour are your eyes? **Blue** **Brown** **Green** **Hazel** **Violet** **Other:_____**

What is your natural hair colour? **Blond** **Brown** **Black** **Red** **Auburn** **Other:_____**

Do you have any primary **biological** relatives (i.e., mother, father, brother, or sister) who are left-handed?
Yes **No** **Don't Know**
Do you have any **biological** extended family members (i.e., grandparents, ***biologically*** related aunts and uncles) who are left-handed? **Yes** **No** **Don't Know**

Please list any medications (including oral contraceptives) that you are currently taking:

Instructions: Please indicate your hand preference for the following activities by circling the appropriate response. If you **always** (i.e., 95% or more of the time) use one hand to perform the described activity, circle **Ra** or **La** (for **right always** or **left always**). If you **usually** (i.e., about 75% of the time) use one hand circle **Ru** or **Lu,** as appropriate. If you use both hands **equally often** (i.e., you use each hand about 50% of the time), circle **Eq.**

1. With which hand would you use a pair of tweezers?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
2. With which hand would you use a paintbrush to paint a wall?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
3. Which hand would you use to pick up a book?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
4. With which hand would you use to eat a bowl of soup?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
5. With which hand would you use the eraser on the end of a pencil?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
6. Which hand would you use to pick up a piece of paper?	**La**	**Lu**	**Eq**	**Ru**	**Ra**

7. Which hand would you use to draw a picture?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
8. Which hand would you use to hammer a nail?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
9. Which hand would you use to insert a plug into an electrical outlet?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
10. Which hand would you use to throw a ball?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
11. In which hand would you hold a needle while sewing?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
12. In which hand would you use to turn on a light switch?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
13. Which hand do you use for writing?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
14. Which hand would you use to saw a piece of wood with a hand saw?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
15. Which hand would you use to open a drawer?	**La**	**Lu**	**Eq**	**Ru**	**Ra**

16. Is there any reason (e.g., injury) why you have changed your hand preference for any of the above activities? **YES** **NO**

17. Have you been given special training or encouragement to use a particular hand for certain activities? **YES** **NO**

18. If you have answered YES to either Questions 16 or 17, please explain.

Instructions: Please indicate your foot preference for the following activities by circling the appropriate response. If you **always** (i.e., 95% or more of the time) use one foot to perform the described activity, circle **Ra** or **La** (for **right always** or **left always**). If you **usually** (i.e., about 75% of the time) use one foot circle **Ru** or **Lu** (for **right usually** or **left usually**). If you use both feet **equally often** (i.e., you use each hand about 50% of the time), circle **Eq**. Please do not simply circle for all questions, but imagine yourself performing each activity in turn, and then mark the appropriate answer.

19. Which foot would you use to kick a stationary ball at a target straight ahead?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
20. If you had to stand on one foot, which foot would it be?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
21. Which foot would you use to smooth sand on a beach?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
22. If you had to step up onto a chair, which foot would you place on the chair first?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
23. Which foot would you use to stomp on a fast moving bug?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
24. If you were to balance on one foot on a railway track, which foot would you use?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
25. If you wanted to pick up a marble with your toes, which foot would you use?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
26. If you had to hop on one foot, which foot would you use?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
27. Which foot would you use to help push a shovel into the ground?	**La**	**Lu**	**Eq**	**Ru**	**Ra**
28. During relaxed standing, most people have one leg fully extended for support and the other slightly bent. Which leg do you have fully extended first?	**La**	**Lu**	**Eq**	**Ru**	**Ra**

29. Is there any reason (i.e. injury) why you have changed your foot preference for any of the above activities? **YES** **NO**

30. Have you ever been given special training or encouragement to use a particular foot for certain activities? **YES** **NO**

31. If you have answered YES for either question 29 or 30, please explain:

The experimenter will complete question 32:

32. Eyedness **Left** **Right**

This questionnaire was adapted from Elias, Bryden, and Bulman-Fleming (1998).

APPENDIX B

Video Game Experience Questionnaire

1. On average, how much time do you spend on computers a day? (Circle your answer)
   a. Less than 30 minutes
   b. 30 – 60 minutes
   c. 1-2 hours
   d. 2-4 hours
   e. 4-8 hours
   f. More than 8 hours

2. How much time do you spend using a word processor, email, or instant messaging? (Circle your answer)
   a. None
   b. Less than 3 hours a week
   c. 3-7 hours a week
   d. 1-2 hours a day
   e. More than 2 hours a day

3. How much time do you spend playing computer, video, or console games? (Circle your answer)
   a. None
   b. Less than 3 hours a week
   c. 3-7 hours a week
   d. 1-2 hours a day
   e. More than 2 hours a day

4. How often do you play driving games? (Circle your answer)
   a. None
   b. Less than 3 hours a week
   c. 3-7 hours a week
   d. 1-2 hours a day
   e. More than 2 hours a day

5. Please list which driving games you play:

   ____

   ____

   ____

6. How much time do you spend playing games with a first-person view?
    a. None
    b. Less than 3 hours a week
    c. 3-7 hours a week
    d. 1-2 hours a day
    e. More than 2 hours a day

7. Please list which first-person games you play:

____

____

____

APPENDIX C

Consent form for Native Reading Direction Modulates Eye Movements During Aesthetic

Preference and Brightness Judgments

Project Title: The Degree to Which Images are Visually explored like Text

Researcher: AUSTEN SMITH, GRADUATE STUDENT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, austen.smith@usask.ca
Supervisor: LORIN ELIAS, DEPARTMENT OF PSYCHOLOGY, 306 966 6657, lorin.elias@usask.ca

Purpose and Objective of the Research:

- This research investigates scanning patterns of images by left-to-right and right-to-left reading individuals. Our objective is to identify differences between reading direction groups.

Procedures:

- You will be asked to view images on a computer screen while your eye movements are recorded with a non-invasive eye tracking camera, which can be turned off at your request at any time. You will have be asked to identify each image. This study will take approximately 30 minutes to complete.
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Funded by: NSERC grant awarded to Lorin Elias.

Potential Risks:

- There are no known or anticipated risks to you by participating in this research.
- Following participation in the experiment, you will be given a debriefing form describing the purpose of the study. This form will also provide you with our contact information in the event that future questions arise about your participation in the study. If you wish to know more about the results of this study we welcome you to provide your contact information and we will contact you once the study is complete and results obtained.

Potential Benefits:

- This study is designed to have scientific benefit in further understanding visual perception, and although not designed to provide personal benefit to the participant, results from this study may aid in understanding the relationship between visual perception and reading direction. Your participation in this study may also provide you with a greater understanding of how the research process works.

Compensation: Right-to-left readers will be compensated ten dollars for participation. Left-to-right readers will be compensated 1 study credit from the Psychology Participant Pool.

Confidentiality:

- Participant anonymity is limited as the researcher is also the experimenter. However, participant confidentiality will be protected – no link will be made between the collected information and the participant's identity. Only the researcher and supervisor will have access to information.

Storage of Data:

- The data obtained in this study will be stored separate from the consent forms, with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the University of Saskatchewan for a minimum of five years following the completion of the study. If the data is no longer needed, it will be destroyed beyond recovery.

Right to Withdraw:

- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.

- Should you wish to withdraw any data that you have contributed will be destroyed beyond recovery. Your right to withdraw data from the study will apply until results have been disseminated. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up: To obtain results from the study, please contact the researcher, Austen Smith at austen.smith@usask.ca

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent: Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

______________________	______________________	____________
Name of Participant	*Signature*	*Date*

______________________	______________________
Researcher's Signature	*Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX D

Debrief form for Native Reading Direction Modulates Eye Movements During Aesthetic Preference and Brightness Judgments

The human visual system is lateralized in such a way that information entering through the left visual field is primarily processed in the right hemisphere of the brain, and right visual field information is handled mostly by the left hemisphere of the brain. These ‘cross-overs’ between side of brain and side of body are quite common and are found in many instances, including hearing and handedness. When a function or perception is processed by the opposite half of the brain (right hand – left hemisphere, for example) it is said to be *contralateral*. Each of the hemispheres of the brain has different responsibilities (as well as some shared ones), which often leads to asymmetries in human function and perception.

It is believed that we look at images in a similar manner to reading text. For those whose native language is read in a left-to-right direction, scanning patterns of images roughly follow a ‘Z’ shape, starting in the upper left moving across to the upper right, cutting down to the bottom left, and then over to the bottom right. The aim of the study you just participated in is to determine if in fact these assumptions are true, as there is currently no empirical research to support these claims. Additionally, we are interested to see if individuals whose native language is read from right-to-left explore images the same or different way as left-to-right readers. A right-to-left reader’s scan patterns may mirror those of a left-to-right reader, or they may follow an ‘S’ shape, similar to the direction text is read (starting in the top right corner, moving across to the left, and then down to the bottom right, and over left again).

Most research examining perceptual asymmetries and aesthetics has been carried out with people whose native language reads left-to-right. In trying to understand the reasons for perceptual asymmetries, it is important for us to find out if asymmetrical attention or preferences result from native reading direction, which influences scanning patterns.

We would appreciate it if you do not tell your friends about the rationale/methodology of the study as they may also participate. Although knowing this information and/or our hypothesis will not likely alter visual scans or answers a participant may make, the most accurate results are obtained when a participant carries out the task without thinking about where they are looking.

Once again, thank you so much for being a part of your study. It is participants like you that allow us, as researchers, to investigate the interesting and complex workings of our brain. It is our hope that your participation will not only help to advance our research, but also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Austen Smith at austen.smith@usask.ca, 306-966-6699 or Dr. Lorin Elias at lorin.elias@usask.ca, 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.

APPENDIX E

Consent form for Is there an Artistry to Lighting? The Complexity of Illuminating Three-dimensional Artworks

Project Title: The Influence of Lighting Bias in Sculptural Art

Researcher: JENNIFER SEDGEWICK, GRADUATE STUDENT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, jrs908@mail.usask.ca
AUSTEN SMITH, GRADUATE STUDENT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, austen.smith@usask.ca
Supervisor: LORIN ELIAS, DEPARTMENT OF PSYCHOLOGY, 306 966 6670, lorin.elias@usask.ca

Purpose and Objective of the Research:

- This research investigates if brain hemisphere differences influence how people place a light source within the context of a 3-dimentional art form.

Procedures:

- You will be asked to complete a computer task that will simulate traveling through an art gallery from a first-person perspective. Each gallery will have one sculpture, you will be asked to illuminate the sculpture in a way you find the most appealing. This study will take less than 30 minutes to complete. You will also be asked to complete a grayscales task where you will be asked to choose which rectangle out of two you find to be darker, and a handedness/footedness question that will contain questions such as “If you were to kick a ball, which foot would you use?”
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Funded by: NSERC grant awarded to Lorin Elias.

Potential Risks:

- There are no known or anticipated risks to you by participating in this research.
- Following participation in the experiment, you will be given a debriefing form describing the purpose of the study. This form will also provide you with our contact information in the event that future questions arise about your participation in the study. If you wish to know more about the results of this study we welcome you to provide your contact information and we will contact you once the study is complete and results obtained.

Potential Benefits:

- This study is designed to have scientific benefit in further understanding visual perception, and although not designed to provide personal benefit to the participant, results from this study may aid in understanding the relationship between visual perception and reading direction. Your participation in this study may also provide you with a greater understanding of how the research process works.

Compensation: Right-to-left readers will be compensated ten dollars for participation. Left-to-right readers will be compensated 1 study credit from the Psychology Participant Pool.

Confidentiality:

- Participant anonymity is limited as the researchers are also the experimenters. However, participant confidentiality will be protected – no link will be made between the collected information and the participant’s identity. Only the researcher and supervisor will have access to information.

Storage of Data:

- The data obtained in this study will be stored separate from the consent forms, with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the

University of Saskatchewan for a minimum of five years following the completion of the study. If the data is no longer needed, it will be destroyed beyond recovery.

Right to Withdraw:

- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Should you wish to withdraw any data that you have contributed will be destroyed beyond recovery. Your right to withdraw data from the study will apply until results have been disseminated. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up: To obtain results from the study, please contact the researchers, Austen Smith or Jennifer Sedgewick at austen.smith@usask.ca or jrs908@mail.usask.ca

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent: Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

________________________ ________________________ ______________

Name of Participant *Signature* *Date*

________________________ __________________

Researcher's Signature *Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX F

Debriefing form for Is there an Artistry to Lighting? The Complexity of Illuminating Three-dimensional Artworks

Thank you very much for participating in this study. The data collected during your participation will help us investigate if individuals place a light source from above and to the left side more often than any other orientation on sculptures.

It is expected that individuals are more likely to place the light source overhead based on previous findings that light is perceived to come from above. This perception is thought to occur due to the expectation that the earth's universal light source, the sun, is consistently overhead. In addition to light from above, lighting was also expected to be chosen more often on the left side than from the right due to findings that suggest that there may be an innate preference for light to come from the left. Sun and Perona (1998) analyzed the lighting direction of master-status paintings from numerous artistic styles and time periods and found that the light source came from the left 77% of the time. Leftward lighting biases have been similarly evidenced among photographs, advertisements, and abstract paintings. What could be producing this left-lighting bias has been theorized to be due to a phenomenon known as pseudoneglect.

Pseudoneglect is the tendency for neuro-typical (no known brain damage) individuals to attend more to the left side of space compared to the right side of space. This means that on average, an individual naturally pays more attention to the left side of space without being consciously aware of where his or her attention is situated. Pseudoneglect is thought to be governed by the activation-orientation hypothesis which states that the visual field opposite to the more activated brain hemisphere will receive the most attention (Bultitude & Davies, 2006). This study is investigating if pseudoneglect could play a role in an individual's lighting placement. More specifically, this research aimed to investigate if lighting in sculpture had a leftwards lighting bias, possibly due to pseudoneglect. The effect that one's native reading direction may have on pseudoneglect is debated. Some studies have found that reading and writing a language in a right-to-left direction rather than left-to-right leads to weaker or reversed pseudoneglect effects (Fagard & Dahmen, 2003).

We would appreciate it if you do not tell your friends about the rationale/methodology of the study as they may also participate. Although knowing this information and/or our hypothesis will not likely alter visual scans or answers a participant may make, the most accurate results are obtained when a participant carries out the task without thinking about where they are looking.

Once again, thank you so much for being a part of your study. It is participants like you that allow us, as researchers, to investigate the interesting and complex workings of our brain. It is our hope that your participation will not only help to advance our research, but also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Austen Smith, austen.smith@usask.ca, Jennifer Sedgewick, jrs908@mail.usask.ca, at 306-966-6699 or Dr. Lorin Elias at lorin.elias@usask.ca, 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.

Bultitude, J. & Davies, A. (2006). Putting attention on the line: Investigating the activation-orientation hypothesis of pseudoneglect. *Neuropsychologia. 44,* 1849-1858.
Fagard, J. & Dahmen, R. (2003) The effects of reading-writing direction on the asymmetry of space perception and directional tendencies: A comparison between French and Tunisian children. *Laterality, 8(1),* 39-52.
Sun, J., & Perona, P. (1998). Where is the sun? *Nature Neuroscience, 1*(3), 183184.

APPENDIX G

Consent form for Lateral Biases in Aesthetic and Spatial Location Judgments: Differences

Between Tasks and Native Reading Directions – Artwork Lighting Task

Project Title: The Influence of Native Reading Direction on Lateral Biases in Lighting of Art

Researcher: AUSTEN SMITH, GRADUATE STUDENT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, austen.smith@usask.ca
Supervisor: LORIN ELIAS, DEPARTMENT OF PSYCHOLOGY, 306 966 6657, lorin.elias@usask.ca

Purpose and Objective of the Research:

- This research investigates aesthetic preferences and lighting of artwork. Our objective is to observe differences between native right-to-left and left-to-right readers' placement of a light source while viewing artwork.

Procedures:

- You will be asked to view images of artwork on a computer screen while your eye movements are recorded with a non-invasive eye tracking camera, which can be turned off at your request at any time. You will have control over the lighting of the image by moving the computer mouse. You will be asked to illuminate each image either in a way that is most aesthetically pleasing to you or in a way that the image will evoke positive or negative emotions from hypothetical future viewers. Once you have positioned the light in the desired location, right-clicking the computer mouse will confirm your selection. This study will take approximately 30 minutes to complete.
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Funded by: NSERC grant awarded to Lorin Elias.

Potential Risks:

- There are no known or anticipated risks to you by participating in this research.
- Following participation in the experiment, you will be given a debriefing form describing the purpose of the study. This form will also provide you with our contact information in the event that future questions arise about your participation in the study. If you wish to know more about the results of this study we welcome you to provide your contact information and we will contact you once the study is complete and results obtained.

Potential Benefits:

- This study is designed to have scientific benefit in further understanding visual perception, and although not designed to provide personal benefit to the participant, results from this study may aid in understanding the relationship between visual perception and reading direction. Your participation in this study may also provide you with a greater understanding of how the research process works.

Compensation: As compensation for your participation you will be granted ten dollars or 1 study credit (participant pool).

Confidentiality:

- Participant anonymity is limited as the researcher is also the experimenter. However, participant confidentiality will be protected – no link will be made between the collected information and the participant's identity. Only the researcher and supervisor will have access to information.

Storage of Data:

- The data obtained in this study will be stored separate from the consent forms, with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the University of Saskatchewan for a minimum of five years following the completion of the study. If the data is no longer needed, it will be destroyed beyond recovery.

Right to Withdraw:

- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort (no loss of SONA study credits).
- Should you wish to withdraw any data that you have contributed will be destroyed beyond recovery. Your right to withdraw data from the study will apply until results have been disseminated. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up: To obtain results from the study, please contact the researcher, Austen Smith at austen.smith@usask.ca

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board (BEH 13-412). Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent: Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

______________________	______________________	____________
Name of Participant	*Signature*	*Date*

______________________ ______________

Researcher's Signature *Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX H

Debrief form for Lateral Biases in Aesthetic and Spatial Location Judgments: Differences Between Tasks and Native Reading Directions – Artwork Lighting Task

The human visual system is lateralized in such a way that information entering through the left visual field is primarily processed in the right hemisphere of the brain, and right visual field information is handled mostly by the left hemisphere of the brain. These ‘cross-overs’ between side of brain and side of body are quite common and are found in many instances, including hearing and handedness. When a function or perception is processed by the opposite half of the brain (right hand – left hemisphere, for example) it is said to be *contralateral*. Each of the hemispheres of the brain has different responsibilities (as well as some shared ones), which often leads to asymmetries in human function and perception.

It is believed that we look at images in a similar manner to reading text. For those whose native language is read in a left-to-right direction, scanning patterns of images roughly follow a ‘Z’ shape, starting in the upper left moving across to the upper right, cutting down to the bottom left, and then over to the bottom right. One of the aims of the study you just participated in is to determine if individuals whose native language is read from right-to-left explore images the same way. A right-to-left reader’s scan patterns may mirror those of a left-to-right reader, or they may follow an ‘S’ shape, similar to the direction text is read (starting in the top right corner, moving across to the left, and then down to the bottom right, and over left again).

Understanding any differences that exist between left-to-right readers and right-to-left readers may help our endeavors to make sense of the *Leftward Lighting Bias*. Intuitively, one might think that an overhead light source originating from directly above is preferred when examining images, perhaps because of living on a planet with one, consistent, overhead light source – the sun. This assumption is, in fact, mistaken. Research has found that a leftward light source is actually preferred and this has been termed the *leftward lighting bias*. Various laboratory tasks using ambiguously lit images, such as shaded circles and texture patches, as well as more complex images like magazine advertisements have replicated the *leftward lighting bias*.

Most of the research finding a *leftward lighting bias* has been carried out with people whose native language reads left-to-right. In trying to understand the reasons for the *leftward lighting bias*, it is important for us to find out if it occurs only in certain populations or across all individuals. If the *leftward lighting bias* disappears or is not as pronounced in individuals who read right-to-left, conclusions about how the brain handles visual information will have to be adjusted accordingly.

We would appreciate it if you do not tell your friends about the rationale/methodology of the study as they may also participate. Although knowing this information and/or our hypothesis will not likely alter visual scans or answers a participant may make, the most accurate results are obtained when a participant carries out the task without thinking about where they are looking.

Once again, thank you so much for being a part of your study. It is participants like you that allow us, as researchers, to investigate the interesting and complex workings of our brain. It is our hope that your participation will not only help to advance our research, but also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Austen Smith at austen.smith@usask.ca, 306-966-6699 or Dr. Lorin Elias at lorin.elias@usask.ca, 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.

APPENDIX I

Consent form for Lateral Biases in Aesthetic and Spatial Location Judgments: Differences Between Tasks and Native Reading Directions – Spatial Location Task

Project Title: Spatial Asymmetries in Navigation Using Virtual Mapping

Researcher: AUSTEN SMITH, GRADUATE STUDENT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, austen.smith@usask.ca
Supervisor: LORIN ELIAS, DEPARTMENT OF PSYCHOLOGY, 306 966 6670, lorin.elias@usask.ca

Purpose and Objective of the Research:

- This research investigates if spatial asymmetries influence an individual's ability to accurately pinpoint desired locations.

Procedures:

- You will be asked to complete a computer task that will simulate using a virtual map. You will be asked to identify locations on the map using varying sizes of half circles as proportional representations of distance. This study will take approximately 30 minutes to complete. You will also be asked to complete a handedness/footedness question that will contain questions such as "If you were to kick a ball, which foot would you use?"
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Funded by: NSERC grant awarded to Lorin Elias.

Potential Risks:

- There are no known or anticipated risks to you by participating in this research**.**
- Following participation in the experiment, you will be given a debriefing form describing the purpose of the study. This form will also provide you with our contact information in the event that future questions arise about your participation in the study. If you wish to know more about the results of this study we welcome you to provide your contact information and we will contact you once the study is complete and results obtained.

Potential Benefits:

- This study is designed to have scientific benefit in further understanding visual perception, and although not designed to provide personal benefit to the participant, results from this study may aid in understanding visual perception and spatial asymmetries. Your participation in this study may also provide you with a greater understanding of how the research process works.

Compensation: You will be compensated 1 study credit from the Psychology Participant Pool.

Confidentiality:

- Participant anonymity is limited as the researchers are also the experimenters. However, participant confidentiality will be protected – no link will be made between the collected information and the participant's identity. Only the researcher and supervisor will have access to information.

Storage of Data:

- The data obtained in this study will be stored separate from the consent forms, with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the University of Saskatchewan for a minimum of five years following the completion of the study. If the data is no longer needed, it will be destroyed beyond recovery.

Right to Withdraw:

- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.

- Should you wish to withdraw any data that you have contributed will be destroyed beyond recovery. Your right to withdraw data from the study will apply until results have been disseminated. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up: To obtain results from the study, please contact the researchers, Austen Smith at austen.smith@usask.ca

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent: Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

______________________	______________________	______________
Name of Participant	*Signature*	*Date*

______________________	______________________
Researcher's Signature	*Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX J

Debrief form for Lateral Biases in Aesthetic and Spatial Location Judgments: Differences Between Tasks and Native Reading Directions – Spatial Location Task

Thank you very much for participating in this study.

The human visual system is lateralized in such a way that information entering through the left visual field is processed primarily in the right hemisphere of the brain and right visual field information is mostly handled in the left hemisphere. These 'cross-overs' between halves of the brain and sides of the body are quite common with other examples being hearing and handedness. Each of the hemispheres of the brain has different responsibilities (as well as some shared ones), which often leads to asymmetries in human function and perception.

The tendency for neuro-typical (no known brain damage) individuals to attend more to the left side of space compared to the right side of space has been labeled pseudoneglect. The *pseudo* prefix is used so as to foil the phenomenon to the clinical condition of neglect, which is the disregard for leftward space often seen in unilateral brain damage to the right hemisphere. In pseudoneglect, on average, an individual naturally pays more attention to the left side of space without being consciously aware of where his or her attention is situated.

In the experiment you just finished participating in we are investigating the possible influence that pseudoneglect may have on an individual's ability to accurately determine distances to target locations. The sections of circles on the maps were chosen as an aide, instead of straight lines, because research has found that neuro-typical individuals will not make accurate assessments of line length. In a line bisection task where individuals are instructed to place a mark in the exact centre of a line they will often overestimate the left side of space – consistent with pseudoneglect – placing the mark to the left of true centre. We are interested to see if by using half circles as indicators of a target individuals are more accurate in estimating the location of the target.

We would appreciate it if you do not tell your friends about the rationale/methodology of the study as they may also participate. Although knowing this information and/or our hypothesis will not likely alter answers a participant may make, the most accurate results are obtained when a participant carries out the task without over-thinking what they are doing.

Once again, thank you so much for being a part of your study. It is participants like you that allow us, as researchers, to investigate the interesting and complex workings of our brain. It is our hope that your participation will not only help to advance our research, but also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Austen Smith, austen.smith@usask.ca or Dr. Lorin Elias at lorin.elias@usask.ca, 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.

APPENDIX K

Consent form for Leftward Spatial Biases during Naturalistic and Simulated Driving: Does Pseudoneglect Influence Performance? – Driving Simulation

Project Title: Spatial Asymmetries in Navigation in a Virtual Driving Environment

Researchers: AUSTEN SMITH, GRADUATE STUDENT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, austen.smith@usask.ca
TRISTA FRIEDRICH, GRADUATE STUDENT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, trista.friedrich@usask.ca
MEGAN FLATH, RESEARCH ASSISTANT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, mef029@mail.usask.ca
JEREMY STORRING, RESEARCH ASSISTANT, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF SASKATCHEWAN, 306 966 6699, jns855@mail.usask.ca
Supervisor: LORIN ELIAS, DEPARTMENT OF PSYCHOLOGY, 306 966 6670, lorin.elias@usask.ca

Purpose and Objective of the Research:

- This research investigates if spatial asymmetries influence different aspects of an individual's ability to (virtually) drive a motor vehicle.

Procedures:

- You will be asked to complete a series of tasks that will simulate driving a motor vehicle. You will be asked to navigate a motor vehicle through varied real world scenarios that include braking for objects, making turns and driving in high and low traffic situations. This study will take approximately 30 minutes to complete. You will also be asked to complete a handedness/footedness questionnaire that will contain questions such as "If you were to kick a ball, which foot would you use?" and a video game experience questionnaire comprised of questions like "On average, how much time do you spend on computers a day?"
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Funded by: NSERC grant awarded to Lorin Elias.

Potential Risks:

- There are no known or anticipated risks to you by participating in this research**.**
- Following participation in the experiment, you will be given a debriefing form describing the purpose of the study. This form will also provide you with our contact information in the event that future questions arise about your participation in the study. If you wish to know more about the results of this study we welcome you to provide your contact information and we will contact you once the study is complete and results obtained.

Potential Benefits:

- This study is designed to have scientific benefit in further understanding visual perception, and although not designed to provide personal benefit to the participant, results from this study may aid in understanding visual perception and spatial asymmetries. Your participation in this study may also provide you with a greater understanding of how the research process works.

Compensation: You will be compensated 1 study credit from the Psychology Participant Pool. If you have been recruited through a method outside of the participant pool you will be compensated $10.

Confidentiality:

- Participant anonymity is limited as the researchers are also the experimenters. However, participant confidentiality will be protected – no link will be made between the collected information and the participant's identity. Only the researcher and supervisor will have access to information.

Storage of Data:

- The data obtained in this study will be stored separate from the consent forms, with no possibility of identification. All data and consent forms will be securely stored by Dr. Lorin Elias at the University of Saskatchewan for a minimum of five years following the completion of the study. If the data is no longer needed, it will be destroyed beyond recovery.

Right to Withdraw:

- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Should you wish to withdraw any data that you have contributed will be destroyed beyond recovery. Your right to withdraw data from the study will apply until results have been disseminated. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up: To obtain results from the study, please contact the researchers, Lorin Elias at lorin.elias@usask.ca; Austen Smith at austen.smith@usask.ca; Trista Friedrich at trista.friedrich@usask.ca.

Questions or Concerns:

- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent: Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

______________________________	______________________________	________________
Name of Participant	*Signature*	*Date*

______________________________ ______________________

Researcher's Signature *Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

APPENDIX L

Debriefing form for Leftward Spatial Biases during Naturalistic and Simulated Driving: Does Pseudoneglect Influence Performance? – Driving Simulation

Thank you very much for participating in this study.

The human visual system is lateralized in such a way that information entering through the left visual field is processed primarily in the right hemisphere of the brain and right visual field information is mostly handled in the left hemisphere. These 'cross-overs' between halves of the brain and sides of the body are quite common with other examples being hearing and handedness. Each of the hemispheres of the brain has different responsibilities (as well as many shared ones), which often leads to asymmetries in human function and perception.

The tendency for neuro-typical (no known brain damage) individuals to attend more to the left side of space compared to the right side of space has been labeled pseudoneglect. The *pseudo* prefix is used so as to foil the phenomenon to the clinical condition of neglect, which is the disregard for leftward space often seen in unilateral brain damage to the right hemisphere. In pseudoneglect, on average, an individual naturally pays more attention to the left side of space without being consciously aware of where his or her attention is situated.

Past research has found spatial misperceptions among humans navigating electric wheelchairs and scooters consistent with pseudoneglect, as right side collisions occurred most often. In the experiment you just finished participating in we are investigating the possible influence that pseudoneglect may have on an individual's ability to navigate an automobile. The situations you were presented with help us further understand differences in ability to recognize and react to objects appearing from the left and right. As well, we will gain a better understanding of individuals' spatial abilities when driving in different traffic volumes and when turning in front of on-coming traffic from the left and right.

We would appreciate it if you do not tell your friends about the rationale/methodology of the study as they may also participate. Although knowing this information and/or our hypothesis will not likely alter answers a participant may make, the most accurate results are obtained when a participant carries out the task without over-thinking what they are doing.

Once again, thank you so much for being a part of your study. It is participants like you that allow us, as researchers, to investigate the interesting and complex workings of our brain. It is our hope that your participation will not only help to advance our research, but also help you to better understand how the research process works. If you have any additional questions or concerns about your participation, you may contact Austen Smith, austen.smith@usask.ca or Dr. Lorin Elias at lorin.elias@usask.ca, 306-966-6670. If you would like to contact the Research Ethics Office, you may do so by calling 306-966-2084.

APPENDIX M

Ethics approval for Native Reading Direction Modulates Eye Movements During Aesthetic Preference and Brightness Judgments

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics

Certificate of Approval

PRINCIPAL INVESTIGATOR
Lorin J. Elias

DEPARTMENT
Psychology

BEH#
14-49

INSTITUTION(S) WHERE RESEARCH WILL BE CONDUCTED
University of Saskatchewan

STUDENT RESEARCHER(S)
Austen Smith

FUNDER(S)
NATURAL SCIENCES & ENGINEERING RESEARCH COUNCIL OF CANADA (NSERC)

TITLE
The Degree to Which Images are Visually Explored like Text

ORIGINAL REVIEW DATE	APPROVAL ON	APPROVAL OF:	EXPIRY DATE
20-Feb-2014	20-Feb-2014	APPLICATION FOR BEHAVIORAL RESEARCH ETHICS REVIEW RECRUITMENT EMAIL RECRUITMENT POSTER PARTICIPANT CONSENT FORM PARTICIPANT QUESTIONNAIRE DEBRIEFING FORM	19-Feb-2015

Full Board Meeting ☐ Delegated Review ☒

CERTIFICATION

The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair for Research Ethics Board consideration in advance of its implementation.

ONGOING REVIEW REQUIREMENTS

In order to receive annual renewal, a status report must be submitted to the REB Chair for Board consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions: http://www.usask.ca/research/ethics_review/

Beth Bilson, Chair
University of Saskatchewan
Behavioural Research Ethics Board

Please send all correspondence to:

Research Ethics Office
University of Saskatchewan
Box 5000 RPO University, 1602-110 Gymnasium Place
Saskatoon SK S7N 4J8
Telephone: (306) 966-2975 Fax: (306) 966-2069

APPENDIX N

Ethics approval for Is there an Artistry to Lighting? The Complexity of Illuminating Three-dimensional Artworks

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics

Certificate of Approval

PRINCIPAL INVESTIGATOR
Lorin J. Elias

DEPARTMENT
Psychology

BEH#
15-31

INSTITUTION(S) WHERE RESEARCH WILL BE CONDUCTED
University of Saskatchewan
4101 Dewdney Ave
S4T 7T1

STUDENT RESEARCHER(S)
Austen Smith

FUNDER(S)
NATURAL SCIENCES & ENGINEERING RESEARCH COUNCIL OF CANADA (NSERC)

TITLE:
The Influence of Lighting Bias in Sculptural Art

ORIGINAL REVIEW DATE	APPROVAL ON	APPROVAL OF:	EXPIRY DATE
06-Feb-2015	02-Mar-2015	Application for Behavioural Research Ethics Review Recruitment Poster and Advertising Posting Participant Consent Form Questionnaire Participant Debriefing Form	01-Mar-2016

Full Board Meeting ☐ Delegated Review ☒

CERTIFICATION

The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

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Vivian Ramsden, Chair
University of Saskatchewan
Behavioural Research Ethics Board

Please send all correspondence to:

Research Ethics Office
University of Saskatchewan
Box 5000 RPO University, 1602-110 Gymnasium Place
Saskatoon SK S7N 4J8
Telephone: (306) 966-2975 Fax: (306) 966-2069

APPENDIX O

Ethics approval for Lateral Biases in Aesthetic and Spatial Location Judgments: Differences Between Tasks and Native Reading Directions – Spatial Location Task

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	BEH#
Lorin J. Elias	Psychology	15-33

INSTITUTION(S) WHERE RESEARCH WILL BE CONDUCTED
University of Saskatchewan

SUB-INVESTIGATOR(S)
Carl Gutwin

STUDENT RESEARCHER(S)
Austen Smith

FUNDER(S)
NATURAL SCIENCES & ENGINEERING RESEARCH COUNCIL OF CANADA (NSERC)

TITLE
Spatial Asymmetries in Navigation Using Virtual Mapping

ORIGINAL REVIEW DATE	APPROVAL ON	APPROVAL OF:	EXPIRY DATE
06-Feb-2015	02-Mar-2015	Application for Behavioural Research Ethics Review Recruitment Advertisement Participant Consent Form Questionnaire Participant Debriefing Form	01-Mar-2016

Full Board Meeting ☐ Delegated Review ☒

CERTIFICATION
The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

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ONGOING REVIEW REQUIREMENTS
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Vivian Ramsden, Chair
University of Saskatchewan
Behavioural Research Ethics Board

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Research Ethics Office
University of Saskatchewan
Box 5000 RPO University, 1602-110 Gymnasium Place
Saskatoon SK S7N 4J8
Telephone: (306) 966-2975 Fax: (306) 966-2069

APPENDIX P

Ethics approval for Lateral Biases in Aesthetic and Spatial Location Judgments: Differences Between Tasks and Native Reading Directions – Artwork Lighting Task

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics

Certificate of Approval

PRINCIPAL INVESTIGATOR
Lorin J. Elias

DEPARTMENT
Psychology

BEH#
13-412

INSTITUTION(S) WHERE RESEARCH WILL BE CONDUCTED
University of Saskatchewan

STUDENT RESEARCHER(S)
Austen Smith

FUNDER(S)
NATURAL SCIENCES & ENGINEERING RESEARCH COUNCIL OF CANADA (NSERC)

TITLE
The Influence of Native Reading Direction on Lateral Biases in Lighting of Abstract Art

ORIGINAL REVIEW DATE	APPROVAL ON	APPROVAL OF:	EXPIRY DATE
20-Dec-2013	20-Dec-2013	Application for Behavioural Research Ethics Review Recruitment Poster Participant Consent Form Debriefing Form Participant Questionnaire	19-Dec-2014

Full Board Meeting ☐ Delegated Review ☒

CERTIFICATION

The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

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Beth Bilson, Chair
University of Saskatchewan
Behavioural Research Ethics Board

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APPENDIX Q

Ethics approval for Leftward Spatial Biases during Naturalistic and Simulated Driving: Does Pseudoneglect Influence Performance? – Driving Simulation

UNIVERSITY OF SASKATCHEWAN

Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	BEH#
Lorin J. Elias	Psychology	15-32

INSTITUTION(S) WHERE RESEARCH WILL BE CONDUCTED
University of Saskatchewan

SUB-INVESTIGATOR(S)
Carl Gutwin

STUDENT RESEARCHER(S)
Austen Smith

FUNDER(S)
NATURAL SCIENCES & ENGINEERING RESEARCH COUNCIL OF CANADA (NSERC)

TITLE
Spatial Asymmetries in Navigation in a Virtual Driving Environment

ORIGINAL REVIEW DATE	APPROVAL ON	APPROVAL OF:	EXPIRY DATE
06-Feb-2015	02-Mar-2015	Application for Behavioural Human Research Ethics Approval Recruitment Poster and Advertising Posting Participant Consent Form Questionnaire Participant Debriefing Form	01-Mar-2016

Full Board Meeting ☐ Delegated Review ☒

CERTIFICATION
The University of Saskatchewan Behavioural Research Ethics Board has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to the conditions outlined in the original protocol submitted for ethics review. This Certificate of Approval is valid for the above time period provided there is no change in experimental protocol or consent process or documents.

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Vivian Ramsden, Chair
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