THAT’S JUST YOUR POINT OF VIEW:
HOW VISUOSPATIAL BIASES AND FUNCTIONAL LATERALIZATION
INFLUENCE THE WAY WE PERCEIVE THE WORLD

A Thesis
Submitted to the Faculty of Graduate Studies and Research
In Partial Fulfillment of the Requirements
For the Degree of

Doctor of Philosophy
in
Experimental and Applied
Psychology
University of Regina

By

Bianca Dominique Marie Hatin
Regina, Saskatchewan
July, 2017

© 2017: B.D.M. Hatin
Bianca Dominique Marie Hatin, candidate for the degree of Doctor of Philosophy in Experimental and Applied Psychology, has presented a thesis titled, *That's just your point of view: How visuospatial biases and functional lateralization influence the way we perceive the world*, in an oral examination held on June 16, 2017. The following committee members have found the thesis acceptable in form and content, and that the candidate demonstrated satisfactory knowledge of the subject material.

External Examiner: Dr. Lorin Elias, University of Saskatchewan

Supervisor: Dr. Laurie Sykes Tottenham, Department of Psychology

Committee Member: Dr. Christopher Oriet, Department of Psychology

Committee Member: *Dr. Katherine Robinson, Department of Psychology

Committee Member: Prof. Leesa Streifler, Department of Visual Arts

Chair of Defense: Dr. Twyla Salm, Faculty of Education

*Not present at defense*
Abstract

How can individual differences in visuospatial attention and other lateralized functions affect the perception of one’s environment? This research question was examined through the four studies which comprise this dissertation. Studies 1 and 2 examined how visuospatial biases (and other lateralized attributes) influence the perception of paintings, Study 3 examined how these factors influence how paintings are created, and Study 4 examined how visuospatial biases themselves can be influenced by the perception and processing of other lateralized attributes. For all studies, biases in visuospatial attention were measured using the line bisection task.

In Study 1, participants rated asymmetrical paintings on evocative impact, aesthetics, technique, novelty, and closure. These ratings were made for paintings in their original orientation, as well as in a mirror-reversed orientation. Leftward bisectors tended to give higher ratings to paintings when they were non-mirrored, whereas rightward bisectors more often gave higher ratings to paintings when they were mirrored. These results suggest that line bisection performance reflects individual differences in visuospatial attention, which in turn affects perception of asymmetrical paintings. However, because most of the attributes examined in Study 1 are typically associated with right hemisphere processing (as is visuospatial attention), individual differences in laterality underlying the processing of the attributes may have also impacted the results. Thus, in Study 2 the influence of visuospatial attention on painting perception was further explored using attributes typically associated with left hemisphere processing (logic, positive valence) and other attributes typically associated with right hemisphere processing and/or
leftward asymmetries in art (negative valence, brightness), in addition to re-examining the attributes from Study 1 using a new forced-choice methodology. Results showed that leftward bisectors more often selected non-mirrored paintings as more emotionally evocative, logical, bright, and positively valenced, whereas rightward bisectors tended to select the mirrored paintings for emotional evocation and technique. The results for left bisectors suggest hemispheric processing of lateralized attributes affects painting preferences over visuospatial biases alone. Together, the results of Studies 1 and 2 also suggest that there are particular asymmetries within the paintings. As such, Study 3 examined whether the attributes from Studies 1 and 2 were arranged within the left or right halves of paintings in a manner consistent with the hemispheric asymmetries typically underlying the processing of these attributes. Results suggest that the right half of asymmetrical paintings conveyed better technique, more logic, and more negative valence, whereas the left half was brighter and more positively valenced. Finally, in order to examine the influence of attribute processing on visuospatial biases, the line bisection task itself was manipulated in Study 4, with different line types (face, word, solid), and emotional valences (positive, negative, neutral). Leftward bisections were generally observed, but line type and valence affected the strength of these biases. The extent of the bias decreased for lines embedded with faces, and increased for lines embedded with words. Overall, the studies in this dissertation showed how individual differences in visuospatial attention work with other aspects of lateralized processing in order to influence the way we perceive and process information in our environments.
Acknowledgements

The completion of this dissertation would not have been possible without the support I was fortunate to receive throughout this journey. First and foremost, I would like to thank my supervisor, Dr. Laurie Sykes Tottenham, for her endless encouragement and positivity every step of the way. I am always inspired by her passion, curiosity, insight, and precision! I am also thankful for the support and guidance of my committee members, Dr. Chris Oriet, Dr. Katherine Robinson, and Leesa Streifler, along with Dr. Dennis Alfano and members of C5. I sincerely thank all of the participants who donated their time and energy to the studies in this dissertation, and the research assistants who helped me input data and measure thousands of lines: Brendan Demyen, Denis Gavigan, Tyler Meadows, Jaime Oakenfold, and Miranda Reid. I would also like to extend my gratitude to Dr. Vianne Timmons for her encouragement to take time away from work to complete my dissertation. Finally, I would like to acknowledge the funding support I received from the Natural Sciences and Engineering Research Council of Canada (NSERC), the Government of Saskatchewan, and the University of Regina. It truly takes a village to raise an academic!
Post Defense Acknowledgement

I would like to extend a sincere thank you to my external examiner, Dr. Lorin Elias, for his challenging yet fair questions at my oral defense. His comments were delightfully thought provoking, and I appreciate the time that he took to attend in person.
Dedication

This dissertation is dedicated to Kalen Christensen, whose patience and support has kept me going through many long days and nights. Your delicious cooking has filled my belly with joy, your incredible mind has sharpened my critical thinking, and your compassion awakens my love for life, the universe, and everything. Thank you.

_The most exciting phrase to hear in science, the one that heralds new discoveries, is not 'Eureka!' (I've found it!), but 'That's funny...’_ - Isaac Asimov
Table of Contents

Abstract ................................................................................................................................. i
Acknowledgements .............................................................................................................. iii
Post Defense Acknowledgement ........................................................................................ iv
Dedication .............................................................................................................................. v
Table of Contents ............................................................................................................... vi
List of Tables ......................................................................................................................... xi
List of Figures ...................................................................................................................... xiii
List of Appendices .............................................................................................................. xv
List of Abbreviations ........................................................................................................... xvi

CHAPTER 1
1. General Introduction ....................................................................................................... 1
   1.1. Visuospatial Attention ............................................................................................... 4
       1.1.1. Neural correlates of visuospatial attention ......................................................... 4
       1.1.2. Line bisection as a measure of visuospatial attention ....................................... 6
   1.2. Emotion Processing ................................................................................................. 9
       1.2.1. Right hemisphere hypothesis ............................................................................. 9
       1.2.2. Valence hypothesis ........................................................................................... 12
   1.3. Line Bisection Performance and Emotion Processing ........................................... 14
   1.4. Overview .................................................................................................................. 17

CHAPTER 2
2. The Relationship Between Line Bisection Performance and Emotion Processing: Where Do You Draw the Line? (Study 1) ...................................................... 18
   2.1. Relationship Between Line Bisection Performance and Emotion Processing .......... 18
   2.2. An Alternative Approach: The Importance of Visuospatial Biases ...................... 22
       2.2.1. Line bisection accuracy or line bisection bias? .................................................. 22
       2.2.2. Artwork asymmetries ......................................................................................... 22
       2.2.3. Ascending versus descending scale direction ..................................................... 24
       2.2.4. Present Study .................................................................................................... 25
   2.3. Method ...................................................................................................................... 25
       2.3.1. Participants ......................................................................................................... 25
       2.3.2. Painting judgement task .................................................................................... 26
       2.3.3. Line bisection ..................................................................................................... 27
       2.3.4. Questionnaires ................................................................................................. 28
       2.3.5. Procedure ......................................................................................................... 28
   2.4. Scoring ..................................................................................................................... 29
       2.4.1. Painting judgement task .................................................................................... 29
CHAPTER 3

3. Individual Differences in Laterality and Ratings of Asymmetrical and Symmetrical Artwork (Study 2) .......................................................... 46

3.1. Neural Basis of Left Versus Right Visuospatial Biases ................. 47

3.2. Asymmetries in Art .................................................................. 49

3.2.1. Artists’ handedness and visuospatial biases ............................... 50

3.3. Visuospatial Attention or Other Hemispheric Asymmetries? ....... 52

3.4. Present Study ........................................................................ 54

3.4.1. Hypotheses ....................................................................... 55

3.5. Method .................................................................................. 58

3.5.1. Participants ........................................................................ 58

3.5.2. Measures ......................................................................... 59

3.5.2.1. Painting attribute task ...................................................... 59

3.5.2.2. Original painting task ...................................................... 59

3.5.2.3. Line bisection task .......................................................... 60

3.5.2.4. Demographics and handedness ....................................... 60

3.5.3. Procedure ........................................................................ 61

3.5.4. Scoring ............................................................................ 61

3.6. Results .................................................................................. 62

3.6.1. Preliminary analyses ............................................................ 62

3.6.2. Main analyses ................................................................... 65

3.6.3. Post-hoc analysis of non-mirrored and mirrored painting selections .......................................................... 67

3.7. Discussion ............................................................................ 70

3.7.1. Distinguishing between the visuospatial and attribute hemispheric activation hypotheses .......................................................... 72

3.7.1.1. The effects of task format ................................................ 73
CHAPTER 4

4. Painting a Picture of how Laterality Influences the Production of Artwork (Study 3) ................................................................. 82

4.1. Laterality and the Creation of Art ........................................... 83

4.2. Study 3a ................................................................................. 84

4.2.1. Study 3a hypotheses ........................................................... 85

4.2.1.1. Do left and right hemi paintings intrinsically differ for the selected attributes? ......................................................... 85

4.2.1.2. Are visuospatial biases related to hemi-painting selection? 87

4.3. Method ...................................................................................... 88

4.3.1. Participants ......................................................................... 88

4.3.2. Measures .............................................................................. 88

4.3.2.1. Hemi-painting attribute task .......................................... 88

4.3.2.2. Line bisection task ............................................................ 89

4.3.2.3. Demographics and handedness ....................................... 89

4.3.3. Procedure ............................................................................. 90

4.3.4. Scoring .................................................................................. 90

4.4. Results ...................................................................................... 91

4.4.1. Preliminary analyses ............................................................ 91

4.4.2. Main analyses ...................................................................... 92

4.4.2.1. Are attributes differentially represented in the left and right halves of the paintings? ......................................................... 92

4.4.2.2. Are visuospatial biases related to hemi-painting attribute selections? ......................................................................... 95

4.5. Study 3a Discussion ................................................................. 96

4.6. Study 3b .................................................................................. 100

4.6.1. Laterality of emotion and logic .......................................... 100

4.6.2. Study 3b hypotheses ............................................................ 103

4.6.2.1. Do left and right hemi-paintings intrinsically differ for the lateralized attributes? ......................................................... 104

4.6.2.2. Are visuospatial biases related to selection of hemi-paintings? ........................................................................... 105

4.7. Method ..................................................................................... 105

4.7.1. Participants ......................................................................... 105

4.7.2. Measures and procedure ................................................... 105

4.7.3. Scoring ................................................................................. 105

4.8. Results ..................................................................................... 106
CHAPTER 5
5. Verbal, Facial, and Emotional Influences on the Line Bisection Task (Study 4) ................................................................. 123
  5.1. Line Bisection and Visuospatial Biases ........................................ 123
  5.2. Line Bisection as an Index of Non-Visuospatial Biases ................. 124
  5.3. Present Study ............................................................................ 125
    5.3.1. Manipulated factors and hypotheses ...................................... 126
      5.3.1.1. Line type: faces versus words ........................................ 126
      5.3.1.2. Line valence ............................................................... 127
      5.3.1.3. Hand-use ................................................................. 128
      5.3.1.4. Interactions .............................................................. 129
  5.4. Method ...................................................................................... 129
    5.4.1. Participants .......................................................................... 129
    5.4.2. Measures ............................................................................. 130
      5.4.2.1. Computerized line bisection .......................................... 130
      5.4.2.2. Pen-and-paper line bisection ....................................... 132
      5.4.2.3. Handedness and demographics questionnaire ............... 133
    5.4.3. Procedure ........................................................................... 133
    5.4.4. Scoring ............................................................................... 136
      5.4.4.1. Computerized line bisection ....................................... 136
      5.4.4.2. Pen-and-paper line bisection ....................................... 136
  5.5. Results ....................................................................................... 137
    5.5.1. Valence identification ........................................................ 137
    5.5.2. Solid lines ............................................................................ 137
      5.5.2.1. Computerized line bisection ....................................... 137
      5.5.2.2. Pen-and-paper line bisection ....................................... 137
      5.5.2.3. Comparison ............................................................... 138
    5.5.3. Emotional and neutral word and face lines ............................ 138
      5.5.3.1. Does valence, line type, and hand use influence bias magnitude? ........................................... 138
      5.5.3.2. Do character lines produce pseudoneglect? .................... 142
5.5.3.3. Comparison of character lines to solid line baseline performance ................................................................. 142
5.6. Discussion .................................................................................................................................................... 144
  5.6.1. Emotional word and face lines ................................................................. 144
    5.6.1.1. Alternative explanations for results .............................................. 146
  5.6.2. Hand-use ................................................................................................................................. 147
  5.6.3. Limitations and future directions ................................................................. 148
5.7. Conclusion ........................................................................................................................................... 149

CHAPTER 6
  6.1. Review of Studies 1-4 .................................................................................................................... 150
  6.2. Line Bisection Across the Studies: Post-Hoc Comparisons ......................................................... 153
  6.3. The Influence of Painting Judgement Task Characteristics ....................................................... 158
  6.4. The Big Picture ............................................................................................................................. 161
  6.5. Conclusion ...................................................................................................................................... 163

References ..................................................................................................................................................... 165
Appendices .................................................................................................................................................. 203
List of Tables

Study 1

Table 1. Pearson correlations between visual analogue and numeric ratings of stimuli and left-hand line bisection (LLB) or right-hand line bisection (RLB) bias scores .......................................................... 31

Table 2. Results of hierarchical multiple regressions demonstrating that stimulus orientation moderated the relationship between left-hand line bisection (LLB) bias scores and ratings of art made in visual analog and numeric formats. ................................. 34

Table 3. Results of hierarchical multiple regressions demonstrating that scale direction moderated the relationship between left-hand line bisection (LLB) bias scores and ratings of art made in visual analog and numeric formats. ........................................... 37

Study 2

Table 4a. Summary of predicted preferences for asymmetrical paintings ........................... 56

Table 4b. Summary of predicted correlations for asymmetrical paintings .......................... 56

Table 5. Correlations between line bisection bias scores and painting orientation preference (POP) bias scores for each attribute, shown separately for asymmetrical and symmetrical paintings. ................................................................. 66

Table 6. Significant results for sign tests examining whether the number of non-mirrored and mirrored painting selections made by left and right bisectors differed from each other. ................................................................. 68

Study 3

Table 7. Pearson correlations between line bisection bias scores and hemi-painting bias scores for asymmetrical and symmetrical paintings in mirrored and non-mirrored orientations for Study 3a. ................................................................. 97

Table 8. Pearson correlations between line bisection bias scores and hemi-painting bias scores for asymmetrical and symmetrical paintings in mirrored and non-mirrored orientations for Study 3b. ................................................................. 112

Study 4

Table 9. Results of the repeated measures ANOVA examining whether line valence, line type, and hand use influenced line bisection performance. ............................................. 140
Table 10. Results of one sample t-tests examining whether participants significantly deviated from true centre on the character line bisection task for each line type.
List of Figures

Study 1

Figure 1. Illustration of line bisection accuracy and bias groups.................................21
Figure 2. Non-mirrored versus mirrored scatterplots......................................................35
Figure 3. Ascending versus descending scatterplots..........................................................38

Study 2

Figure 4. Comparison of line bisection bias scores for each hand use condition ..........64

Study 3

Figure 5. Mean hemi-painting selection scores for asymmetrical paintings
(±SEM)..........................................................................................................................93
Figure 6. Mean hemi-painting selection scores for symmetrical paintings (±SEM) ....94
Figure 7. Mean hemi-painting selection scores (±SEM) of lateralized attributes for
asymmetrical paintings. .................................................................................................108
Figure 8. Mean hemi-painting selection scores (±SEM) of lateralized attributes for
symmetrical paintings. .................................................................................................109

Study 4

Figure 9. (a) Examples of the negative, positive, and neutral word and face lines
used in the character line bisection task. Humintell/David Matsumoto have
granted permission to the authors to print the JACFEE and JACNeuF faces. (b)
Screenshot of the solid thick line bisection page, demonstrating randomized line
placement. .......................................................................................................................131
Figure 10. Counterbalanced structure of the computerized line bisection task. ............135
Figure 11. Differential influence of line type (face, word) and valence (neutral,
positive, negative) on line bisection performance, as compared to baseline line
bisection performance on solid lines.............................................................................141

Synthesis of Studies

Figure 12. Comparison of left and right hand line bisection bias scores (±SEM)
across all studies..........................................................................................................154
Figure 13. Comparison of left hand, two-hand, and right hand line bisection bias scores (±SEM) across Studies 2-4.
List of Appendices

Appendix 1. Non-mirrored asymmetrical paintings used in Studies 1-3..........................203

Appendix 2. Supplementary Tables A and B for Study 1................................................204

Appendix 3. Non-mirrored symmetrical paintings used in Studies 2 and 3 .....................206

Appendix 4. University of Regina Research Ethics Board approvals. .........................207
List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANEW</td>
<td>Affective Norms for English Words</td>
</tr>
<tr>
<td>CES-D</td>
<td>Center for Epidemiologic Studies Depression Scale</td>
</tr>
<tr>
<td>DVA</td>
<td>degrees of visual angle</td>
</tr>
<tr>
<td>ERP</td>
<td>event-related potential</td>
</tr>
<tr>
<td>FFA</td>
<td>fusiform face area</td>
</tr>
<tr>
<td>fMRI</td>
<td>functional magnetic resonance imaging</td>
</tr>
<tr>
<td>LLB</td>
<td>left hand line bisection</td>
</tr>
<tr>
<td>LLBI</td>
<td>left hand line bisection inaccuracy</td>
</tr>
<tr>
<td>PET</td>
<td>positron emission tomography</td>
</tr>
<tr>
<td>POP</td>
<td>painting orientation preference</td>
</tr>
<tr>
<td>RLB</td>
<td>right hand line bisection</td>
</tr>
<tr>
<td>RLBI</td>
<td>right hand line bisection inaccuracy</td>
</tr>
<tr>
<td>SLF II</td>
<td>superior longitudinal fasciculus II</td>
</tr>
<tr>
<td>SPECT</td>
<td>single photon emission computed tomography</td>
</tr>
<tr>
<td>TAS-20</td>
<td>Toronto Alexithymia Scale</td>
</tr>
<tr>
<td>VWFA</td>
<td>visual word form area</td>
</tr>
</tbody>
</table>
That’s just your point of view: How visuospatial biases and functional lateralization influence the way we perceive the world

1. General Introduction

The left and right hemispheres of the human brain are known to have structural differences and functional specializations. For example, the left hemisphere typically has a larger primary auditory cortex (Penhune, Zatorre, MacDonald, & Evans, 1996) and planum temporale (Galaburda, Corsiglia, Rosen, & Sherman, 1987) than the right hemisphere. These structures are important for language-related processing, which is a function for which the left hemisphere is dominant (Knecht et al., 2000). In contrast to the left hemisphere dominance for language, the right hemisphere is dominant for functions such as facial recognition (Barbeau et al., 2008; Kadosh, Walsh, & Kadosh, 2011), as well as spatial attention (Corbetta, Shulman, Miezin, & Petersen, 1995; Gitelman, Parrish, Friston, & Mesulam, 2002; Macaluso & Driver, 2001; Nobre et al., 1997; Shulman et al., 2010) and emotion processing (Borod et al., 1998; De Renzi, Perani, Carlesimo, Silveri, & Fazio, 1994; Harciarek, Heilman, & Jodzio, 2006; Ley & Bryden, 1982).

These left-right hemispheric distinctions apply to a majority of individuals, with a number of studies demonstrating that the left hemisphere is dominant for language processing for approximately 95% of right-handed individuals (Borod, Carper, Naeser, & Goodglass, 1985; Knecht et al., 2000; Rasmussen & Milner, 1977) and approximately 70% of left-handed individuals (Rasmussen & Milner, 1977). Further, studies of functional lateralization have found that the left-hemisphere dominance for language is typically complemented with right-hemisphere dominance for spatial processing.
Interestingly, some individuals display a strong degree of lateralization, whereas others display less hemispheric specialization. For example, males (Ingalhalikar et al., 2014; Levy & Reid, 1978; Tomasi & Volkow, 2012) and individuals with autism (Kana, Keller, Carkassky, Minshew, & Just, 2006) tend to be more strongly lateralized. In contrast, females display greater functional connectivity between the two hemispheres (Ingalhalikar et al., 2014; Levy & Reid, 1978; Tomasi & Volkow, 2012), and left-handed individuals are also more likely to display a lower degree of lateralization compared to right handers (Ingalhalikar et al., 2014; Levy & Reid, 1978; Tomasi & Volkow, 2012).

Lateralized functions do not occur in isolation, and as such they can interact to influence processing. For example, facial processing can influence the perception of language, giving rise to the McGurk effect (MacDonald & McGurk, 1978; McGurk & MacDonald, 1976). In this effect, a person’s lip movements will appear to speak one syllable (e.g., Ga Ga), whereas the actual syllable that is spoken is different (e.g., Ba Ba). This conflicting information is “averaged” and can result in the perception of a completely new syllable (e.g., Da Da). Baynes, Funnell, and Fowler (1994) reported that the McGurk effect is most consistently observed in right handed individuals who have right hemisphere dominant facial processing and left hemisphere dominant language processing. In contrast, left handed individuals and individuals with callosotomies (a lesion through the corpus callosum, a structure which connects the two hemispheres) did not experience the McGurk effect very consistently, if at all. The authors suggested that
the two hemispheres work together to produce this effect, which demonstrates how different lateralized functions can influence each other and affect perception.

Although the McGurk effect may result from interaction between functions lateralized to each cerebral hemisphere, within a single hemisphere functions with shared neural correlates are often related in some manner as well. In the right hemisphere, emotion processing and spatial processing are two functions that have been demonstrated to influence each other and affect perception. For example, emotion can serve as a salient cue that can draw one’s attention toward a particular region of space (Bannerman, Temminck, & Sahraie, 2012; Vuilleumier & Schwartz, 2001). Also, when asked to identify emotion in chimeric faces (half-neutral, half-emotional faces spliced together, or faces with two different emotions spliced together), responses are more often based on the expression (or lack thereof) present on the left half of the face than on the right half (Christman & Hackworth, 1993; Levine & Levy, 1986; Levy, Heller, Banich, & Burton, 1983; Luh, Rueckert, & Levy, 1991; Wirsen, af Klinteberg, Levander, & Schalling, 1990), suggesting that visuospatial attention can influence emotion processing. Evidence for a potential relationship between spatial and emotion functions is strengthened by the fact that they share some overlapping neural correlates in the right temporoparietal region (Aftanas, Savotina, Makhnev, & Reva, 2005; Chokron, Bartolomeo, Perenin, Helft, & Imbert, 1998; Heilman, Scholes, & Watson, 1975; Macaluso & Driver, 2001; Marshall & Halligan, 1989; Rorden, Fruhmann Berger, & Karnath, 2006). The experiments described throughout this dissertation will investigate how the relationship between visuospatial attention and other lateralised functions, such as emotion processing, can influence the way humans perceive the world around them.
1.1. Visuospatial Attention

Visuospatial attention is a cognitive process that involves the selective processing of a visual stimulus based on its location in space (Vecera & Rizzo, 2003). This selection process often begins in early visual processing (e.g., Martínez et al., 1999; Woldorff et al., 1997) prior to conscious awareness of what the stimulus actually is (Beaver, Mogg, & Bradley, 2005; Vecera & Rizzo, 2003). Once the area is selected, further processing of the stimulus can occur. For example, the stimulus can be verbally identified, or can become the target of a movement (Vecera & Rizzo, 2003). Often, spatial attention is focused at the location in which the eyes are fixating, although attention can also be drawn to stimuli in the peripheral visual field as well (Corbetta et al., 1998; Smith & Chatterjee, 2008; Yantis et al., 2002).

1.1.1. Neural correlates of visuospatial attention. Spatial attention appears to be controlled by a fronto-parietal network of neural regions (LaBar, Gitelman, Parrish, & Mesulam, 1999; Szczepanski, Konen, & Kastner, 2010). This network includes the intraparietal sulcus and the superior parietal cortex (Mesulam, 1981, 1990; Pessoa, Kastner, & Ungerleider, 2002; Posner, 1994; Posner & Petersen, 1990; Yantis et al., 2002), which, together with the pulvinar nucleus and the superior colliculus, produce an internal perceptual representation of the environment and direct attention in space (Çiçek, Deouell, & Knight, 2009). The spatial attention network also includes the frontal and supplemental eye fields (Mesulam, 1981, 1990; Nobre et al., 1997; Pessoa, et al., 2002), which allow for the coordination of motoric interactions with the environment, such as visual scanning and fixating, and reaching movements.
Corbetta and colleagues found that the bottom-up orientation of spatial attention involves a lateralized ventral network, such that the right temporoparietal junction and right inferior frontal regions were activated when salient stimuli oriented attention to a previously unattended location in space (Corbetta, Kincade, Ollinger, McAvoy, & Schulman, 2000; Corbetta, Kincade, & Schulman, 2002). Additional studies have provided support for a right hemispheric lateralization of spatial attention (Macaluso & Driver, 2001; Nobre et al., 1997; Shulman et al., 2010). For example, functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) studies have shown that using spatial attention to search for a target among distractors activates the right superior and posterior parietal lobe (Corbetta et al., 1995; Gitelman et al., 2002).

Furthermore, damage to the right parietal lobe can result in a severe deficit in spatial attention called hemispatial neglect (Halligan, Fink, Marshall, & Vallar, 2003; Halligan & Marshall, 1991; Mesulam, 1999; Vallar & Perani, 1986). Neglect patients typically ignore the left side of space, which can result in patterns of behaviour such as colliding into objects on the left side of space (Grossi, Lepore, Napolitano, & Trojano, 2001; Webster, Rapport, Godlewska, & Abadee, 1994), or eating food from only the right half of a plate, copying only the right half of a picture, and skipping letters or words on the left side of a page when reading (Driver & Mattingley, 1998). Neglect may also be caused by damage to other brain regions such as the right superior temporal cortex and right insula (Karnath, Fruhmann Berger, Kuker, & Rorden, 2004) and right parahippocampal region (Mort et al., 2003), and it can sometimes occur after left hemisphere damage, leading to right neglect rather than left neglect (Beis et al., 2004).
However, right neglect occurs substantially less frequently than left neglect, and when it does occur it is typically less severe and pervasive than left neglect (Beis et al., 2004).

1.1.2. Line bisection as a measure of visuospatial attention. A common test for neglect is the line bisection task, which involves marking the perceived midpoint of a line. Neglect patients typically bisect lines to the far right of true center (Olk & Harvey, 2002; Schenkenberg, Bradford, & Ajax, 1980; Urbanski & Bartolomeo, 2008). Neurologically healthy individuals also display a spatial bias on the line bisection task, though it is typically leftwards and very slight compared to neglect patients. This leftward bias is referred to as pseudoneglect (Bowers & Heilman, 1980). Pseudoneglect may be explained by the activation-orientation hypothesis, which states that more attention is given to information in the visual field contralateral to the more highly-activated hemisphere (Bultitude & Aimola Davies, 2006; Kinsbourne, 1993; Reuter-Lorenz & Posner, 1990). Briefly, the visual system functions such that light in the left visual field is refracted onto the right half of the retina in each eye, and this information is then sent to the right hemisphere for processing. Likewise, light in the right visual field is refracted onto the left half of the retina in each eye, and the left hemisphere processes this information (Lambot, Depasse, Noel, & Vanderhaeghen, 2005). Essentially, this means stimuli in one visual field are initially processed by the contralateral hemisphere of the brain. In the case of spatial attention, a right hemisphere process, the activation-orientation hypothesis suggests that pseudoneglect occurs because more attention is given to stimuli in the left visual field. As such, when asked to bisect a line, the perceived midpoint is shifted to the left because the left side of the line is overattended (Bultitude & Aimola Davies, 2006). In support of this interpretation, right
hemispheric dominance for the line bisection task, particularly in the parietal regions and
the temporoparietal junction, has been reported in a number of studies using fMRI
(Çiçek et al., 2009; Fink et al., 2000; Fink, Marshall, Weiss, & Zilles, 2001), event-
related potential (ERP) recordings (Foxe, McCourt, & Javitt, 2003), single photon
emission computed tomography (SPECT; Marshall et al., 1997), and functional
transcranial doppler sonography (Flöel, Buyx, Breitenstein, Lohmann, & Knecht, 2005;
Flöel et al., 2001).

Neurologically healthy individuals’ performance on the line bisection task can be
influenced by a number of factors (for a review, see Jewell & McCourt, 2000). For
example, completing the task with the left hand can lead to larger leftward deviations
than completing the task with the right hand, perhaps due to increased right hemispheric
activation associated with left hand movement resulting in a stronger leftward attentional
bias in accordance with the activation-orientation hypothesis (Brodie & Pettigrew, 1996).
Also in line with this hypothesis, cues placed at the left end of a line increase the
leftward bisection bias, whereas rightward cues reduce this bias (Milner, Brechmann, &
Pagliarini, 1992), presumably as a result of contralateral hemispheric activation from
processing the cue. McCourt and Jewell (1999) also noted that longer lines, leftward line
placement, and upper visual field line placement all lead to greater leftward bissections
compared to short lines, rightward line placement, and lower visual field line elevation.

Although line bisection performance can be used to measure pseudoneglect, not
every neurologically healthy individual displays this leftward line bisection bias.
Individuals may have rightward bisection biases, though there is no particular name for a
bias in this direction. Of particular relevance to this dissertation, some studies suggest
that leftward and rightward biases may arise from opposite patterns of hemispheric organization for visuospatial processing (Benwell, Thut, Learmonth, & Harvey, 2013; de Schotten et al., 2011). For example, Benwell et al. (2013) showed that leftward bisectors tend to shift their bisections to the right as the task continued, likely due to right hemisphere fatigue for visuospatial processing, whereas rightward bisectors showed the opposite pattern, likely due to left hemisphere fatigue for visuospatial processing.

Further, de Schotten et al. (2011) found that leftward bisectors had a larger superior longitudinal fasciculus (SLF II, a fronto-parietal pathway) in the right hemisphere whereas rightward bisectors had a larger SLF II in the left hemisphere.

Whereas a large number of studies have reported leftward bisections in right-handed individuals when using their right hands (see Jewell & McCourt, 2000, for a review), other studies have reported no bias (e.g., Rosenberger, 1974) or even a rightward bias with right hand line bisection (e.g., Manning, Halligan, & Marshall, 1990; McCourt & Olafson, 1997). For example, Manning et al. (1990) examined individual differences in right hand line bisection performance, and found that approximately half of their 22 participants were leftward bisectors whereas the other half were rightward bisectors. They suggested that studies with a relatively small sample size ($n = 10-30$) may not display consistent leftward line bisection biases due to this heavy individual variability. McCourt and Olafson (1997) also reported significant individual differences in right-hand line bisection performance in their strongly right-handed male participants, and Halligan, Manning, and Marshall (1990) noted the same for their sample of older individuals. Based on this information, it appears important to consider both the hand
used and the number of leftward and rightward bisectors in studies using a line bisection task.

1.2. Emotion Processing

Emotion is the main lateralized function that was examined in relation to visuospatial bias throughout all of the studies in the present dissertation. Emotion is thought to contain four major components: physiological (autonomic) responses to a stimulus, cognitive processes, affective processes, and behavioural responses (Kleinginna & Kleinginna, 1981). For the purposes of this dissertation, the emotion processes are of particular importance (the underlying mental and neurological operations that occur in response to an emotional stimulus). Emotion processing may include the cognitive processing of the emotional information conveyed by the stimulus (e.g., recognizing, rating, or identifying an emotional facial expression) and the affective experiences arising from exposure to the emotional stimulus (e.g., feeling fear, empathy).

There are two major hypotheses about how emotion is lateralized in the brain: the right hemisphere hypothesis, and the valence hypothesis. Each hypothesis is described below.

1.2.1. Right hemisphere hypothesis. Similar to spatial attention, there is evidence that the right hemisphere is dominant for emotion processing (Borod, 1992; Borod et al., 1998; De Renzi et al., 1994; Harciarek et al., 2006; Ley & Bryden, 1982). Some evidence for this comes from studies demonstrating that damage to the right hemisphere can affect emotion processing more consistently than damage to the left hemisphere (Blonder, Bowers, & Heilman, 1991; Borod, 1992; Bowers, Blonder, Feinberg, & Heilman, 1991; De Renzi et al., 1994; DeKosky, Heilman, Bowers, & Valenstein, 1980; Harciarek et al., 2006). For example, patients with right hemispheric
lesions, in comparison to those with left hemispheric lesions or no brain damage, reportedly have: poorer emotion and facial discrimination, as well as impaired labeling of emotional scenes (DeKosky et al., 1980); impaired labeling of emotional faces (DeKosky et al., 1980; Harciarek et al., 2006); and impaired ability to label the emotions depicted by sentences that described facial expressions, body language, and prosodic tone of voice (Blonder et al., 1991). Additionally, there is evidence that right hemispheric dysfunction may underlie a number of disorders related to poor emotion processing, such as alexithymia (Jessimer & Markham, 1997; Kano et al., 2003; Spalletta et al., 2001), Asperger’s syndrome (McKelvey, Lambert, Mottron, & Shevell, 1995), and even amyotrophic lateral sclerosis (Palmieri et al., 2010).

Evidence of right hemisphere dominance for emotion processing has also been observed in neurologically healthy individuals, in behavioural and neuroimaging studies (e.g., Buchanan et al., 2000; Coolican, Eskes, McMullen, & Lecky, 2008; George et al., 1996; Heller & Levy, 1981; Nakamura et al., 1999; Rueckert & Naybar, 2008). A number of behavioural studies have taken advantage of the contralateral visual, auditory, and motor pathways to demonstrate a right hemisphere advantage for a number of emotion-related tasks. For example, when viewing half-neutral and half-emotional composite images of faces, emotional expressions are better recognized when they are present on the left rather than the right side of the image (Christman & Hackworth, 1993; Coolican et al., 2008; Heller & Levy, 1981; Levine & Levy, 1986; Levy et al., 1983; Rueckert & Naybar, 2008; Wirsen et al., 1990). Also, emotional expressions are more prominently expressed on the left half of the face than on the right (Asthana & Mandal, 1998; Borod, Kent, Koff, Martin, & Alpert, 1988; Sackeim, Gur, & Saucy, 1978).
Furthermore, a left ear (right hemisphere) advantage has been found for accurately identifying emotional prosody (Bryden & MacRae, 1988; Christman & Hackworth, 1993; Ley & Bryden, 1982), and fMRI studies have confirmed predominantly right hemispheric activation in response to emotional prosody (Buchanan et al., 2000; George et al., 1996; but see Morris, Scott, & Dolan, 1999; Rämä et al., 2001). Imaging studies have demonstrated that emotional perception of visual stimuli, such as emotional faces, activates a number of right hemisphere regions to a greater extent than the corresponding left hemisphere regions, including the orbitofrontal cortex (Morris et al., 1998), the lateral occipital gyrus (Kesler/West et al., 2001), and the right anterior and superior temporal sulcus (Narumoto, Okada, Sadato, Fukui, & Yonekura, 2001; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). Furthermore, experiencing and expressing emotions activates the right temporoparietal region (Heller, 1993; Heller, Nitschke, & Lindsay, 1997; Moratti, Rubio, Campo, Keil, & Ortiz, 2008). However, in a systematic review of lateralized amygdala activation in response to emotional stimuli, Baas, Aleman, and Kahn (2004) reported that the left amygdala is most consistently activated compared to the right. They proposed that the left and right amygdala play different roles in emotion processing. The right amygdala appears to habituate faster than the left to emotional stimuli (Wright et al., 2001), and is involved in fast and automatic emotional reactions to stimuli (Gläscher & Adolphs, 2003). In contrast, the left amygdala appears to be involved in more sustained and detailed cognitive processing of emotional stimuli (Gläscher & Adolphs, 2003), and as such, imaging studies that use techniques with low temporal resolution, like fMRI and PET, may be more likely to detect sustained
activation of the left amygdala than the automatic and quickly-habituating activation of the right (Baas et al., 2004).

**1.2.2. Valence hypothesis.** Although a large body of evidence suggests that the right hemisphere is dominant for numerous types of emotion processing, as discussed above, research has also demonstrated that each hemisphere may be differentially activated based on the valence of the emotional stimulus to be processed (Davidson, 1995; Kinsbourne, 1978). This valence hypothesis states that the left hemisphere is dominant for processing positive or approach-related emotional information, whereas the right hemisphere is dominant for processing negative or withdraw-related emotional information. For example, Reuter-Lorenz and Davidson (1981) randomly presented emotional faces (happiness, sadness, anger, disgust) and neutral faces to participants’ left and right visual fields, and participants had to indicate on which side the emotional face appeared. Participants responded to happy faces significantly faster than sad faces when they were presented in the right visual field (left hemisphere), and the opposite pattern was found for left visual field (right hemisphere) presentation of these emotional expressions. Results for anger and disgust were not discussed in this study. Similarly, differently valenced stimuli can produce different lateralized asymmetries for the visual perception and discrimination of emotional faces (Balconi & Pozzoli, 2003; Jansari, Tranel, & Adolphs, 2000; Shamay-Tsoory, Lavidor, & Aharon-Peretz, 2008; Tapia, Carretié, Sierra, & Mercado, 2008) and words (Smith & Bulman-Fleming, 2005), as well as in the auditory perception of differently-valenced sentences (Rodway & Schepman, 2007). Furthermore, in an fMRI study, Canli, Desmond, Zhao, Glover, and Gabrieli (1998) reported greater general activation of the left hemisphere than the right in
response to positive pictures, and greater activation of the right hemisphere than the left in response to negative pictures.

Research on the valence hypothesis of emotion has not been entirely consistent, however, with some studies not finding an effect of valence (e.g., Borod, 1992; Borod et al., 1998). These inconsistent results largely have been found for the perception of emotional valence, whereas research on the production of valenced emotional behaviours has produced more consistent results. For example, right hemisphere damage is often associated with euphoria (Gainotti, 1972; Starkstein, Robinson, Honig, Parikh, Joselyn, & Price, 1989), whereas left hemisphere damage is often associated with depressive symptoms (Carson et al., 2000; Gainotti, 1972; Grajny et al., 2016). Similar patterns of emotional behaviour have been found in patients undergoing Wada testing in preparation for brain surgery (e.g., Lee, Loring, Meader, & Brooks, 1990).

It has been suggested that both the right hemisphere and the valence hypothesis are correct to a certain extent when considering the perception of emotion (Killgore & Yurgelun-Todd, 2007; Prete, Laeng, Fabri, Foschi, & Tommasi, 2015; Shamay-Tsoory, Tomer, Goldsher, Berger, & Aharon-Peretz, 2004). For example, in an fMRI study, Killgore and Yurgelun-Todd (2007) examined neural activation in response to viewing briefly presented chimeric faces (half neutral, half happy or sad). They found that the right hemisphere was more strongly activated than the left regardless of valence, consistent with the right hemisphere hypothesis. However, more detailed analyses revealed stronger activation in response to sad than happy stimuli when the emotional half of the chimeras appeared in the left visual field (right hemisphere). Furthermore, the left hemisphere was more strongly activated for happy chimeras than for sad chimeras.
when the emotional half of the face was presented in the right visual field (left hemisphere). Additionally, right visual field presentation of the emotional half of sad chimeras resulted in bilateral activation compared to happy chimeras, perhaps because right hemispheric resources were recruited in order to process the negative valence. Taken together, this suggests that although the right hemisphere excels at processing emotion, the left hemisphere may be able to process positively-valenced emotional expressions. Killgore and Yurgelun-Todd suggest this is because positively-valenced emotional expressions all fall within the general category of “happy”, thus they are easier to process than negatively-valenced emotional expressions which are more complex and difficult to discriminate (e.g., there are many subtle nuances between disgust and anger).

1.3. Line Bisection Performance and Emotion Processing.

To date, few studies have examined how line bisection performance relates to the processing of emotion stimuli. A few studies have suggested no relationship, such as Luh (1995) who noted that line bisection biases did not correlate with biases in processing chimeric faces, nor with other perceptual asymmetries for dot-filled rectangles and the Muller-Lyer illusion. Tamietto et al. (2005) also found no effect of emotion processing on line bisection performance, at least for individuals with relatively intact spatial-attention networks. In their study, one hemispatial neglect patient with right hemispheric parietal damage and four right hemisphere brain-damaged controls completed a line bisection task with emotional (happy or angry) and neutral facial cues at alternating ends of the line. The emotional content of the cues only influenced performance for the hemispatial neglect patient (producing more leftward bisections, or less error), and only when these cues were presented on the left (neglected) end of the line. However, in a
group of neurologically healthy participants, Armaghani et al. (2014) and Cattaneo et al. (2014) found that line bisection was influenced by flanking emotional faces. Cattaneo et al. found that negative and neutral faces were associated with larger leftward bisections than were positive faces, whereas Armaghani et al. found that both positive and negative faces drew bisections leftward relative to neutral faces, with negative faces producing a larger leftward bisection bias than positive faces. Leggett et al. (2016) also found that negative face primes were associated with leftward biases, while neutral and positive face primes were not, though this pattern was not replicated in four studies that followed – the last of which was an exact replication of the first.

When line bisection performance was treated as a trait which indicated general spatial-attentional ability, relationships between spatial attention and emotion processing have also been found in neurologically healthy individuals. For example, Drago et al. (2008) had participants complete a line bisection task and rate the evocative impact of abstract paintings. They placed their participants (all of whom displayed a rightward bisection bias) into “more accurate” and “less accurate” line bisector groups, and found that the more accurate bisectors gave higher ratings of evocative impact compared to the less accurate bisectors. Drago and colleagues suggested that in order to receive the full evocative impact of the paintings, attention needed to be distributed to the whole image. From this, they proposed that the more accurate bisectors were able to attend to the entire painting, and thus to receive the full evocative impact, compared to the less accurate bisectors who were less adept at distributing attention over the entire painting. Drago and colleagues concluded by suggesting that the line bisection task may serve as a general indicator, or “barometer”, of right hemisphere function.
Tamagni, Mantei, and Brugger (2009) also grouped participants based on line bisection performance in order to compare spatial attention to emotion processing. In their study, participants completed a line bisection task with their dominant (right) hands, and were then placed into a “left bisector” or a “right bisector” group based on whether they bisected the lines to the left or right of true center. Participants also completed a lexical decision task wherein randomly presented pronounceable non-words and positively- and negatively-valenced words were shown in their left or right visual fields, and they had to indicate as quickly as possible whether the item was a word or not. Tamagni et al. (2009) found that regardless of visual field presentation, the left bisector group was significantly better at detecting negatively-valenced words than positively-valenced words, whereas no such difference was found for the right bisector group. However, they did find a positive correlation between individual differences in line bisection deviation and correct detection of positively-valenced words, indicating that the more rightward the bisectors, the more accurate the detection of these words. Tamagni and colleagues suggested that leftward line bisection, indicating right hemispheric activation, was related to the right hemispheric dominance for processing negatively-valenced emotion information, whereas rightward line bisection, indicating left hemispheric activation, was related to the left hemispheric dominance for processing positively-valenced emotion information, adding support to the valence hypothesis.

Overall, it appears as though individual differences in line bisection performance may be related to emotion processing capabilities, though to what extent and in what manner still needs to be clarified. Tamagni et al. (2009) suggest that direction of line bisection biases may relate to better processing of emotional information depending on
valence, whereas Drago et al. (2008) suggest that line bisection accuracy may relate to a general right hemisphere ability to process emotional information.

1.4. Overview

In the present dissertation, four studies were conducted in order to more closely examine how the relationship between individual differences in spatial attention and other lateralized factors, such as emotion processing, influence the way we perceive and interact with our environments. In these studies, the line bisection task served as a measure of visuospatial attention. The first three studies used painting stimuli to examine how differences in visuospatial attention affect the perception (Studies 1-3) and creation (Study 3) of artwork. Study 1 followed up on Drago et al. ’s (2008) study to examine whether line bisection accuracy and/or direction of line bisection bias could indeed be used as a barometer of emotional evocation from paintings, and perhaps general right hemisphere function. Study 2 further examined some of the proposed explanations for the results of Study 1 by investigating whether individual differences in visuospatial attention (as indexed by line bisection performance) or other aspects of lateralized processing (e.g., emotional valence, logic) influenced the perception of the paintings. Study 3 examined whether the painting stimuli used in the first two studies contained inherent asymmetries, presumably as a result of the artists’ lateralization. Finally, Study 4 focused on the line bisection task itself, examining how integrating emotional and linguistic information into the lines affects line bisection biases. Collectively, these four studies shed light on how individual differences in visuospatial attention and other lateralized attributes can affect the perception and creation of artwork and other aspects of our environments.
2. The Relationship Between Line Bisection Performance and Emotion Processing: Where Do You Draw the Line? (Study 1)¹

Visuospatial attention and emotion processing are distinct functions that both demonstrate right hemisphere dominance and have a number of shared neural correlates (Aftanas et al., 2005; Blonder et al., 1991). In light of these shared correlates, Drago et al. (2008) examined the relationship between visuospatial attention and emotional evocation, using line bisection and painting judgment tasks. Individuals who performed more accurately on the line bisection task gave the paintings higher evocation ratings, compared to those who were less accurate. In light of this finding, and the shared neural bases of these processes, Drago and colleagues hypothesised that line bisection accuracy may be a useful measure of right hemispheric abilities in general, including visuospatial and emotional processing. The present study tests an alternative laterality-based explanation for Drago et al.’s findings, by manipulating characteristics of the scale and stimuli used in their study. In brief, we examined whether individual differences in visuospatial laterality influenced painting ratings in a fashion related to inherent asymmetries in the paintings themselves, in addition to examining whether responses were influenced by asymmetric properties of the rating scales.

2.1. Relationship Between Line Bisection Performance and Emotion Processing

The right temporoparietal region is involved in both emotion processing (Aftanas et al., 2005; Moratti et al., 2008) and line bisection performance (Fink et al., 2001; Foxe et al., 2003). The line bisection task is a simple measure of visuospatial attention that

¹ This study has been peer-reviewed and published as follows: Hatin, B., & Sykes Tottenham, L. (2016). The relationship between line bisection performance and emotion processing: Where do you draw the line? Laterality: Asymmetries of Body, Brain and Cognition, 21(4-6), 709-731.
involves marking the perceived midpoint of a line. Neurologically healthy individuals display slight but robust leftward spatial biases on this task, called pseudoneglect (Bowers & Heilman, 1980). Pseudoneglect appears to occur because more attention is given to the left visual field, due to right hemispheric parietal and temporoparietal dominance for this task (Bultitude & Aimola Davies, 2006; Çiçek et al., 2009; Fink et al., 2000; Foxe et al., 2003).

Because line bisection and emotion processing both involve the right temporoparietal region, some have suggested that these activities may be related (e.g., Drago et al., 2008; Foster et al., 2008). Support for this idea has been found when line bisection performance was treated as a trait-like indicator of general spatial-attentional ability (Drago et al., 2008; Tamagni et al., 2009). Relevant to the present study, Drago et al. grouped participants based on line bisection accuracy in order to examine how visuospatial attention related to emotion processing. Right-handed older adults ($M = 66$ years, $SD = 9.55$) completed a line bisection task and rated the evocative impact of abstract paintings, in addition to rating aesthetics, novelty, technique, and closure. The participants, all of whom displayed rightward bisection biases, were placed into “more accurate” and “less accurate” line bisector groups. They found more accurate bisectors gave higher evocation ratings compared to less accurate bisectors (no differences were found for aesthetics, novelty, technique, and closure), and suggested the relationship between evocative impact and line bisection may result from shared neural correlates underlying these tasks. For ease of reference, we call this the Shared Neural Correlates hypothesis. Drago and colleagues concluded by suggesting that line bisection accuracy
may serve as a “barometer” for both spatial and emotional abilities, and perhaps for right hemisphere functioning in general.

If the line bisection task can be used as an indicator of right temporoparietal functioning, or right hemisphere functioning in general, it would suggest the task has greater utility than previously thought. However, because Drago et al.’s (2008) sample was comprised of older individuals, the extended utility of this task may not apply to younger individuals. The typical leftward bisection bias observed in young adults shifts to the right with age (Fujii, Fukatsu, Yamadori, & Kimura, 1995; Jewell & McCourt, 2000), most notably from 40-50 years onwards (Park et al., 2002), particularly when completed with the right hand (Failla, Sheppard, & Bradshaw, 2003). Drago et al. reported a rightward line bisection bias for all of their participants, whose known ages were 46-82 years (4 participants’ ages were not reported), and who presumably completed the task with their dominant right hand only (hand-use was not reported). Thus, findings from this older sample may not generalize to younger populations.

A second consideration is that line bisection accuracy was confounded with line bisection bias in their sample (Figure 1a), which may change the interpretation of their results. That is, participants with lower accuracy also bisected more rightward relative to those with higher accuracy. This may be particularly problematic given the rating scale and painting stimuli used in the study demonstrated asymmetries, which may have caused ratings to be related to visuospatial biases. Below we discuss these potentially influential factors, and propose and test an alternative explanation for their results.
Figure 1. Illustration of line bisection accuracy and bias groups.
2.2. An Alternative Approach: The Importance of Visuospatial Biases

2.2.1. Line bisection accuracy or line bisection bias? In Drago and colleagues’ study, all participants demonstrated rightward bisection errors on the line bisection task, which confounded line bisection accuracy with line bisection biases. Because of this, it is unclear whether line bisection bias or accuracy was underlying the relationship with emotional evocation ratings. This consideration is important because if visuospatial biases were underlying the results instead of line bisection accuracy, then it is also possible that the results were influenced by other variables affected by visuospatial biases, namely asymmetries in the paintings and in the visual-analogue rating scales.

2.2.2. Artwork asymmetries. The stimuli used by Drago et al. (2008) were asymmetrical paintings, which may have produced a relationship between line bisection biases and ratings of emotional evocation. That is, if the left and right halves of the paintings differ in their emotionally evocative content, then it stands to reason that individuals who have relatively leftward or rightward visuospatial biases (attending more leftward versus rightward when viewing lines and paintings) would give different ratings to the paintings.

Previous research has suggested that there are asymmetries in the creation, perception, and appreciation of artwork, portraits, and advertisements, particularly in the leftward direction (e.g., Bhushan & Rai Sapru, 2008; Conesa, Brunold-Conesa, & Miron, 1995; Harris, Cárdenas, Spradlin, & Almerigi, 2010; Hutchison, Thomas, & Elias, 2011; McDine, Livingston, Thomas, & Elias, 2011; Nicholls, Clode, Wood, & Wood, 1999; Thomas, Burkitt, Patrick, & Elias, 2008). Although no studies have directly demonstrated asymmetries in emotional content of paintings, it is possible that leftward
asymmetries in brightness (Hutchison et al., 2011; McDine et al., 2011), aesthetic pleasantness (Hutchison et al., 2011), aesthetic influence (Nelson & MacDonald, 1971), nearness (Adair & Bartley, 1958), vividness or clarity (Dallenbach, 1923; White & Dallenbach, 1932), and meaningfulness and importance (Gaffron, 1950; Nelson & MacDonald, 1971; Woelfflin, 1932) could influence emotional evocation ratings, particularly if an individual is attending more to one side of a painting than the other. If the paintings used in Drago et al.’s (2008) study contained leftward asymmetries, then individuals who attended more to the left half of the paintings may have reported more of an evocative impact than those attending more to the right half. Indeed, the more accurate group displayed leftward biases relative to the less accurate/more rightward group and gave higher evocation ratings than the less accurate/more rightward group. Thus, these individual differences in visuospatial biases may have produced greater emotional evocation ratings in the more accurate/more leftward group compared to the less accurate/more rightward group as a result of leftward biases inherent in the paintings themselves. As such, in the present study we examined normal and mirrored versions of the paintings in order to determine whether manipulating the direction of asymmetries in the paintings influenced ratings given by individuals who demonstrated differing visuospatial biases on the line bisection task.

Given the asymmetrical nature of the paintings, if visuospatial attentional biases affect whether participants attend more to the left or right side of paintings, then ratings will differ between mirrored and non-mirrored paintings in predictable patterns for individuals demonstrating relative leftward and rightward biases on the line bisection task. Specifically, individuals who display leftward biases on the line bisection task will
report higher ratings for non-mirrored paintings (i.e., paintings with leftward asymmetries) than for mirrored paintings, whereas individuals with rightward biases will report higher ratings for mirrored paintings (i.e., paintings with rightward asymmetries) than non-mirrored paintings.

2.2.3. Ascending versus descending scale direction. A second factor considered in the present study is the scale type and direction used for the painting ratings. The participants in Drago and colleagues’ (2008) study rated the paintings by placing a mark on a line that was flanked by the numbers ‘1’ and ‘10’ on the left and right ends, respectively, indicating very low to very high ratings. However, the fact that this visual-analogue scale was not counterbalanced to include a descending scale option may have been problematic. Past research has suggested that spatial biases may influence ratings that are made on ascending versus descending scales. For example, Nicholls, Orr, Okubo, and Loftus (2006) found that lower ratings were over-represented on an ascending scale, and underrepresented on a descending scale. Nicholls et al. (2006) suggested their findings may be due to pseudoneglect, such that the leftward attentional bias in the general population may skew ratings or selections towards items presented on the left side of space. As such, in Drago et al., visuospatial biases may have skewed the given ratings due to the fact that scale direction was not counterbalanced, which may have confounded the ratings with performance on the line bisection task. Drago and colleagues suggested using a different scale type in the future to account for issues arising from visual-analogue ratings.

In the present study, participants rated paintings using both visual-analogue and numeric scales that were in either an ascending or descending format. If ratings of
emotional evocation can be assessed accurately using a visual-analogue scale, then the scale direction and scale type will not change the ratings. However, if visuospatial biases affect ratings, particularly on the visual-analogue scale, then emotional evocation ratings (as well as other attribute ratings) will shift in the direction towards where one’s attention is biased, as indicated by the line bisection task.

2.2.4. Present study. The present study aimed to: 1) determine whether the results from Drago and colleagues’ (2008) older sample could be replicated in a younger sample (in light of age-related changes in visuospatial processing; Jewell & McCourt, 2000); 2) investigate whether differences in ratings of paintings are associated with line bisection accuracy, or whether the pattern of results is better explained by line bisection biases; and 3) examine the influence of rating scale type (visual analog/numeric) and direction (ascending/descending), and asymmetries in the painting stimuli (using mirrored and non-mirrored paintings), to further examine the alternative explanation that visuospatial biases, not line bisection accuracy, affect the ratings. Taken together, this study will allow for comment on whether or not the line bisection task appears to function as a general measure of right hemisphere activation, as suggested by Drago and colleagues.

2.3. Method

2.3.1. Participants. Data were collected from 62 participants (49 female). All participants were enrolled in a first- or second-year psychology course and received course credit. Participants were right-handed as assessed by questionnaire (Elias, Bryden, & Bulman-Fleming, 1998), between ages 18-23 years ($M = 19.81$, $SD = 1.90$),
and had normal or corrected-to-normal vision. This study was approved by the University’s Research Ethics Board.

### 2.3.2. Painting judgement task.

Participants completed a painting judgement task in which they viewed paintings in either a mirrored or non-mirrored orientation, and then rated the paintings on five attributes using both visual analog and numeric scales, that were in either an ascending or descending format. Scale direction (ascending/descending) and stimulus orientation (mirrored/non-mirrored) were between-subject variables, whereas scale type (visual analog/numeric) was a within-subjects variable.

Eight of the ten paintings that comprised the stimuli used by Drago et al. (2008) were used in the present study. Paintings can be viewed at [www.robertallenfineart.com](http://www.robertallenfineart.com) by selecting “Stephen Duren” from the artist registry. The paintings included Église 2001, Lavendar and Wheat 2001, Untitled 90-1990, Vineyard and Wheat 2001, Wheat II 2001, 9-88/11, 9-88/5, and 9-88/20. The artist granted us permission to use these works. Non-mirrored and mirrored versions of the paintings were printed in high-quality colour on letter-size paper with 1-inch margins, and laminated for protection. Some participants viewed and rated paintings in the original orientation, whereas others viewed and rated paintings in a mirror-reversed orientation. Participants were placed into only one orientation condition in order to keep the experiment under one hour in duration.

Participants had unlimited time to view each painting, but were asked to give their immediate impression of five different attributes, by responding on a rating scale to the five questions that were also asked in Drago et al. (2008): “How strongly does the painting induce feelings or thoughts?” (Evocative Impact); “How beautiful is the

---

2 The paintings by Stephen Duren can also be viewed in Appendix 1 of this dissertation.
painting?” (Aesthetics); “How original or new is the painting?” (Novelty); “How much skill does the painting show?” (Technique); “How complete is the painting?” (Closure).

All paintings were viewed twice, in two separate blocks. Attribute ratings were provided in pen-and-paper format, using visual-analogue scales in one block and numeric scales in the other block (counterbalanced order). These scales were either ascending or descending—scale direction was constant within-subjects to reduce potential confusion.

For the visual-analogue scale, ratings of each painting were made on separate pieces of paper, each of which had five response lines corresponding to the five questions. The response lines were equally-spaced, left-aligned, and 100 mm in length. For the ascending visual-analogue condition, lines were flanked by the numbers “1” and “10” on the left and right, respectively, as per Drago et al. (2008), whereas for the descending visual-analogue condition, lines were flanked by “10” and “1” on the left and right, respectively. For the numeric scale, ratings of each painting were made for each of the five questions by completing the statement “On a scale of 0-100, I would rate my response to be _____” for the ascending scale condition, and “On a scale of 100-0, I would rate my response to be _____” for the descending scale condition. In sum, there were four different response conditions, in which participants completed either ascending visual analogue and numeric scales, or descending visual analogue and numeric scales.

2.3.3. Line bisection. Four pen-and-paper line bisection pages were given to each participant. These pages were modeled on the line bisection task used by Nicholls et al. (2008) and Hatin, Sykes Tottenham, and Oriet (2012), such that each page contained five lines that were 100 mm long and 2 mm thick. The lines were equally spaced apart by 45 mm, and staggered from the center of the page by 0 mm, ±20 mm,
and ±45 mm. Two pages were completed with each hand (counterbalanced order). The line bisection task differed from Drago et al. (2008) in that it was done separately from the rating task (to increase the independence of the ratings and line bisections), and ten lines were bisected with each hand. Hand-use was manipulated in order to control for hand effects known to arise from contralateral motoric processing (McCourt, Freeman, Tahmahkera-Stevens, & Chaussee, 2001)—left and right hand use increases and decreases the extent of pseudoneglect, respectively (Jewell & McCourt, 2000).

2.3.4. Questionnaires. Participants completed a demographics and laterality questionnaire, the Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994; Bagby, Taylor, & Parker, 1994), and the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). The demographics and laterality questionnaire was adapted from Elias et al. (1998), and used to account for subject variables (e.g., sex, age, handedness, footedness). The laterality portion of the questionnaire included questions such as, “With which hand would you use a pair of tweezers?” and “Which hand would you use to throw a ball?” The TAS-20 and CES-D were used to account for potential influence of depression and alexithymia. Scores on the laterality, TAS-20, and CES-D measures were not related to the overall results, and thus are not discussed further.

2.3.5. Procedure. After informed consent, participants were assigned to either the non-mirrored or mirrored painting condition (between-subjects variable). Participants then completed the first block of the painting judgement task, in which paintings were presented in a random order. Responses were made using either a visual-analogue or numeric scale (within-subjects variable, counterbalanced order), which was in either an ascending or descending format (between-subjects variable). Next, they completed one
of the questionnaires, and then the second block of the painting judgement task (using the scale type not previously used). After this, participants completed the line bisection task and the remaining questionnaires.

2.4. Scoring

2.4.1. Painting judgement task. Visual-analogue responses were scored using digital calipers to measure the distance between the left end of the line and participants’ response marks (to the nearest 0.5 mm). The descending visual-analogue responses were reverse-scored by measuring the distance between the right end of the line and response marks. As such, scores could range between 0 mm-100 mm, similar to the 0-100 numeric rating scale. One participant did not complete the numeric judgements correctly, and was subsequently removed from the analyses (non-mirrored descending condition). For both the visual-analogue and numeric format, answers for each of the five questions were averaged across the 8 paintings to obtain an overall assessment of evocative impact, aesthetics, novelty, technique, and closure.

2.4.2. Line bisection. Line bisection error scores were determined using digital calipers by measuring the distance between the perceived midpoint and true centre regardless of deviation direction (to the nearest 0.5 mm). Line bisection accuracy scores were calculated by subtracting error scores from half the line length (50 mm), as the maximum possible error score for bisection was 50 mm. Accuracy scores could range from 0-50, with higher numbers indicating greater accuracy. Average accuracy scores were calculated separately for the left and right hand.

Line bisection bias scores were determined using digital calipers to measure the distance between the perceived midpoint and true centre (to the nearest 0.5 mm).
Bisection scores left of true centre were multiplied by -1, so negative scores indicated leftward biases, positive scores indicated rightward biases, and a score of 0 indicated no bias. Average bias scores were calculated separately for the left and right hand.

Our sample demonstrated both leftward and rightward line bisection biases, whereas Drago et al.’s sample only demonstrated rightward biases. This is noteworthy because it means that line bisection accuracy and bias were not confounded in the present study (Figure 1b), therefore allowing us to decouple accuracy and bias in the following analyses, and determine which was related to the attribute ratings.

2.5. Results

2.5.1. Analyses of line bisection accuracy and bias. First, Pearson Correlations were run to examine whether accuracy results from Drago et al.’s (2008) older sample were replicated in our younger sample, or whether the pattern of results could be better explained by line bisection bias. This was done using a subset of 22 participants who completed the rating task in a manner that matched Drago and colleagues’ approach: rating non-mirrored paintings using an ascending scale. Additionally, we examined whether the use of numeric versus visual-analogue scales changed the results. Separate correlations were run for each attribute that was rated, and for each hand condition of the line bisection task.

The accuracy analyses produced no significant correlations between line bisection accuracy and ratings, all $p > .13$. For the bias analyses, numerous significant negative correlations were observed between left-hand line bisection bias scores and both visual-analogue and numeric ratings (Table 1), indicating that leftward bisectors gave higher ratings on the attributes (including emotional evocation) compared to
Table 1. Pearson correlations between visual analogue and numeric ratings of stimuli and left-hand line bisection (LLB) or right-hand line bisection (RLB) bias scores.

<table>
<thead>
<tr>
<th>Rating Type</th>
<th>LLB Bias Pearson r</th>
<th>p (2-tailed)</th>
<th>RLB Bias Pearson r</th>
<th>p (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual Analogue Scale:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evocative Impact</td>
<td>-.53*</td>
<td>.01</td>
<td>.21</td>
<td>.36</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>-.47*</td>
<td>.03</td>
<td>.11</td>
<td>.64</td>
</tr>
<tr>
<td>Novelty</td>
<td>-.45*</td>
<td>.04</td>
<td>.02</td>
<td>.92</td>
</tr>
<tr>
<td>Technique</td>
<td>-.46*</td>
<td>.04</td>
<td>.11</td>
<td>.63</td>
</tr>
<tr>
<td>Closure</td>
<td>-.28</td>
<td>.23</td>
<td>.22</td>
<td>.35</td>
</tr>
<tr>
<td><strong>Numeric Scale:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evocative Impact</td>
<td>-.62*</td>
<td>.002</td>
<td>.04</td>
<td>.87</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>-.47*</td>
<td>.03</td>
<td>.12</td>
<td>.60</td>
</tr>
<tr>
<td>Novelty</td>
<td>-.59*</td>
<td>.004</td>
<td>.09</td>
<td>.69</td>
</tr>
<tr>
<td>Technique</td>
<td>-.48*</td>
<td>.03</td>
<td>-.03</td>
<td>.89</td>
</tr>
<tr>
<td>Closure</td>
<td>-.44*</td>
<td>.04</td>
<td>-.03</td>
<td>.91</td>
</tr>
</tbody>
</table>
rightward bisectors. No significant correlations were observed between right-hand line bisection bias scores and ratings.

2.5.2. Analyses of moderator variables. Because line bisection bias, but not accuracy, was related to the painting ratings, we next assessed whether the asymmetrical nature of the stimuli and the direction of the rating scale affected the results. Specifically, Dichotomous Moderated Regressions were run to examine whether stimulus orientation and scale direction moderated the relationship between line bisection bias and ratings. This type of regression analysis allows for the examination of interaction effects by coding a dichotomous interaction term (original and mirrored painting orientation; ascending and descending scale direction; Laerd Statistics, 2015a).

2.5.2.1. Stimulus orientation as a moderator. Participants’ bias scores were used in Dichotomous Moderated Hierarchical Regressions to examine whether stimulus orientation (non-mirrored, mirrored) moderated the relationship between line bisection bias and painting ratings. Assumption tests were conducted and provided sufficient evidence that our data met the necessary assumptions.\(^3\) Hierarchical Multiple Regressions were run for each attribute, separately for left- and right-hand line bisection bias scores. In order to allow for comparison with Drago et al.’s results (2008), the outcome variable was comprised of ratings on the ascending scale formats only (n = 37; 3 There was no evidence of multicollinearity, as no tolerance values were less than .377 (Cohen et al., 2003). Three possible outliers were identified using Studentized Deleted Residuals, and Shapiro-Wilk’s tests indicated that the Studentized residuals were normally distributed (all ps > .05). However, these possible outliers were not overly unusual, as Cook’s distances were all smaller than 1, indicating that there were no influential cases (Cook & Weisberg, 1982), and leverage points were fairly close to the suggested cutoff, indicating no unusual combination of the independent variables. In addition, the assumption of homoscedasticity was reached, based on visual inspection of studentized residuals plotted against predicted values for mirrored and non-mirrored stimuli. Taken together, there is sufficient evidence that our data meet the necessary assumptions.)
non-mirrored = 22; mirrored = 15).

Significant moderator effects of stimulus orientation were observed for analyses of left-hand line bisection bias scores and evocative impact, aesthetics, novelty, and technique, explaining an additional 15.6% to 36.8% of the total variance (Table 2). This was the same for both visual-analogue and numeric ratings. To examine these moderator interactions further, simple slopes analyses were run on each level of the moderator variable (non-mirrored paintings, mirrored paintings) to see which was contributing to the interaction (Figure 2). A significant negative linear relationship existed between ratings of paintings and left-hand line bisection bias scores for non-mirrored paintings, and this changed to a positive linear relationship for mirrored paintings. This pattern is clearly visible in Figure 2, and was observed for each of the significant interaction terms reported in Table 2, with the exception of visual-analogue ratings of novelty and technique for non-mirrored paintings, and numeric ratings of technique for mirrored paintings. No significant results were observed for right-hand line bisection analyses, or for any ratings of closure (all $F$-change $p$s > .11).

2.5.2.2. Scale direction as a moderator. Next, Dichotomous Moderated Hierarchical Regressions were run to examine whether scale direction (ascending, descending) moderated the relationship between line bisection bias and ratings of paintings, after tests of assumptions were met.\(^4\) Hierarchical Multiple Regressions were

---

\(^4\) There was no evidence of multicollinearity, nor were there any outlying cases according to the Studentized Deleted Residuals. Shapiro-Wilk’s tests indicated that the Studentized residuals were normally distributed (all $p$s > .08). Cook’s distances and leverage values all fell within their expected ranges. Homoscedasticity was reached based on visual inspection of Studentized residuals plotted against predicted values for ascending and descending scale type. Altogether, our data met the necessary assumptions for this analysis.
Table 2. Results of hierarchical multiple regressions demonstrating that stimulus orientation moderated the relationship between left-hand line bisection (LLB) bias scores and ratings of art made in visual analog and numeric formats.

<table>
<thead>
<tr>
<th></th>
<th>Evocative Impact</th>
<th>Aesthetics</th>
<th>Novelty</th>
<th>Technique</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$ Change sig.</td>
<td>&lt; .001</td>
<td>.001</td>
<td>.005</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td>$R^2$ Change</td>
<td>.34</td>
<td>.28</td>
<td>.22</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>$df$ Change</td>
<td>1, 32</td>
<td>1, 32</td>
<td>1, 32</td>
<td>1, 32</td>
</tr>
<tr>
<td></td>
<td>$F$ Change sig.</td>
<td>&lt; .001</td>
<td>.004</td>
<td>.003</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>$R^2$ Change</td>
<td>.37</td>
<td>.21</td>
<td>.23</td>
<td>.16</td>
</tr>
<tr>
<td></td>
<td>$df$ Change</td>
<td>1, 33</td>
<td>1, 33</td>
<td>1, 33</td>
<td>1, 33</td>
</tr>
</tbody>
</table>
**Figure 2.** Non-mirrored versus mirrored scatterplots.
run for each attribute, separately for left- and right-hand line bisection bias scores. In order to compare the results to Drago et al. (2008), the analyses were run using participants in the non-mirrored condition only ($n = 46$; ascending condition = 22; descending condition = 24).

Significant moderator effects of scale direction were found for analyses involving evocative impact, aesthetics, novelty, technique, and closure when using left-hand line bisection bias scores as the predictor variable and numeric ratings as the outcome variable (Table 3). The same results were found for visual-analogue ratings, with the exception of a non-significant result for ratings of closure. The moderator interaction term (scale direction x left-hand line bisection bias) explained an additional 10.5%-23.4% of the total variance. No significant results were observed when using right-hand line bisection bias scores as the predictor variable (all $F$-change $p$s $> .54$). To examine the significant interactions further, simple slopes analyses were run on each level of the moderator variable (ascending scale, descending scale) to see which was contributing to the interaction. A significant negative linear relationship existed between all ascending ratings of paintings (excluding closure) and left-hand line bisection bias scores, and a positive linear relationship occurred for descending ratings, though statistical significance was reached only for visual-analogue ratings of novelty (Figure 3).

### 2.6. Discussion

Results show that asymmetries in paintings and rating scales differentially influence ratings given by individuals with left and right visuospatial biases, as indicated by left hand performance on the line bisection task. Specifically, non-mirrored paintings were given higher ratings of evocative impact, aesthetics, novelty, and technique than
Table 3. Results of hierarchical multiple regressions demonstrating that scale direction moderated the relationship between left-hand line bisection (LLB) bias scores and ratings of art made in visual analog and numeric formats.

<table>
<thead>
<tr>
<th></th>
<th>Evocative Impact</th>
<th>Aesthetics</th>
<th>Novelty</th>
<th>Technique</th>
<th>Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LLB Visual Analogue</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F$ Change</td>
<td>4.88*</td>
<td>5.94*</td>
<td>11.40*</td>
<td>6.02*</td>
<td>2.30</td>
</tr>
<tr>
<td>$F$ Change sig.</td>
<td>.03</td>
<td>.02</td>
<td>.002</td>
<td>.02</td>
<td>.14</td>
</tr>
<tr>
<td>$R^2$ Change</td>
<td>.11</td>
<td>.13</td>
<td>.21</td>
<td>.13</td>
<td>.05</td>
</tr>
<tr>
<td>$df$ Change</td>
<td>1, 41</td>
<td>1, 41</td>
<td>1, 41</td>
<td>1, 41</td>
<td>1, 41</td>
</tr>
<tr>
<td><strong>LLB Numeric</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F$ Change</td>
<td>13.30*</td>
<td>6.82*</td>
<td>11.99*</td>
<td>8.26*</td>
<td>7.18*</td>
</tr>
<tr>
<td>$F$ Change sig.</td>
<td>.001</td>
<td>.01</td>
<td>.001</td>
<td>.006</td>
<td>.01</td>
</tr>
<tr>
<td>$R^2$ Change</td>
<td>.23</td>
<td>.14</td>
<td>.22</td>
<td>.16</td>
<td>.15</td>
</tr>
<tr>
<td>$df$ Change</td>
<td>1, 42</td>
<td>1, 42</td>
<td>1, 42</td>
<td>1, 42</td>
<td>1, 42</td>
</tr>
</tbody>
</table>
Figure 3. Ascending versus descending scatterplots.
mirrored paintings by individuals demonstrating leftward line bisection biases, and the opposite pattern was observed for individuals demonstrating rightward line bisection biases. Further, ratings of evocative impact, aesthetics, novelty, technique, and closure made on ascending and descending scales were also found to be differentially related to left-hand line bisection biases. No support was found for the hypothesis that line bisection accuracy is a reliable indicator of general right hemisphere processing, as suggested by Drago et al. (2008), since no relationship was found between line bisection accuracy and painting ratings in our young adult sample. Our results add to the literature that suggests line bisection is a sensitive measure of spatial-attentional bias, which influences perception of left and right hemi-space and thereby affects judgements of asymmetrical stimuli—in this case, paintings.

2.6.1. The moderating effect of asymmetrical paintings and asymmetrical rating scales. Studies of the leftward-biased pseudoneglect phenomenon and rightward-biased hemispatial neglect show that spatial biases influence: perception of brightness, size, and numerosity (Nicholls, Bradshaw, & Mattingley, 1999) and facial expressiveness (Luh et al., 1991; Mattingley, Bradshaw, Phillips, & Bradshaw, 1993); mental imagery and recall (McGeorge, Beschin, Colnaghi, Rusconi, & Della Sala, 2007; Rode, Rossetti, & Boisson, 2001); and physical tasks such as navigating through a doorway (Grossi et al., 2001; Nicholls, Loftus, Mayer, & Mattingley, 2007; Nicholls, Loftus, Orr, & Barre, 2008; Nicholls et al., 2010). The results of the present study extend this literature and show that asymmetrical paintings and directional scales (both visual-analogue scales and numeric) are perceived or processed differently according to the direction and strength of an individual’s spatial bias (as determined by left-hand line
bisection performance). Generally speaking, the more leftward the line bisection bias, the higher the ratings of non-mirrored paintings and the lower the ratings of mirrored paintings, with the opposite applying to individuals demonstrating rightward line bisection biases. Similarly, the more leftward the bisector, the higher the ratings when using an ascending scale and the lower the ratings when using a descending scale, with the opposite pattern of results observed in rightward bisectors. These interactions were observed for both visual-analogue and numeric ratings, and were found consistently for ratings of evocative impact, aesthetics, novelty, and technique.

These findings make sense considering asymmetries inherent in the paintings and rating scales themselves. Previous research has suggested the left side of pictures contain more coherence, meaning, and importance than the right side (Gaffron, 1950; Nelson & MacDonald, 1971; Woelfflin, 1932), and that artwork contains leftward lighting asymmetries (McManus, 1979; Sun & Perona, 1998). In support of this, a post-hoc examination of brightness in the stimulus paintings showed that left halves were significantly brighter than right halves.\(^5\) As for the rating scales, past researchers have found differences between ratings made on ascending and descending scales (Nicholls et al., 2006) and have hypothesised that these differences result from pseudoneglect, or more generally, visuospatial biases. However, to our knowledge, our study is the first to directly look at the relationship between line bisection performance and ratings made on descending and ascending scales.

\(^5\) The paintings were converted into 1-bit black and white images using GNU Image Manipulation Program (GIMP), and the percentage of white pixels in the left and right halves of each painting was calculated and then compared, using a paired samples t-test. The left halves had significantly more white pixels than the right halves, \(t(7) = 4.01, \text{SEM} = 4.33, p = .005\).
2.6.1.1. Hand-use. In the present study, all statistically significant effects were for left-hand line bisection biases, not right.\textsuperscript{6} Because the left hand is controlled by the right hemisphere (e.g., Kawashima et al., 1998), and because the right hemisphere is dominant for visuospatial attention in the majority of people (e.g., Corbetta et al., 1995, 2000, 2002), it may be the case that left-hand line bisection performance is more sensitive to visuospatial bias. Alternatively, right-hand line bisection performance may be affected by confounding cross-hemispheric activation caused by the right-sided motor activity (Bultitude & Aimola Davies, 2002), making left-hand line bisection a more accurate measure of visuospatial bias. In either case, this would further support that the interactions described above result from a general visuospatial bias.

2.6.2. Individual differences in visuospatial biases. The results of our stimulus orientation analyses suggest that the direction and strength of a person’s left-hand line bisection bias score is a predictor of where that person generally focuses his or her attention. Individuals who bisect to the left of centre may attend more to the left side of space in general, and thus attend more to the leftward asymmetries in non-mirrored paintings and subsequently give them higher ratings than mirrored paintings. The opposite would be true for rightward bisectors—they may attend to the right half of the paintings, and thus miss the leftward asymmetries in non-mirrored images, resulting in lower ratings compared to the mirrored images.

\textsuperscript{6}This was further supported by supplementary analyses using z difference scores between left- and right-hand line bisection correlations (Table1). Table A (see online supplemental file at http://dx.doi.org/10.1080/1357650X.2015.1134564, or Appendix 2 of this dissertation) demonstrates that attribute rating correlations with LLB and RLB biases do significantly differ from each other, whereas Table B (see online supplemental file at http://dx.doi.org/10.1080/1357650X.2015.1134564, or Appendix 2 of this dissertation) demonstrates that correlations between line bisection biases and attribute ratings made on the two scale formats (visual-analogue and numeric) do not differ from each other.
An interesting question arises from our findings: why is it that more leftward and more rightward line bisectors display opposite patterns of results on our manipulated variables? In addition to the painting orientation effects, we found that the stronger the leftward bias, the more rightward the ratings (higher ratings on the ascending scale, and lower ratings on the descending scale), and the stronger the rightward the bias, the more leftward the ratings (lower ratings on the ascending scale, and higher ratings on the descending scale). This pattern was observed by Drago et al. (2008) on the ascending scale, and in the present study on both the ascending and descending scales, suggesting that it results from a spatial bias. Considering that the leftward bias of pseudoneglect is observed in a general population, rightward biases are seemingly less common and are rarely examined. One possibility is that rightward bisectors have the opposite hemispheric organisation than that of leftward bisectors. That is, spatial processing which typically activates the right hemisphere in a population that displays pseudoneglect may activate the left hemisphere in a population that displays rightward biases (Benwell et al., 2013; de Schotten et al., 2011).

In the present study, all participants were right-handed, and participants were more leftward biased as a whole. In addition, some were more strongly biased than others, such that line bisection performance fell on a spectrum from very leftward to very rightward. The strength of lateralized brain functioning also appears to fall on a spectrum, with some individuals displaying more strongly lateralized processing (e.g., males: Ingalhalikar et al., 2014; Levy & Reid, 1978; Tomasi & Volkow, 2012, individuals with autism: Kana et al., 2006) and other individuals displaying greater functional connectivity between the two hemispheres (e.g., females and some left-
handed individuals: Ingalhalikar et al., 2014; Levy & Reid, 1978; Tomasi & Volkow, 2012) or even opposite brain organisation (e.g., some left-handed individuals: Levy & Reid, 1978). Because leftward visuospatial biases appear to result from lateralized right hemisphere processing of spatial information (e.g., Corbetta et al., 2000, 2002; Foxe et al., 2003), it is possible that the more likely a person is to have the opposite functional organisation, the more rightward he or she would bisect lines. If this is the case it could explain both: 1) their propensity to bisect to the right of true centre; and 2) the fact that we found fairly consistent opposite patterns from those observed in leftward bisectors on ratings of mirrored and non-mirrored paintings, and on ratings made using ascending and descending scales. This is an intriguing area for future research.

2.6.3. Revisiting the shared neural correlates hypothesis. Although our data do not support the Shared Neural Correlates hypothesis as proposed by Drago et al. (2008), as we found no significant correlations between line bisection accuracy and the ratings, many relationships were observed for processes that have shared neural correlates. In the present study, line bisection biases were consistently related to ratings of four of five tested attributes: emotional evocative impact, aesthetics, novelty, and technique (Table 1). Drago et al. noted that emotional evocation is likely processed by neural regions involved in line bisection performance, and judgements of aesthetics and novelty also appear to involve neural correlates shared with line bisection, such as the right superior and inferior parietal cortex (Junghöfer, Bradley, Elbert, & Lang, 2001; Lang et al., 1998) and other temporoparietal regions (Aftanas et al., 2005; Fink et al., 2009, Heilman et al., 1975; Heller et al., 1997; Jacobsen, Schubotz, Höfel, & Cramon, 2006; Moratti et al., 2008). Thus, shared neural regions may be underlying these relationships, but in a
different fashion than previously proposed. The neural correlates of technique, along with the unrelated attribute of closure, are unknown.

Future fMRI research examining the Shared Neural Correlates hypothesis is needed to elucidate the neural correlates of perceived technique and closure, and to examine whether the perception of emotional evocation, aesthetics, and novelty in this task paradigm are indeed processed in the same regions that are involved in line bisection performance. If it is confirmed that neural regions involved in these processes overlap, it may be that individual differences in structure and/or functioning of these regions account for the relationships observed between line bisection bias and the attribute ratings. For example, individuals who demonstrate greater activation in these regions may display larger visuospatial biases (in line with the Activation-Orientation hypothesis; Bultitude & Aimola Davies, 2002) and more intense experiences of the rated attributes.

2.6.4. Limitations. A large number of analyses were performed to address the hypotheses, and no corrections were made for experiment-wise error rates. Corrections for multiple comparisons (e.g., Bonferroni) limit Type I errors, but have the undesirable side-effect of reduced power and greatly increase the likelihood of Type II errors (Moran, 2003; Nakagawa, 2004; Perneger, 1998). With this, very few, if any, of the otherwise telling results would have reached statistical significance. It should be noted that a number of similar patterns of results emerged repeatedly in different analyses (Figures 2 & 3), giving support to the idea that these patterns were not simply Type I errors but instead reflect underlying visuospatial phenomena.
Additionally, prior experience with or interest in art was not accounted for in the present study. Past research has shown that artists perform better than non-artists on a wide variety of perceptual and drawing tasks (Kozbelt, 2001; Kozbelt & Seeley, 2007). As such, this factor may influence overall line bisection accuracy; however, it seems unlikely that it would change the direction of one’s line bisection bias. Further, we did not ask if participants were familiar with the paintings, which could influence the ratings given. These are extraneous variables that could be accounted for in future research.

2.7. Conclusion

In sum, our findings suggest that line bisection accuracy is not a measure of general right hemisphere functioning, but instead line bisection bias is a sensitive measure of a person’s visuospatial biases. The results suggest that this bias influences where a person attends, and thus influences the stimuli that are processed and perceived—ffecting responses to asymmetrical paintings and on asymmetrical rating scales. Further research is needed directly investigating whether individual differences in visuospatial attentional biases correspond with line bisection bias scores, and whether these relationships arise from individual differences in functional cerebral asymmetries.
3. Individual Differences in Laterality and Ratings of Asymmetrical and Symmetrical Artwork (Study 2)

The results of Study 1 suggest that individual differences in visuospatial attention, as indexed by line bisection performance, can influence the way asymmetrical paintings are perceived and processed. Leftward bisectors gave non-mirrored paintings higher ratings of evocative impact, aesthetics, novelty, and technique, whereas rightward bisectors gave higher ratings of these attributes to mirrored paintings. However, because the attributes examined in Study 1 are predominantly associated with a right hemisphere dominance in the majority of the population (e.g., Heller et al., 1997; Moratti et al., 2008; Fink et al., 2009; Jacobsen et al., 2006), as is visuospatial attention (Corbetta et al., 1995; Gitelman et al., 2002; Macaluso & Driver, 2001; Nobre et al., 1997; Shulman et al., 2010), it is unclear if the individual differences on the painting judgement task occurred as a direct result of opposite patterns of lateralization for visuospatial attention, or if they resulted from opposite patterns of lateralization for the processing of these particular attributes.

In terms of visuospatial attention, it is possible that left bisectors attend to the left side of space in general, resulting from lateralization of visuospatial attention to the right hemisphere (e.g., Benwell et al., 2014; Çiçek et al., 2009; Foxe et al., 2003; Fink et al., 2001), whereas right bisectors may attend to the right side of space due to visuospatial attention being lateralized to the left hemisphere (see de Schotten et al., 2011). Thus, because the paintings used in Study 1 had different features in the left and right sides, leftward and rightward bisectors may have given non-mirrored and mirrored paintings
different ratings due to individual differences in the lateralization of visuospatial attention.

However, if leftward and rightward bisectors have opposite hemispheric organization overall, then this also brings up the possibility that the results of Study 1 were produced by other lateralized functions besides visuospatial attention. In particular, the attributes under investigation (e.g., emotional evocation) may have resulted in preferential activation of the right hemisphere (or left hemisphere in those with atypical lateralization), leading to opposing preferences for non-mirrored or mirrored paintings by leftward or rightward line bisectors. However, because Study 1 did not examine any attributes that are typically associated with left hemisphere lateralization, these two competing explanations could not be addressed by the results of Study 1. As such, these competing explanations were explored in the present study by including judgments of attributes for which the left hemisphere is typically dominant. This was done to try to determine whether leftward and rightward line bisectors differ in their perception of attributes in paintings due to opposite patterns of visuospatial attention, or due to differences in hemispheric dominance for the processing of lateralized attributes

3.1. Neural Basis of Left Versus Right Visuospatial Biases

The phenomenon of pseudoneglect, or leftward bisections on a line bisection task, is associated with right hemisphere dominance for visuospatial attention (Macaluso & Driver, 2001; Nobre et al., 1997; Shulman et al., 2010). Recent evidence suggests that individuals with a rightward bisection bias may have opposite hemispheric organization for visuospatial attention (Benwell et al., 2013; de Schotten et al., 2011). Benwell et al. (2013) examined the time-on-task effect of pseudoneglect, in which leftward spatial
Biases have been shown to shift rightward as an experimental session continues, likely because the right hemisphere dominance for task processing decreases with increasing fatigue (Dufour, Touzalin, & Candas, 2007, Fimm, Willmes, & Spijkers, 2006; Manly, Dobler, Dodds, & George, 2005). In their study, Benwell and colleagues found the reported effect in their leftward biased individuals, but found the opposite in their rightward biased individuals such that the longer they were in the experimental session, the more leftward their spatial biases shifted. The authors suggested that this demonstrates that there are subtypes of individuals who may be differentiated by opposing hemispheric asymmetries for visuospatial attention.

Additional support for the idea of different subtypes comes from de Schotten et al. (2011), who found that asymmetries in a fronto-parietal pathway, the SLF II, corresponded with asymmetries in spatial biases. In particular, left bisectors had larger right than left SLF II, whereas right bisectors had a bilateral or reversed pattern of SLF II asymmetry. Further, in animal models the direction and extent of visuospatial biases appears to be influenced by asymmetries in striatal dopamine levels (Shapiro, Glick, & Hough, 1986; Zimmerberg, Glick, & Jerussi, 1974), such that rodents orient in the direction contralateral to the hemisphere with higher dopamine levels in the striatum. In humans, visuospatial biases may even be predicted by DNA variations in the dopamine transporter gene DAT1 (Newman, O’Connell, Nathan, & Bellgrove, 2012), which is heavily expressed in the striatum (Krause, Dresel, Krause, la Fougere, & Ackenheil, 2003). Individuals with a particular expression of this gene showed pronounced leftward asymmetries in spatial attention, whereas others without this particular gene expression
showed no systematic visuospatial biases (Newman et al., 2012). This suggests that DAT1 variability only accounts for leftward, not rightward, visuospatial biases.

Taken together, these findings suggest that leftward and rightward visuospatial biases on the line bisection task are associated with differing neurochemical and structural asymmetries. Thus, it is likely that participants in Study 1 had differences in the lateral organization of hemispheric functions, which could account for the different patterns of responses observed on the painting judgement task. That is, individuals with leftward visuospatial biases may have had differing patterns of hemispheric organization than individuals with rightward visuospatial biases, leading them to give higher ratings to the non-mirrored and mirrored paintings, respectively.

3.2. Asymmetries in Art

The idea that hemispheric differences influence the perception of paintings relies on the assumption that there are asymmetries in the paintings themselves which are differentially perceived. In support of this assumption, past research has demonstrated that there are some consistent asymmetries in artwork and other images. For example, artwork typically contains an upper-leftward light source, producing a leftward bias in brightness (Hutchison et al., 2011, McDine et al., 2011, McManus, 1979; Sun & Perona, 1998). Further, the left halves of images are shown to be more meaningful and more important (Gaffron, 1950; Nelson & MacDonald, 1971; Woelfflin, 1932); artwork is often named after events depicted in the left side of a picture rather than the right side (Nelson & MacDonald, 1971); and items or individuals with greater agency are typically placed on the left side of images (Maass, Suitner, Favaretto, & Cignacchi, 2009). These leftward asymmetries may be indicative of an underlying neurologically-driven bias
towards the left due to right hemisphere dominance for spatial attention (e.g., Nicholls, Bradshaw, et al., 1999; Nicholls, Clode, et al., 1999), though some researchers suggest that culturally-based scanning biases also play a role (Chokron & De Agostini, 2000; Maass et al., 2009; Tversky, Kugelmass, & Winter, 1991).

Overall, there is support for the idea that certain attributes are represented asymmetrically in artwork in general, and that these asymmetries may relate to hemispheric laterality. In the present study, both asymmetrical and symmetrical paintings were used as stimuli, with symmetrical paintings serving as a control because they were not expected to have substantial differences between the left and right halves. For the asymmetrical paintings, it is likely that the attributes examined in the present study are asymmetrically represented in the left and right halves, as discussed below.

3.2.1. Artists’ handedness and visuospatial biases. Asymmetries within paintings may result from hemispheric asymmetries of the artists themselves. As such, it is important to examine whether the artist of the asymmetrical paintings used in the present study, and in Study 1, was likely to have typical hemispheric organization. To do this, the artist of these asymmetrical paintings was invited to complete a line bisection task with both the left and the right hand, in addition to completing a handedness questionnaire (Elias et al., 1998). He reported a strong right hand preference, and displayed pseudoneglect when using his left and right hand to complete the line bisection task. As discussed in the General Introduction, the majority of right handed individuals (approximately 95%; Borod et al., 1985; Knecht et al., 2000; Rasmussen & Milner, 1977) display neurotypical hemispheric organization. Further, visuospatial processing is typically found in the hemisphere opposite to the language-dominant side (Bryden,
Hécaen, & DeAgostini, 1983; Cai, Van der Haegen, & Brysbaert, 2013; McGlone & Davidson, 1973). Based on this knowledge, it was presumed that the artist of the asymmetrical paintings displayed typical hemispheric organisation. This point is especially important because typical hemispheric organization in the artist allows for the assumption that attributes associated with right hemisphere processing were primarily represented on the left side of paintings, and other attributes associated with left hemisphere processing (e.g., logic; see next section) were primarily represented on the right side of paintings.

The two living artists who contributed symmetrical paintings to the study were also invited to complete the line bisection task and handedness questionnaire. One artist responded, who also reported a strong right hand preference and displayed pseudoneglect when using his right and left hand to complete the line bisection task. This artist contributed one of the symmetrical paintings used in the present study. The deceased artists, whose symmetrical works were used, included Wassily Kandinsky and Paul Klee. Klee was left handed (Lanthony, 1995), and two of his works were selected for the present study. One more painting was included by Kandinsky, who was presumably right handed, as there is no mention of his handedness noted and historical literature usually only mentions handedness when it is atypical (i.e., left handed or ambidextrous). Further, it is estimated that approximately 90% of the population is right handed (Hardyck & Petrinovich, 1977), supporting the assumption that Kandinsky was likely right handed. However, visuospatial biases and handedness were not major considerations for the artists of the symmetrical paintings, in contrast to the importance of these factors for the artist of the asymmetrical works. Indeed, the symmetrical paintings were used as a
control, because they were not expected to have substantial differences between the left and right halves.

3.3. Visuospatial Attention or Other Hemispheric Asymmetries?

The results of Study 1 may have arisen from individual differences in visuospatial attention, or from individual differences in processing the attributes of emotional evocation, novelty, aesthetics, technique, and closure. Differences in visuospatial biases (resulting from differences in hemispheric organisation) would lead to left (or right) bisectors attending more to the left (or right) side of space in general, and thus expressing preference for images with asymmetries towards the preferred side. In the case of Study 1, non-mirrored paintings likely had leftward asymmetries which were preferred by relatively leftward bisectors; mirroring these paintings moved the asymmetries to the right side, and thus they were subsequently preferred by relatively rightward bisectors.

Alternatively, individual differences in the hemispheric organization underlying the processing of the different attributes could have produced the pattern of results observed in Study 1, if different attributes are differentially represented in the right and left sides of the paintings themselves. Emotionally evocative experience and expression are associated with right hemisphere processing in neurologically typical individuals (Heller, 1993; Heller et al., 1997; Moratti et al., 2008), and the attributes of novelty and aesthetics may also involve right hemisphere processing (Fink et al., 2009; Jacobsen et al., 2006). Thus, because emotional evocation, novelty, and aesthetics are associated with right hemisphere dominance, it could be the case that leftward bisectors (who are thought to display typical asymmetries in hemispheric organization) expressed a
preference for paintings with more of the attribute on the left (non-mirrored paintings in Study 1) due to right hemisphere dominance for processing these attributes. In contrast, rightward bisectors may have opposite hemispheric organization in general (de Schotten et al., 2011), and so may have left hemisphere dominance for processing these attributes, leading to a preference for paintings with more of the attribute on the right (mirrored versions of the paintings). It is unclear whether there may be hemispheric asymmetries associated with judgements of the attributes of technique and closure, though these attributes also displayed the relationship discussed above. In summary, because the right hemisphere is typically dominant for visuospatial processing, and also for making judgements of emotional evocation, novelty, and aesthetics, it is difficult to disentangle which factor was underlying the pattern of results observed in Study 1. As such, the present study included attributes which are typically processed by the left hemisphere in order to try to disentangle these competing hypotheses.

One such left-hemisphere attribute is logic. Research suggests that the left hemisphere excels for tasks involving analytical, logical processing (Bever & Chiarello, 2009; Hellige & Michimata, 1989; Kosslyn, 1987; Stalans & Wedding, 1984). Further to this, although artists’ paintings of portraits typically display the left cheek more often than the right cheek (Bruno & Bertamini, 2013; Conesa et al., 1995; McManus & Humphrey, 1973; Nicholls, Clode, et al., 1999; Schirillo, 2000), paintings of males, scientists, and professors are more likely to display the right cheek, which is thought to be due to left hemispheric activation resulting from a wish to convey a more logical or analytical profile (Cate, 2002; Nicholls, Clode, et al., 1999; see also Duerksen, Friedrich, & Elias, 2016).
In addition to logic, some studies have demonstrated that the left hemisphere may be capable of, or even dominant for, processing positively-valenced emotions (Canli et al., 1998), leading to a right visual field attentional bias (Bultitude & Aimola Davies, 2006; Kinsbourne, 1993; Reuter-Lorenz & Posner, 1990). In contrast to logic and positive valence, negative valence is an attribute the right hemisphere is particularly adept at processing (Canli et al., 1998), resulting in a left visual field attentional bias (Bultitude & Aimola Davies, 2006; Kinsbourne, 1993; Reuter-Lorenz & Posner, 1990).

Overall, the attributes examined in Study 1, particularly evocative impact, aesthetics, and novelty, all appear to be preferentially processed by the right hemisphere (though the underlying neural correlates are not known for technique and closure). These attributes were originally introduced by Drago et al. (2008), and were not selected for their known lateralisation. As such, in the present study, additional attributes were selected based on known lateralization: logic and positive valence appear to be lateralized to the left hemisphere, whereas negative valence is lateralized to the right hemisphere. Importantly, the competing explanations for Study 1 (visuospatial bias or attribute processing) can be disentangled by examining attributes associated with the left hemisphere, which should be more greatly expressed in the right half of non-mirrored paintings if they were created by someone with neurotypical hemispheric organization.

3.4. Present Study

The present study examined whether leftward and rightward line bisectors differ in their perception of attributes in paintings due to opposite patterns of visuospatial attention, or due to differences in hemispheric dominance for the processing of lateralized attributes (attribute hemispheric activation hypothesis). To do this, non-
mirrored and mirrored versions of paintings were simultaneously presented, and participants indicated which painting was perceived to display more of a certain attribute. The five attributes examined in Study 1 (evocative impact, aesthetics, novelty, technique, and closure) were used in the present study to see if results could be replicated using a new design that did not require making ratings (due to biases associated with the use of rating scales, as discussed in Study 1). As noted above, the first three of these attributes are typically associated with right hemispheric dominance, and while technique and closure produced similar, albeit less consistent, results to the other three attributes in Study 1, there does not appear to be much research on which hemisphere is dominant for making judgements of these attributes. Importantly, four new attributes were included in the present study—two of which were selected because they have been previously associated with left hemispheric dominance (logic and positive valence), one of which was selected because it has been previously associated with right hemispheric dominance (negative valence), and one of which was selected because of its demonstrated leftward placement in artwork (brightness). By using attributes that are predominately processed by the right hemisphere or the left hemisphere in neurotypical individuals, different predictions can be made depending on whether or not the individual differences in painting judgements arise from lateralized differences in underlying neural architecture for visuospatial attention only, or for attribute processing.

3.4.1. Hypotheses. In the present design, support for each set of hypotheses would produce different patterns of results for the asymmetrical paintings (See Tables 4a and 4b for a summary). First, if individual differences in visuospatial attention led to the
Table 4a. Summary of predicted preferences for asymmetrical paintings.

<table>
<thead>
<tr>
<th>Painting Orientation Preference (POP) for right hemisphere attributes</th>
<th>Visuospatial Processing Hypothesis</th>
<th>Attribute Hemispheric Activation Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relatively Leftward Bisector</td>
<td>Relatively Rightward Bisector</td>
</tr>
<tr>
<td></td>
<td>Non-Mirrored</td>
<td>Mirrored</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Painting Orientation Preference for left hemisphere attributes</th>
<th>Visuospatial Processing Hypothesis</th>
<th>Attribute Hemispheric Activation Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mirrored</td>
<td>Non-Mirrored</td>
</tr>
</tbody>
</table>

Table 4b. Summary of predicted correlations for asymmetrical paintings.

<table>
<thead>
<tr>
<th>Correlation direction between LB bias* and POP bias** scores for right hemisphere attributes</th>
<th>Visuospatial Processing Hypothesis</th>
<th>Attribute Hemispheric Activation Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>Positive</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Correlation direction between LB bias* and POP bias** scores for left hemisphere attributes</th>
<th>Visuospatial Processing Hypothesis</th>
<th>Attribute Hemispheric Activation Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>Positive</td>
<td></td>
</tr>
</tbody>
</table>

*For line bisection bias scores, negative values indicate a leftward bias and positive values indicate a rightward bias.

**For POP bias scores, negative values indicate a preference for non-mirrored images and positive values indicate a preference for mirrored images.
results of Study 1, then the following was predicted for the asymmetrical paintings in the present study:

- The more to the left that a person bisects lines, the more he or she will attend to the left side of paintings, and thus will prefer paintings that display more of the attribute in question on that side. This means that as leftward bias increases non-mirrored paintings will be selected more frequently for attributes expected to demonstrate leftward asymmetries in the original artwork (emotionally evocative impact, negative valence, aesthetics, novelty, and brightness), whereas mirrored paintings will be selected more frequently for attributes expected to demonstrate rightward asymmetries in the original artwork (logic and positive valence).

- In contrast, the more to the right a person bisects lines, the more likely he or she is to attend to the right side of paintings, and thus will prefer paintings that display more of the attribute in question on that side. Specifically, for attributes that display leftward asymmetries in the original paintings, mirrored paintings will be selected more frequently as rightward bias increases, and for attributes that display rightward asymmetries in the original paintings, non-mirrored paintings will be selected more frequently.

However, if hemispheric activation resulting from processing of the relevant attribute contributed to the results of Study 1, with left and right bisectors demonstrating overall opposite hemispheric organization beyond visuospatial processing, then the following was predicted for the asymmetrical paintings in the present study:

- Because pseudoneglect is observed in the majority of the population, leftward bisectors are assumed to have typical laterality. As such, attributes for which the
left hemisphere is typically dominant (i.e., positive valence and logic) will be associated with a rightward attentional bias in leftward bisectors, whereas attributes for which the right hemisphere is dominant (i.e., negative valence, emotional evocation, aesthetics, and novelty) will be associated with a leftward attention bias. Thus, leftward bisectors will select the non-mirrored paintings more frequently regardless of attribute.

- If rightward bisectors have hemispheric organization that is opposite of leftward bisectors overall, then they should select the mirrored paintings more frequently regardless of attribute.

These competing sets of hypotheses applied to the asymmetrical paintings only. Symmetrical paintings were not expected to display more of a particular attribute in only one half, and thus painting orientation preferences were not expected to be correlated with line bisection performance. In this way, symmetrical paintings were used as a control.

### 3.5. Method

#### 3.5.1. Participants.

A total of 57 participants (42 female) completed the present study. All participants were strongly right handed as assessed by questionnaire (Elias et al., 1998; \( M = 4.48; SD = 0.40 \)), with a mean age of 21.04 years (\( SD = 3.87 \)). Participants had normal or corrected vision, and no major neurological or psychiatric conditions according to self-report. Participants were recruited through the Department of Psychology Pool of Research Participants, and received one bonus mark in an undergraduate psychology course in exchange for their time. This study was approved by the University of Regina Research Ethics Board.
3.5.2. Measures.

3.5.2.1. Painting attribute task. To test participants’ preferences for painting orientation based on each attribute, non-mirrored and mirrored painting pairs were presented one above the other on a computer screen, using E-Prime software. The question regarding each attribute was displayed in a single typed line across the centre of the screen (in between the pair of paintings) in 17 point Arial font. Painting stimuli included the eight asymmetrical colour paintings used in Study 1, and seven additional symmetrical colour paintings which served as a control. The symmetrical paintings, viewable in Appendix 3, included: Cycles Top (1996), Cycles Bottom (1996), and Plain (2002) by Holly Fay; Forge (2011) by Ernest Klinger; Farbtafel (1930) and Highways and Byways (1929) by Paul Klee; and Farbstudie Quadrate by Wassel Kandinsky (1913). Each painting pair was shown twice for each of the judged attributes, counterbalanced for top and bottom presentation. The attributes included aesthetics, novelty, technique, closure, emotional evocation, logic, positive valence, negative valence, and brightness. Attributes were completed in blocks so that participants could focus on a single attribute at a time, and these blocks were presented in a random order. The order in which the painting pairs were presented within each block was also randomized. Participants made 30 judgements per attribute, for a total of 270 judgements.

3.5.2.2. Original painting task. In addition to the painting attribute task, participants were tested on whether they could determine which of the two images was the original and which was the mirrored copy. All pairs of non-mirrored and mirrored paintings were displayed one above the other in a random order. Ultimately, painting pairs were displayed two times each, counterbalancing which image appeared on the top
and which appeared on the bottom. As such, there were a total of 30 trials. Half of the participants were asked to identify which painting was the original artwork, and the other half were asked to identify which painting was the mirror-reversed version.

3.5.2.3. Line bisection task. To measure visuospatial biases, a pen-and-paper line bisection task was administered. Like Study 1, each line bisection page consisted of five lines 100 mm in length and 2 mm thick. The lines were equally spaced apart by 4.5 mm on the vertical axis, and staggered from the center of the page by 0 mm, ±20 mm, and ±45 mm. One page was completed with the left hand, one with the right hand, and one with both hands.

The two-hands line bisection condition was introduced to decrease the influence of asymmetric hemispheric motor activation resulting from use of only the right or left hand to complete the line bisection task (McCourt et al., 2001). Theoretically, by using two hands to bisect a line, both hemispheres should be equally activated for motoric factors (Failla et al., 2003). As such, differences in line bisection bias should result from differential hemispheric activation related to visuospatial processing, not motor use, making two-hands line bisection a purer index of individual differences in visuospatial biases. For this condition, participants were shown how to hold the pen, and instructed to use both hands equally when moving and using the pen. This was done to deter participants from favouring one hand over the other, resulting in unintended motor biases.

3.5.2.4. Demographics and handedness. Participants completed a handedness questionnaire by Elias et al. (1998), and provided information about age, sex, and any previously-diagnosed neurological or psychological conditions. For the handedness
measure, scores can range from 1 to 5. A score of less than 3 indicates left handedness, greater than 3 indicates right handedness, and exactly 3 indicates ambidextrousness.

3.5.3. Procedure. Participants first reviewed an informed consent form with the researcher. After giving consent, participants completed the line bisection task. Three pages were completed, one for each hand condition: holding the pen in the left hand, the right hand, and two hands simultaneously. The order of hand conditions was counterbalanced between participants. Next, the painting attribute task was completed, followed by the completion of the demographics and handedness questions. Participants then completed the original painting task. At the end of the study, participants were given an educational debriefing, thanked for their time, and issued a participation credit.

3.5.4. Scoring. The line bisection task was scored by using digital calipers to measure the distance between the true center of the line and participants’ perceived midpoint to the nearest .5 mm. If the bisection deviated to the left of true centre, it was multiplied by -1, whereas rightward bisections were multiplied by +1, so that negative numbers indicated leftward bisection biases and positive numbers indicated rightward bisection biases. The average deviation from the center was calculated separately for left-hand, right-hand, and two-hands line bisections, producing three line bisection bias scores.

Bias scores were also calculated for each attribute in the painting attribute task. Participants’ selections of mirrored and non-mirrored paintings were transformed to painting orientation preference (POP) bias scores using the formula \((M-N)/(M+N)\), where M equals the total number of times the mirrored painting was selected for a given attribute, and N equals the total number of times the non-mirrored painting was selected
for that attribute. POP bias scores ranged from -1 (selected non-mirrored paintings exclusively) to +1 (selected mirrored paintings exclusively). Separate POP bias scores were calculated for responses to asymmetrical paintings and symmetrical paintings, leading to a total of 9 POP bias scores for each painting type.

Finally, for the original painting task, correct responses were given a score of ‘1’ and incorrect responses were scored as ‘0’. From this, the proportion of times participants accurately identified which was the original or mirrored version of the paintings was calculated. A score of 0.5 indicated that participants’ responses were at chance levels. Separate scores were calculated for asymmetrical and symmetrical paintings, leading to a total of two accuracy scores per participant.

3.6. Results

3.6.1. Preliminary analyses. An examination of boxplots revealed a few outliers within the line bisection task and the painting attribute task. For both tasks, these outliers were found in both directions; that is, the values were unusually strong biases to the left or right, or an unusually large proportion of selections of non-mirrored or mirrored art. The outliers were modified by replacing their values with one that was slightly larger than the second largest value (e.g., a person who displayed a left hand line bisection bias of -8.4mm was adjusted to a value of -6.8mm; the next largest score was -6.7mm). In doing so, the value maintained its rank as the largest score, but was no longer so extreme that it had a disproportional influence on the data (Laerd Statistics, 2015b).

One-sample t-tests comparing against a value of ‘0’ (indicating no bias) were used to examine whether the sample displayed a typical pattern of pseudoneglect on the line bisection task. A significant leftward bias was found when the task was completed
with the left hand, \( t(56) = -7.24, p < .001, d = -1.93 (M = -1.93, SD = 2.01) \), consistent with the literature on pseudoneglect. Significant leftward biases were also observed for right hand line bisection, \( t(56) = -5.00, p < .001, d = -1.34 (M = -1.17, SD = 1.77) \), and two-hands line bisection \( t(56) = -4.79, p < .001, d = -1.28 (M = -1.21, SD = 1.91) \).

Notably, the means for both hands line bisection fell between the means for left and right hand line bisection, which is consistent with the idea that it is controlling for the extraneous influence of unilateral motor activation that occurs with one-hand line bisection (Failla et al., 2003; McCourt et al., 2001). A repeated measures ANOVA comparing hand use conditions on the line bisection task showed that the hand conditions significantly differed, \( F(2, 112) = 11.49, MSE = .89, p < .001, \eta^2_p = .17 \). As shown in Figure 4, pairwise comparisons demonstrated that left hand line bisection produced significantly stronger leftward biases compared to right hand line bisection and two-hands line bisection, whereas two-hands and right hand use did not differ from each other.

To determine if participants could identify which painting was mirrored or which was original, one-sample t-tests were run examining whether the scores on the original painting task differed from a value of 0.5, indicating chance levels of identification. The original orientation of the asymmetrical paintings could not be identified at above-chance levels, \( t(52) = .48, p = .63, d = 0.13 (M = .51, SD = .16) \). Surprisingly, for symmetrical paintings, the original painting orientation was identified at a level significantly greater than chance, \( t(52) = 4.34, p < .001, d = 1.20 (M = .60, SD = .16) \). However, because predictions for the main analyses were based only on asymmetrical paintings, it is not a concern that the original orientation of symmetrical paintings was
Figure 4. Comparison of line bisection bias scores for each hand use condition. 
* Difference between conditions is significant at $p < .001$
identified at greater than chance levels. Instead, what is important is that the result of the asymmetrical painting analysis indicates that the sample was not aware of the original painting orientations, and thus possible knowledge of painting orientation could not have influenced performance on the painting attribute task for the asymmetrical paintings.

**3.6.2. Main analyses.** Pearson correlations were run to test the hypotheses outlined in Table 4b, to determine whether line bisection bias scores were related to POP bias scores. Results, displayed in Table 5, revealed significant correlations only for emotionally evocative impact, which has been previously associated with right hemisphere dominance, and thus is likely to be more expressed on the left half of paintings. Importantly, the significant correlations for evocative impact were found only for asymmetrical paintings, not symmetrical paintings, as predicted. In particular, a moderate positive correlation was observed between two-hands line bisection bias scores and POP bias scores for emotional evocation in asymmetrical paintings, and a small positive correlation was also observed between right-hand line bisection and emotional evocation (see Cohen, 1988, for guidelines on assigning strength of correlation to coefficient values). As confirmed by visual inspection of scatterplots, these results indicate that participants with more leftward line bisection bias scores were more likely to choose non-mirrored paintings as more emotionally evocative than those with more rightward line bisection bias scores. Trends towards a positive correlation were also observed for novelty and right-hand and two-hands line bisections, possibly suggesting that leftward bisectors are more likely to perceive non-mirrored paintings as more new or original than mirrored paintings, whereas rightward bisectors may be more likely to
Table 5. Correlations between line bisection bias scores and painting orientation preference (POP) bias scores for each attribute, shown separately for asymmetrical and symmetrical paintings.

<table>
<thead>
<tr>
<th></th>
<th>Asymmetrical Paintings</th>
<th>Symmetrical Paintings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left hand</td>
<td>Right hand</td>
</tr>
<tr>
<td><strong>Right hemisphere attributes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evocative</td>
<td>$r = .21$</td>
<td>$r = .27^*$</td>
</tr>
<tr>
<td>Impact</td>
<td>$p = .12$</td>
<td>$p = .05$</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>$r = .04$</td>
<td>$r = -.02$</td>
</tr>
<tr>
<td>$p = .79$</td>
<td>$p = .87$</td>
<td>$p = .70$</td>
</tr>
<tr>
<td>Novelty</td>
<td>$r = .18$</td>
<td>$r = .23$</td>
</tr>
<tr>
<td>$p = .17$</td>
<td>$p = .09$</td>
<td>$p = .08$</td>
</tr>
<tr>
<td>Negative</td>
<td>$r = .11$</td>
<td>$r = .04$</td>
</tr>
<tr>
<td>$p = .43$</td>
<td>$p = .79$</td>
<td>$p = .63$</td>
</tr>
<tr>
<td><strong>Left hemisphere attributes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logic</td>
<td>$r = -.03$</td>
<td>$r = .14$</td>
</tr>
<tr>
<td>$p = .85$</td>
<td>$p = .31$</td>
<td>$p = .77$</td>
</tr>
<tr>
<td>Positive</td>
<td>$r = .04$</td>
<td>$r = .05$</td>
</tr>
<tr>
<td>$p = .76$</td>
<td>$p = .70$</td>
<td>$p = .81$</td>
</tr>
<tr>
<td>Valence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attributes with unknown laterality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technique</td>
<td>$r = .03$</td>
<td>$r = .02$</td>
</tr>
<tr>
<td></td>
<td>$p = .86$</td>
<td>$p = .91$</td>
</tr>
<tr>
<td>Closure</td>
<td>$r = .02$</td>
<td>$r = .10$</td>
</tr>
<tr>
<td></td>
<td>$p = .89$</td>
<td>$p = .45$</td>
</tr>
<tr>
<td>Brightness</td>
<td>$r = -.09$</td>
<td>$r = -.05$</td>
</tr>
<tr>
<td></td>
<td>$p = .50$</td>
<td>$p = .71$</td>
</tr>
</tbody>
</table>

* correlation is significant at $p < .05$ (2-tailed)

†Note: positive correlations indicate leftward bisectors selected non-mirrored and rightward bisectors selected mirrored. Negative correlations indicate leftward bisectors selected mirrored and rightward bisectors selected non-mirrored.
perceive mirrored paintings as more new or original. However, these correlations did not reach statistical significance.

The above-reported correlations were in the predicted directions, and no other significant correlations were found. No significant results were observed for painting attributes that were expected to display rightward asymmetries as a function of left hemisphere dominance.

3.6.3. Post-hoc analyses of non-mirrored and mirrored painting selections. The above correlations provided a way to examine whether the degree of spatial bias was associated with the proportion of times participants were likely to make mirrored or non-mirrored selections of asymmetrical paintings. However, these analyses were not able to directly indicate whether the number of non-mirrored versus mirrored selections differed among those who bisect to the left, compared to those who bisect to the right. That is, the correlations tested degree of bias moreso than direction of bias. Further, no significant results were found that could address the hypotheses in a meaningful way, and the large number of correlations warrants care in interpreting statistical significance. To address these concerns, post-hoc non-parametric sign tests were run. The number of non-mirrored asymmetrical painting selections was compared to the number of mirrored asymmetrical painting selections, separately for participants who bisected to the left and right of centre when using their left hands (left bisector n = 49, right bisector n = 7), right hands (left bisector n = 42, right bisector n = 14), and two hands (left bisector n = 41, right bisector n = 16) to complete the line bisection task. Data are medians unless otherwise stated. See Table 6 for a summary of statistically significant findings.
Table 6. Significant results for sign tests examining whether the number of non-mirrored and mirrored painting selections made by left and right bisectors differed from each other.

<table>
<thead>
<tr>
<th></th>
<th>Non-mirrored median</th>
<th>Mirrored median</th>
<th>Median of the differences*</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left bisectors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brightness, LLB</td>
<td>10.0</td>
<td>6.0</td>
<td>-4.0</td>
<td>-3.28</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Brightness, RLB</td>
<td>10.0</td>
<td>6.0</td>
<td>-4.0</td>
<td>-3.73</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Brightness, TLB</td>
<td>10.0</td>
<td>6.0</td>
<td>-4.0</td>
<td>-2.96</td>
<td>.003</td>
</tr>
<tr>
<td>Positive, LLB</td>
<td>9.0</td>
<td>7.0</td>
<td>-2.0</td>
<td>-2.01</td>
<td>.05</td>
</tr>
<tr>
<td>Logic, RLB</td>
<td>9.0</td>
<td>7.0</td>
<td>-2.0</td>
<td>-2.09</td>
<td>.04</td>
</tr>
<tr>
<td><strong>Right bisectors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technique, RLB</td>
<td>6.5</td>
<td>9.5</td>
<td>3.0</td>
<td>n/a</td>
<td>.04</td>
</tr>
</tbody>
</table>

Note: LLB = bisection group based on left-hand line bisection performance; RLB = bisection group based on right-hand line bisection performance; TLB = bisection group based on two-hand line bisection performance.

* Differences were calculated by subtracting the number of non-mirrored selections from the number of mirrored selections, such that negative numbers indicate a non-mirrored painting preference and positive numbers indicate a mirrored painting preference.
Sign tests (with continuity corrections) for the left bisectors in all three hand-use conditions showed a statistically significant decrease in the median of the differences for painting selections related to brightness, suggesting that they generally selected the non-mirrored paintings as appearing brighter than the mirrored paintings. Of those in the left-hand condition, 34 selected the non-mirrored paintings, 11 selected the mirrored paintings, and 4 showed no preference. For the left bisectors in the right-hand condition, 31 selected non-mirrored, 7 selected mirrored, and 4 showed no preference. Finally, of those in the two-hand condition, 28 selected non-mirrored, 9 selected mirrored and 4 showed no preference.

Left bisectors in the left-hand condition also demonstrated a statistically significant decrease in the median of the differences for painting selections based on positive valence, suggesting that they perceived the non-mirrored paintings to be more positive than mirrored paintings. In particular, 28 of these left bisectors selected the non-mirrored paintings, 14 selected the mirrored paintings, and 7 displayed no preference.

Of particular relevance to the hypotheses, left bisectors in the right-hand condition demonstrated a statistically significant decrease in the median of the differences for painting selections based on logic. This suggests that they perceived the non-mirrored paintings as appearing more logical; 23 of these participants selected non-mirrored, 10 selected mirrored, and 9 displayed no preference.

Turning to the right bisectors, results of an exact sign test showed a significant increase in the median of the differences for painting selections based on technique, suggesting that these participants preferred the mirrored paintings for this attribute. Of the 14 in the right hand condition, only 2 selected the non-mirrored paintings as
displaying more technique, compared to 10 who selected the mirrored paintings, and 2 who showed no preference. No other significant results were found, all $ps > .07$, including nothing for emotional evocation.

3.7. Discussion

The present study was conducted to shed light on whether the previously observed relationship between orientation-dependent painting ratings and line bisection biases in Study 1 was more likely to have resulted from differences in visuospatial biases or from differences in hemispheric organization for processing the attributes themselves. Both of these explanations suggest that rightward and leftward line bisectors display opposite patterns of hemispheric asymmetries, in line with others’ findings (Benwell et al., 2013; de Schotten et al., 2011), and both are credible explanations for why leftward and rightward bisectors would differ in their perception of artwork. For individuals who bisect lines to the left, visuospatial biases could produce exclusive preferences for paintings which display any attribute of interest on the left side, whereas individuals who are rightward bisectors would prefer paintings that have any attribute of interest on the right side. On the other hand, if hemispheric activation associated with processing the given attribute is underlying the effect, leftward bisectors may have typical hemispheric asymmetries overall, and thus prefer paintings which display left-hemisphere attributes on the right side, and right hemisphere attributes on the left side, as would be expected in non-mirrored paintings created by artists who have typical lateralization. Along this vein, rightward bisectors would prefer mirrored paintings, due to an opposite pattern of lateralization. As such, the present study aimed to distinguish between these two hypotheses by including attributes associated with a left hemispheric dominance (logic
and positive valence) in addition to continuing to examine attributes associated with a right hemispheric dominance (emotional evocation, aesthetics, novelty, and negative valence), and comparing patterns of correlations between line bisection bias and painting orientation preferences for these attributes (see Tables 4a and 4b for these predictions).

The present study found results partially consistent with the results of Study 1, using a new method in which pairs of mirrored and non-mirrored paintings were selected between, rather than rating mirrored and non-mirrored paintings separately. The results of correlations showed that the more that participants bisected lines to the left when using two-hands or the right hand, the more likely they were to select the non-mirrored orientation of asymmetrical paintings as being more emotionally evocative, whereas those who bisected lines more rightward were more likely to select the mirrored paintings when judging this attribute. This effect for evocative impact is similar to the effect observed in Study 1 for this attribute, with the exception that in Study 1 this effect was only found when examining left hand line bisection, and in the present study no significant effect was found for this hand condition. Overall, these results support the idea that evocative impact is indeed represented differently in the left and right halves of paintings. Moreover, this effect further suggests that leftward and rightward line bisectors do perceive asymmetrical paintings differently. However, both evocative impact (for which significant correlations were found), and novelty (for which non-significant patterns similar to evocative impact were found) are primarily processed by the right hemisphere (Fink et al., 2009; Heller, 1993; Heller et al., 1997; Moratti et al., 2008), and visuospatial processing is also a function of the right hemisphere, so it remains unclear whether hemispheric activation related to visuospatial biases or attribute
processing is the best explanation. No correlations were observed for the attributes which should be rightward biased in the non-mirrored paintings as a function of left hemisphere dominance, which would have allowed for the differentiation between the two competing hypotheses for the asymmetrical paintings. No orientation preferences were displayed for symmetrical paintings, as predicted.

3.7.1. Distinguishing between the visuospatial and attribute hemispheric activation hypotheses. The visuospatial hypothesis and the attribute hemispheric activation hypothesis can only be distinguished based on how participants respond to attributes associated with left hemisphere processing, which would display rightward asymmetries in non-mirrored paintings. However, the significant correlational findings in the present study were only for evocative impact, which demonstrates right hemisphere dominance and appears to display leftward asymmetries in the asymmetrical paintings. Importantly, these results were in the predicted direction, which was in line with the results of Study 1 and reinforces the idea that the left side of the original (non-mirrored) paintings is more emotionally evocative.

In contrast, the results of post-hoc analyses did show results for the two left hemisphere attributes, positive valence and logic, in addition to two attributes with no particular known hemispheric laterality, brightness and technique. The findings for logic and positive valence lend tentative support to the attribute hemispheric activation hypothesis. That is, left bisectors seem to direct their attention based on the hemisphere used to process these attributes (left hemisphere), moreso than the hemisphere used to process visuospatial attention (right hemisphere). However, complementary results were not observed for right bisectors, perhaps due to the smaller sample size. The results for
brightness are in line with previous work suggesting that light sources in artwork and advertisements tend to appear on the left (Hutchison et al., 2011, McDine et al., 2011, McManus, 1979; Sun & Perona, 1998). Because brightness is not associated with a particular pattern of laterality, it is assumed that left bisectors attended more to the left when examining paintings for this attribute, thus leading to more selections of non-mirrored paintings (rather than mirrored, which placed the brighter half on the right). The results for technique were also in line with the results of Study 1, in that right bisectors perceived this attribute as more apparent in the mirrored paintings than the non-mirrored paintings, which suggests that the left halves of non-mirrored paintings may display greater technique. Further research on the influence of attribute processing on attentional biases is warranted.

It is unclear why the results of the correlations showed no support for either of the two tested hypotheses, whereas the results of post-hoc analyses showed support for the attribute hemispheric activation hypothesis. One of the main differences is that the correlations compared both the degree and direction of line bisection bias to the degree and direction of painting orientation preference, whereas the post-hoc sign tests focused exclusively on the direction of biases (left or right) and the comparison of number of non-mirrored and mirrored painting selections. By examining the left bisectors and the right bisectors separately, the post-hoc analyses were able to identify what the correlations may not have been sensitive enough to detect. Further, the format of the task may have affected the results of the correlations as discussed in the following section.

3.7.1.1. The effects of task format. The present study used a forced judgement paradigm, which may have led to participants using different cognitive strategies than
they did for Study 1, in turn producing somewhat differing results. Participants were no longer simply viewing a painting and rating how much of an attribute was present, as was done in Study 1, but instead were simultaneously viewing the same image in two orientations (non-mirrored and mirrored), and selecting which of those orientations displayed more of the attribute in question. This was done because in Study 1, both visual analogue and numeric rating scales were influenced by individual differences in visuospatial biases. As such, the use of a forced judgement task removed the influence of visuospatial biases on participant selections.

Forced judgement tasks require participants to work on the assumption the attribute in question is more apparent within one of the two images, so they must detect it. In contrast, rating paintings from 0-100, as was done in Study 1, allows participants to explore and decide for themselves whether or not the attribute exists within the single image. For example, in the present study when deciding which image is more beautiful, one must analyze the details of the images and detect in which image aesthetics is more strongly represented. The analysis of the details requires the use of analytical processing—specifically local processing—which is predominately carried out by the left hemisphere in the majority of the population (Han et al., 2002). As such, it is possible that local processing of the images due to the task type produced unintentional left hemispheric activation in those with typical lateralization (or right hemisphere activation in those with atypical lateralization). This in turn could compete with the right hemispheric activation during the processing of right hemisphere dominant attributes, such as emotional evocation, novelty, aesthetics, and negative valence, reducing the relatively greater right hemisphere advantage and subsequently reducing the overall...
effects. Similarly, if right hemisphere visuospatial biases are underlying the observed effect, the left hemispheric activation from local processing could decrease the extent of the bias, leading to nonsignificant results. This would explain why no additional right hemisphere attributes were correlated with line bisection biases. However, this explanation would also imply accentuated left hemisphere activation when processing left-hemisphere attributes, but no significant correlations were observed for these attributes.

Alternatively, the forced-choice nature of this study may have led participants to simply randomly select from the pair or use a selection strategy (e.g., always picking the top painting), despite being instructed not to do so. It would have been easy to tell that the pairs of images were the same painting, with one being mirrored, so participants may not have been motivated to make genuine comparisons. This could explain why fewer significant correlations were observed in this study compared to Study 1. It should be noted, however, that other studies have successfully used similar free-viewing forced-choice tasks to demonstrate lateralized processing. For example, the greyscales task involves viewing mirrored and non-mirrored luminance gradients and selecting which appears brighter (e.g., Friedrich & Elias, 2014; Nicholls, Bradshaw, et al., 1999; Okubo & Nicholls, 2006), and the chimeric faces task involves viewing mirrored and non-mirrored chimeras (wherein the left and right halves of a face are different) and selecting which displays more of a given attribute such as anger (e.g., Indersmitten & Gur, 2003; Levy et al., 1983). Both of these tasks typically demonstrate leftward preferences (e.g., selecting the images with the brightest/angriest stimuli on the left), which has been associated with right hemisphere dominance for visuospatial attention and emotion.
processing. Further, the results of post-hoc analyses do seem to suggest that a selection strategy was not in place, at least not for left bisectors, who demonstrated a clear preference for non-mirrored images.

Another consideration about the format of the present study is the fact that participants made a total of 270 judgements about the artwork, compared to only 80 in Study 1. The greater number of judgements may have led to right hemisphere fatigue (or left hemisphere fatigue in those with atypical lateralization), a phenomenon discussed in relation to pseudoneglect in Section 3.1. Numerous studies have reported that leftward spatial biases on the line bisection task shift rightward as an experimental session continues; this likely occurs because the right hemisphere dominance for task processing decreases with increasing fatigue (Benwell et al., 2013; Dufour, Touzalin, & Candas, 2007; Fimm, Willmes, & Spijkers, 2006; Manly, Dobler, Dodds, & George, 2005). The painting attribute task was a test that involved, in part, visuospatial processing, in addition to other right hemispheric processes for judgements of evocative impact, aesthetics, novelty, and negative valence. Thus, it is reasonable to think that right hemisphere fatigue (or left hemisphere fatigue in those with atypical lateralization) may have played a role in the present study, leading to decreased asymmetrical processing, and thus fewer significant results compared to Study 1.

A final task-related consideration is that the painting attribute task in the present study was completed on a computer, whereas in Study 1 participants completed a pen-and-paper version of the task. The paintings were smaller when shown on a computer screen, compared to the printouts, due to space constraints. Thus, the larger prints may have allowed for the image to be seen in better detail in Study 1, perhaps leading to a
greater perception of the attributes in question, and potentially explaining some of the differences between that study and the present study.

3.7.2. **Line bisection performance.** Participants in the present study displayed a significant leftward bias when using the right hand to complete the line bisection task. This effect is not entirely surprising based on prior research showing that bisection errors with either hand are generally leftward, though some studies have also shown that right hand use can reduce or even reverse this leftward bisection bias (see Jewell & McCourt, 2000, for a review of the influence of hand use on line bisection). It should be noted, however, that in Study 1 right hand line bisection performance was slightly to the right of centre, albeit non-significantly. Thus, the present sample of participants may have demonstrated stronger right hemispheric lateralization for visuospatial attention than the sample in Study 1. As such, the sample in the present study may demonstrate fewer individual differences in visuospatial biases than the sample in Study 1, perhaps leading to fewer individual differences on the painting judgment task, resulting in fewer significant correlations in the present study compared to the results of Study 1.

With regard to the two-hands line bisection task, it was thought that line bisection biases would fall between the observed biases for left and right hand use, consistent with the idea that the use of two hands is an effective control for motor effects, as discussed in section 3.5.2.3. While this was technically observed, comparing the right-hand and two-hands bias scores in Figure 4 shows that they are actually quite similar, and further that they did not statistically differ from each other. One possible explanation is that participants, all of whom were right handed, still used their right hand more so than their left to guide the bisection lines, despite instructions to use both hands equally. Overall,
two-hand line bisection is worth investigating further to see if it continues to mimic right hand line bisection performance.

3.7.3. Are participants aware of original painting orientation? Participants were unable to accurately distinguish which was the original painting when comparing non-mirrored and mirrored variations of the asymmetrical paintings, so prior familiarity with (and perhaps subsequent preference for) the original orientation of paintings does not factor into the explanation for the results of the present study. However, participants were able to identify the orientation of symmetrical paintings. In this instance, some of the symmetrical paintings are fairly well-known, so it may have been the case that participants were familiar with these paintings and thus able to make correct identifications. Post-hoc one-sample t-tests were run to test this hypothesis, and results did not support this explanation: On their own, neither the famous paintings \((n = 3)\) nor the paintings by local artists \((n = 4)\) were correctly identified as original or mirrored \((p > .15)\). The small number of paintings and low number of participant responses (2 per painting) make it difficult to detect any effect, however, if there was one to be found. Future research may address this by avoiding the use of famous paintings altogether. Nevertheless, because line bisection biases only related to asymmetrical paintings, and participants were unable to detect the original orientation of the asymmetrical paintings, the better-than-chance orientation identification of the symmetrical paintings does not impact the interpretation of the present study’s results.

3.7.4. Limitations and future directions. A limitation to note about the present study is the fact that, when making POP selections, participants were presented with instructions about which attribute to rate. These instructions were presented in the centre
of the screen, between the two paintings. This may have caused some interference in the form of unwanted left hemispheric activation due to language processing (Knecht et al., 2000). While this would explain why not all right hemisphere attributes were correlated with line bisection biases (similar to the description of left hemispheric activation from local processing, as discussed above), this does not explain why there were no significant correlations for left hemisphere attributes. Language processing should have accentuated left hemisphere activation when processing left-hemisphere attributes, increasing the likelihood of significant correlations for these attributes, but no significant results were observed in this situation. However, it should be noted that significant results were observed for both of the left-hemisphere attributes in the post-hoc analyses, and not for the right-hemisphere attributes, which may in fact suggest influence of additional left hemisphere processing, at least in left bisectors.

Alternatively, the left-to-right scanning of the instructions may have also biased attention to the left. Past research has shown that scanning biases can influence the direction of attention (Brodie & Pettigrew, 1996; Chokron & Imbert, 1993; Hurwitz, Valadao, & Danckert, 2011; Nicholls & Roberts, 2002; Sosa & McCourt, 2011). However, even if participants were scanning the paintings from left to right, this would not have influenced painting selection, as the mirrored and non-mirrored paintings were presented concurrently in pairs. In addition, because each attribute was judged in a block, it is likely that participants did not read the instructions repeatedly, because the same attribute would have been under investigation for all trials within the block. Overall, this possible limitation does not appear to be a concern.
Another limitation for the present study is that assumptions were made about where certain attributes are represented within paintings. These assumptions were based on the substantial body of literature demonstrating hemispheric asymmetries for these attributes, and on additional research demonstrating asymmetries in paintings and other images (see sections 3.2 and 3.3). Although the results reinforce the idea that some attributes are asymmetrically placed (i.e., emotional evocation and perhaps novelty, in addition to logic, positive valence, brightness, and technique), at least in the paintings that were used, it is not an idea that was explicitly tested. The next study in this dissertation will address this limitation by examining the left and right halves of the paintings independently, by asking participants to determine which half of a painting appears more emotionally evocative for example. If the left half is selected more often by participants, then one can more conclusively determine that the asymmetries within the paintings fall as predicted.

3.8. Conclusion

The present study was designed to try to determine whether leftward and rightward line bisectors differently perceive attributes in paintings due to opposing patterns of visuospatial attention, or due to differences in hemispheric activation from processing lateralized attributes. The results of Study 1 could be explained with either type of processing due to the fact that both involved preferential right hemisphere activation in those with typical laterality. As such, the present study was meant to disentangle these processes by examining whether attributes typically associated with left hemisphere activation changed the pattern of results. Correlational results suggested that the asymmetrical paintings contained more emotionally evocative imagery on the
left half in the original orientation, as leftward bisectors preferred the original orientation and rightward bisectors preferred the mirrored orientation for this attribute, but no results were observed for attributes typically associated with left hemisphere processing. In contrast, post-hoc analyses demonstrated that leftward bisectors preferred non-mirrored versions of asymmetrical paintings compared to the mirrored counterparts, particularly for the left hemisphere attributes (positive valence, logic) and attributes with no known lateralized hemispheric processing (brightness, technique). As such, it appears as though lateralized attribute processing is a better explanation for the results of Study 1 above and beyond visuospatial processing. The results of the present study also demonstrate that individuals with opposite patterns of visuospatial bias (as indexed by line bisection performance) perceive paintings differently, at least when considering emotionally evocative content.
4. Painting A Picture of How Laterality Influences the Production of Artwork (Study 3)

The results of Study 1, and to some extent Study 2, suggest that there are asymmetries in the content of the paintings that can differentially influence the way they are perceived by individuals with leftward or rightward biases in visuospatial attention. These individual differences in perception appear to be due to opposite hemispheric organization for processing the attributes in question.

In the present study, the asymmetrical paintings which were used in Studies 1 and 2 were examined in order to determine whether the investigated attributes are in fact differentially represented in the left and right halves of these particular artworks in a way that would further support the interpretation of the results of Studies 1 and 2. In addition, consistent with Study 2, paintings that were more symmetrical in their appearance were also examined, based on the expectation that these would be suitable control stimuli; it was expected that only the asymmetrical paintings would display asymmetries in the distribution of content related to the attributes.

The present study was a two-part design, which required participants to compare the left and right halves of the paintings and indicate which half had more of a given attribute. Participants were blind to which half was which, and selected one or the other in a forced-choice judgement paradigm. The forced-choice task was used as a way to address the concern that rating scales introduce visuospatial biases (see Nichols et al., 2006); further, the fact that each half of the asymmetrical painting was quite different from the other meant that there should be less of a concern in terms of motivation and guessing, as described in the discussion of Study 2.
In Study 3a, the paintings were examined for asymmetries related to the attributes used in Study 1, namely: evocative impact, aesthetics, novelty, technique, and closure. Study 3b examined whether the paintings demonstrated asymmetrical representation of the attributes that were introduced in Study 2, namely logic, positive valence, negative valence, and brightness, along with evocative impact once again. The attributes in Studies 3a and 3b were examined separately, by two different groups of participants, to keep the duration of the painting judgement task reasonable.

4.1. Laterality and the Creation of Art

As reviewed in Study 2, researchers have demonstrated that some attributes are represented asymmetrically in artwork, and suggest that some of these asymmetries are related to cerebral lateralization (e.g., Beaumont, 1985; Levy, 1976; Nicholls, Bradshaw, et al., 1999; Nicholls, Clode, et al., 1999). This body of research suggests that the cerebral lateralization of the artists themselves influences the creation of the paintings, and the asymmetries therein. Many of these studies suggest that the typically observed leftward bias in spatial attention influences how images are perceived and how artwork itself is created (e.g., Beaumont, 1985; Nicholls, Bradshaw, et al., 1999; Nicholls, Clode, et al., 1999). As such, it is possible that artists with rightward biases in spatial attention, rather than the more-often reported leftward biases, will structure their paintings differently. Importantly, as discussed in Study 2, it appears that the artist who created the asymmetrical paintings used in Studies 1 and 2 has typical laterality (e.g., right hemisphere dominance for spatial attention), which factored into the hypotheses discussed below. It is also likely that most of the artists who created the symmetrical paintings used in Study 2 had typical laterality.
It is possible that other lateralized processes, besides spatial attention, can influence the creation and perception of artwork, which would lead to either leftward or rightward asymmetries for different attributes in paintings depending on whether there is a right or left hemisphere dominance, respectively, for processing the attribute. This idea is explored in Study 3b, which used the lateralized attributes introduced in Study 2 to see if they were more prominently represented on the right (logic, positive valence) or left (negative valence, brightness, evocative impact) half of the paintings. First, though, in Study 3a, the attributes of evocative impact, aesthetics, novelty, technique, and closure (originally introduced by Drago et al., 2008) were examined to see if they were more prominently represented on the left side of paintings.

4.2. Study 3a

In Study 1, it appeared that the attributes of evocative impact, aesthetics, novelty, technique, and perhaps closure were all leftward biased in paintings (as leftward bisectors gave higher ratings to non-mirrored paintings, whereas rightward bisectors rated mirrored paintings higher), which may suggest right hemispheric involvement of the artist for these attributes in the creation of the paintings. The results of Study 2 also suggested that emotional evocation, and perhaps novelty and technique, were leftward biased in these same paintings. In agreement with these findings, emotionally evocative experience and expression have been associated with right hemisphere processing in neurotypical individuals (Heller, 1993; Heller et al., 1997; Moratti et al., 2008), and novelty may also involve right hemisphere processing (Fink et al., 2009). This idea is further explored in the present study.
The present study was designed to explicitly test whether the above-named attributes are indeed more apparent in the left half of paintings. To test this, the left and right halves of the eight asymmetrical paintings used in Studies 1 and 2, and the seven symmetrical paintings used in Study 2, were compared by participants to determine which half better represented these attributes. The left and right halves of the asymmetrical and symmetrical paintings were centrally presented one above the other in either mirrored or non-mirrored orientations in a counterbalanced fashion, and participants selected which hemi-painting better represented the attribute in question.

Participants also completed a line bisection task to account for the possibility that leftward and rightward bisectors may differ in their evaluations of centrally-presented hemi-paintings. Participants completed the line bisection task using their left and right hands as usual, in addition to using two-hands simultaneously, as was done in Study 2. This two-handed line bisection condition was employed in order to account for the small, but significant, influence that unilateral motor activation is known to have on line bisection performance (McCourt et al., 2001).

4.2.1. Study 3a hypotheses.

4.2.1.1. Do left and right hemi-paintings intrinsically differ for the selected attributes? The artist whose asymmetrical works were used in the present study displayed pseudoneglect on a line bisection task and was right handed, as discussed in Study 2, and thus appears to demonstrate typical hemispheric organization. Furthermore, the results of Study 1 (and Study 2, in part) suggest that there may be leftward asymmetries in these paintings for evocative impact, aesthetics, novelty, technique, and
perhaps closure. As such, the following predictions were made for each attribute for the asymmetrical paintings:

- Evocative impact, aesthetics, and novelty: The results of Study 1 (and Study 2, in part) suggest that these attributes may be biased to the left in non-mirrored paintings. Further, as noted above, there is evidence that the right hemisphere is dominant for processing these three attributes, which in turn may produce leftward biases in attention. As such, the artist who created the asymmetrical paintings may have been more likely to place emotionally evocative, aesthetic, and novel imagery in the left half of the paintings. Therefore, it was predicted that participants in the present study would more often select the left hemi-paintings as having more evocative impact, aesthetics, and novelty than the right hemi-paintings.

- Technique and Closure: It does not appear that the neural correlates for making judgements of technique and closure have been examined to date. If the artist of the asymmetrical paintings does not favour the left or right halves of his artwork in terms of technique (skillful execution) or closure (completeness), then participants should select the left and right hemi-paintings an approximately equal number of times. However, if the artist favours the left half of the paintings for these attributes, as suggested by the results of Study 1 (and Study 2, in part), then it is predicted that participants will select the left hemi-paintings as displaying more technique and closure than the right hemi-paintings.

The above predictions were only expected to apply to the asymmetrical paintings, which have noticeable differences in the left and right halves. In contrast, it was expected that
the symmetrical paintings would not display substantial differences between the left and right halves, considering that each half was remarkably similar in appearance.

**4.2.1.2. Are visuospatial biases related to hemi-painting selection?** The orientation of the asymmetrical hemi-paintings was not expected to affect selections of the left or right half. For example, if the left hemi-paintings contained more aesthetically-pleasing imagery than the right hemi-paintings, then this should not change as a result of mirroring each hemi-painting. Along a similar line, visuospatial biases (as indexed by line bisection performance) were not expected to relate to hemi-painting selections, as each hemi-painting pair was presented centrally. Going back to the example of the left hemi-painting being more aesthetically pleasing than the right: If this quality is inherent in the hemi-painting, then participants, regardless of visuospatial bias, should pick the left hemi-painting more often than the right when comparing the centrally presented left and right halves of the painting.

However, it is possible that each half of the asymmetric hemi-paintings may themselves contain differential representation of the attributes; for example, the left half of the left hemi-painting may display more of a given attribute than the right half of the left hemi-painting. In this instance, it is possible that visuospatial biases, as indexed by line bisection performance, will influence hemi-painting selections. If this is the case, then line bisection performance will be related to hemi-painting selections in a manner that interacts with the painting orientation, as was observed in Studies 1 and 2. For example, if the left half of the left hemi-painting has more evocative impact than the right half of the left hemi-painting, then:
• When presented in a non-mirrored orientation, leftward bisectors should select the left hemi-painting more often than rightward bisectors (demonstrating a positive correlation, as explained in the scoring section below);

• And, when presented in a mirrored orientation, rightward bisectors should select the left hemi-painting more often than leftward bisectors (demonstrating a negative correlation, as explained in the scoring section below).

As such, if line bisection performance and painting orientation do affect hemi-painting painting selections, they must do so together, and in opposite patterns for non-mirrored and mirrored orientations. Further, this effect would only be expected for the asymmetrical hemi-paintings, not the symmetrical hemi-paintings.

4.3. Method

4.3.1. Participants. A total of 28 individuals (24 female) participated in the present study. Participants scored an average of 4.41 out of 5 (SD = .34) on a handedness questionnaire (Elias et al., 1998) and had a mean age of 23.04 years (SD = 4.69). All participants had normal or corrected vision and no major psychiatric or neurological conditions, as assessed by self-report. This study was approved by the University of Regina’s Research Ethics Board, and participants received one bonus mark in an undergraduate psychology course in exchange for their time.

4.3.2. Measures.

4.3.2.1. Hemi-painting attribute task. Painting stimuli included the left and right halves of the eight asymmetrical colour paintings used in Studies 1 and 2, and the left and right halves of the seven symmetrical colour paintings used in Study 2. Digital copies of the paintings were split in half at the mid-line. Both original and mirror-
reversed variations of the paintings were used in the present study. Using E-Prime software, the left and right hemi-paintings were displayed in the centre of the screen, one above the other in a counterbalanced fashion. Participants free-viewed each hemi-painting pair and selected whether the top or bottom hemi-painting better represented the attribute in question. The program recorded whether the selected hemi-painting was the left or the right half.

Within a trial, hemi-paintings were shown in either a non-mirrored or a mirrored format. Attributes were judged in blocks that were presented in a randomized order, such that the five blocks included Evocative Impact, Aesthetics, Technique, Novelty, and Closure. For each of the five blocks, participants made a total of 30 hemi-painting selections: 15 for the non-mirrored asymmetrical and symmetrical hemi-paintings, and 15 for the mirrored variants. The order of the hemi-painting pairs was randomized within each block. Participants made a total of 150 selections throughout the course of the study.

**4.3.2.2. Line bisection task.** In addition to the hemi-painting attribute task, participants completed a pen-and-paper line bisection task. This task was the same as that used in Study 2: each line bisection page consisted of five lines 100 mm in length and 2 mm thick. The lines were equally spaced apart by 4.5 mm, and staggered from the center of the page by 0 mm, ±20 mm, and ±45 mm. One page was completed with the left hand, one with the right hand, and one with both hands.

**4.3.2.3. Demographics and handedness.** Participants also completed a computerized E-Prime version of the demographics questionnaire used in Study 2, which was used to collect information such as age and sex. The Waterloo Handedness
Questionnaire – Revised (Elias et al., 1998) was also administered to assess direction and strength of handedness.

**4.3.3. Procedure.** After informed consent was obtained, participants completed the line bisection task. Three line bisection pages were completed in a counterbalanced order: left hand, right hand, and two-hands. For the two-hands line bisection condition, participants were shown how to hold the pen, and instructed to use both hands equally when moving and using the pen. This was done to try to avoid the inadvertent favouring of one hand over the other, resulting in unintended motor biases. After the hemi-painting attribute task, participants completed the demographics and handedness questionnaires, and then were debriefed, thanked for their time, and awarded their participation mark.

**4.3.4. Scoring.** For the line bisection task, the distance between the true center of the line and the perceived midpoint was measured to the nearest .5 mm using digital calipers. Leftward bisection measurements were multiplied by -1, and rightward measurements were multiplied by +1, so that negative numbers indicated deviations to the left of center, and positive numbers indicated deviations to the right of center. The average deviation from the center was calculated separately for left-hand line bisection, right-hand line bisection, and two-hands line bisection.

A hemi-painting bias score was calculated for the hemi-painting attribute task. The selections made for asymmetrical and symmetrical hemi-paintings were transformed to a hemi-painting bias score using the formula \( \frac{R-L}{R+L} \), where \( R \) represents the total number of times the right hemi-painting was selected and \( L \) represents the total number of times the left hemi-painting was selected. Hemi-painting bias scores ranged
from -1 (selected left half of paintings exclusively) to +1 (selected right half of paintings exclusively).

4.4. Results

4.4.1. Preliminary analyses. Visual examination of boxplots revealed a few outliers for specific attributes within the hemi-painting attribute task. So that these outliers did not exert undue influence on the following analyses, but still maintained their rank as the largest value, the outlying values were changed to be slightly larger than the second-largest value (Laerd Statistics, 2015a).

First, analyses were run to determine whether the sample displayed the typically-reported leftward line bisection biases. One-sample t-tests demonstrated that the sample displayed a significant leftward bias when using the left hand to complete the line bisection task, \( t(27) = -4.97, p < .001, d = -1.91 (M = -1.59, SD = 1.69) \). No significant bias was observed for line bisection using two-hands, \( t(27) = -1.35, p = .19, d = 0.52 (M = -0.42, SD = 1.64) \), or the right hand, \( t(27) = 0.45, p = .66, d = 0.02 (M = 0.13, SD = 1.55) \). These results for left and right hand line bisection performance are typical (see Jewell & McCourt, 2000); it is interesting to note that two hand line bisection performance fell in between left and right hand performance, as initially predicted. Furthermore, two hand performance was still to the left of centre much like left hand performance, suggesting pseudoneglect (albeit non-significantly). A repeated measures ANOVA comparing hand use conditions on the line bisection task showed that the hand conditions significantly differed, \( F(2, 54) = 12.51, p < .001, \eta^2_p = .32 \). Pairwise comparisons showed that the left hand line bisection condition produced significantly stronger leftward bisections than right hand line bisection, \( p < .001, SEM = .40 \), and two-
hands line bisection, \( p < .002 \), \( SEM \leq .35 \). The right hand and two-hands condition did not significantly differ from each other, \( p = .08 \).

4.4.2. Main analyses.

4.4.2.1. Are attributes differentially represented in the right and left halves of the paintings? Analyses were run to examine the direction and extent of biases that might be inherent in the paintings, to see whether these biases matched the prediction that the left hemi-paintings would be selected as displaying more of each attribute. Specifically, one-sample t-tests were conducted to examine whether the hemi-painting bias scores were significantly different from zero for each of the attributes – that is, whether the left or right hemi-painting was selected significantly greater than chance. Significant bias scores were expected for the asymmetrical paintings only.

Unexpectedly, results for asymmetrical paintings showed that the right half of paintings were selected as displaying more technique, \( t (27) = 4.03, p < .001, d = 1.55 \), at above chance-levels, as seen in Figure 5. No other attributes demonstrated significant bias scores for the asymmetrical paintings, all \( ps > .08 \). For symmetrical paintings, results showed that the left half of paintings were selected as more aesthetically pleasing, \( t (27) = -4.89, p < .001, d = -1.88 \), as seen in Figure 6. No other attributes demonstrated significant bias scores for the symmetrical paintings, all \( ps > .09 \).

Although any potential influence of orientation on the results was primarily examined in the next section, it should be noted that re-running the above analyses

---

7 Post-hoc sign tests were also run to examine whether there were significant differences in the number of times the left and right hemi-paintings were selected. Results were similar to those produced by the correlations: the right asymmetrical hemi-paintings were selected as showing more technique (\( p = .001 \)), and the left symmetrical hemi-paintings were selected as being more aesthetically pleasing (\( p = .001 \)). When examining non-mirrored and mirrored paintings separately, the same pattern of results was also found.
Figure 5. Mean hemi-painting selection scores for asymmetrical paintings (±SEM).

* $p < .001$
Figure 6. Mean hemi-painting selection scores for symmetrical paintings (±SEM).
* $p < .001$
separately for the non-mirrored and mirrored conditions showed the same pattern of significant results for both orientations, in addition to showing significant leftward bias scores for technique and closure only in the mirrored conditions for symmetrical paintings, $ps < .05$. Corresponding to this, paired sample t-tests comparing the mirrored and non-mirrored conditions demonstrated an effect of orientation on symmetrical hemi-painting selections of technique, $t(27) = 2.82, p = .009, d = 1.09$. When symmetrical paintings were presented in a non-mirrored orientation, no significant hemi-painting bias was observed ($M = .05, SD = .36$), but in a mirrored orientation the left half was selected as displaying greater technique ($M = -.17, SD = .41$). No other significant results were found, all $ps > .11$.

**4.4.2.2. Are visuospatial biases related to hemi-painting attribute selections?**

Visuospatial biases (as indexed by line bisection performance) were not expected to relate to hemi-painting selections, as each hemi-painting pair was presented centrally. To evaluate whether visuospatial biases had an unexpected influence on the results, Pearson correlations were used to examine the relationship between line bisection biases and hemi-painting selections (collapsed over mirrored and non-mirrored conditions). No significant results were found, all $ps > .09$. These results suggest that leftward and rightward bisectors do not have intrinsic preferences for the left or the right side of the paintings, when they are centrally presented.

Although it does not seem that visuospatial biases had undue influence on the overall results, it is still possible that the asymmetrical hemi-paintings may themselves contain asymmetries that could affect perception of the attributes, particularly as some orientation differences were found as noted in the previous section. For example, the left
half of the left hemi-paintings may display more of a given attribute than the right half of the left hemi-paintings. In this instance, it is still possible that visuospatial biases and hemi-painting orientation worked together to influence selections. As discussed in the hypotheses, if visuospatial bias (as indexed by line bisection performance) and painting orientation do affect hemi-painting selections, they must do so together, and in opposite patterns for non-mirrored and mirrored orientations. As such, Pearson correlations were conducted to determine if line bisection scores were related to hemi-painting biases in a predictable and opposing fashion for mirrored and non-mirrored orientations.

Pearson Correlations between line bisection bias scores and hemi-painting bias scores for mirrored and non-mirrored orientations (separately) revealed no significant correlations out of 60 (Table 7). Thus, it appears that visuospatial biases and hemi-painting orientation do not affect these hemi-painting selections.

4.5. Study 3a Discussion

The present study examined whether certain attributes—emotion evocation, aesthetics, and novelty, which are processed predominantly by the right hemisphere (Fink, et al., 2009; Heller, 1993; Heller et al., 1997; Jacobsen et al., 2006; Moratti et al., 2008)—are manifested primarily in the left half of asymmetrical paintings. As expected, different results were observed for asymmetrical and symmetrical paintings. However, the direction of the only significant asymmetric painting result was unexpected, as was the attribute for which it was found – a right hemi-painting bias for technique. Based on the results of Study 1 and to some extent Study 2, and on literature suggesting right hemisphere dominance, it was predicted that participants would select the left half of asymmetrical paintings as displaying more emotion evocation, aesthetics, and novelty.
Table 7. Pearson correlations between line bisection bias scores* and hemi-painting bias scores** for asymmetrical and symmetrical paintings in mirrored and non-mirrored orientations for Study 3a.

<table>
<thead>
<tr>
<th></th>
<th>Asymmetrical Paintings</th>
<th>Symmetrical Paintings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-mirrored</td>
<td>Mirrored</td>
</tr>
<tr>
<td><strong>Aesthetics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = .12$</td>
<td>$r = .16$</td>
</tr>
<tr>
<td></td>
<td>$p = .55$</td>
<td>$p = .41$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = -.23$</td>
<td>$r = -.13$</td>
</tr>
<tr>
<td></td>
<td>$p = .25$</td>
<td>$p = .51$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = .03$</td>
<td>$r = .11$</td>
</tr>
<tr>
<td></td>
<td>$p = .90$</td>
<td>$p = .59$</td>
</tr>
<tr>
<td><strong>Closure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = -.21$</td>
<td>$r = -.25$</td>
</tr>
<tr>
<td></td>
<td>$p = .28$</td>
<td>$p = .21$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = .22$</td>
<td>$r = -.12$</td>
</tr>
<tr>
<td></td>
<td>$p = .25$</td>
<td>$p = .55$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = .01$</td>
<td>$r = -.16$</td>
</tr>
<tr>
<td></td>
<td>$p = .95$</td>
<td>$p = .42$</td>
</tr>
<tr>
<td><strong>Evocative Impact</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = -.01$</td>
<td>$r = -.16$</td>
</tr>
<tr>
<td></td>
<td>$p = .95$</td>
<td>$p = .42$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = .28$</td>
<td>$r = .06$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = .29$</td>
<td>$r = -.13$</td>
</tr>
<tr>
<td></td>
<td>$p = .13$</td>
<td>$p = .51$</td>
</tr>
<tr>
<td><strong>Novelty/Originality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = .15$</td>
<td>$r = -.14$</td>
</tr>
<tr>
<td></td>
<td>$p = .46$</td>
<td>$p = .48$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = .03$</td>
<td>$r = .04$</td>
</tr>
<tr>
<td></td>
<td>$p = .87$</td>
<td>$p = .85$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = .37$</td>
<td>$r = -.09$</td>
</tr>
<tr>
<td></td>
<td>$p = .054$</td>
<td>$p = .64$</td>
</tr>
<tr>
<td><strong>Technique</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = -.15$</td>
<td>$r = -.10$</td>
</tr>
<tr>
<td></td>
<td>$p = .45$</td>
<td>$p = .60$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = .17$</td>
<td>$r = .31$</td>
</tr>
<tr>
<td></td>
<td>$p = .39$</td>
<td>$p = .11$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = -.04$</td>
<td>$r = -.08$</td>
</tr>
<tr>
<td></td>
<td>$p = .85$</td>
<td>$p = .70$</td>
</tr>
</tbody>
</table>

* Negative values indicate leftward line bisection bias scores, whereas positive values indicate rightward line bisection bias scores. †
** Negative values indicate leftward hemi-painting bias scores, whereas positive values indicate rightward hemi-painting bias scores. †
† Thus, positive correlations are associated with leftward bisectors selecting the left hemi-painting, and rightward bisectors selecting the right hemi-painting.
However, no significant results were found for these variables. Further, based on the results of Study 1, it was predicted that participants would select the left half of asymmetrical paintings as displaying more skill (technique) and completeness (closure), if biases were observed for these variables at all. Oddly, participants selected the right half of asymmetrical paintings as displaying greater technique than the left half. This was one of the two attributes for which there is no literature suggesting any lateralized processing, and which appeared to be leftward biased based on the results of Studies 1 and 2.

Furthermore, no consistent biases were expected for symmetrical paintings, but the left half was selected as more aesthetically pleasing significantly more often than the right half. It was predicted that a left hemi-painting preference would be observed for this attribute, but only for asymmetrical paintings. This result may be spurious, or it may be that there are subtle differences in the left and right halves of symmetrical paintings, at least in terms of beauty/aesthetics. No other attributes were found to significantly differ between the right and left halves of the asymmetrical and symmetrical paintings. However, when examining only mirrored symmetrical hemi-paintings, the left hemi-painting was more often selected for technique.

In addition, consistent with the hypotheses, there does not appear to be a relationship between visuospatial bias and hemi-painting selections. Thus, it does not appear that the attributes are differentially represented in the right and left halves of the hemi-paintings (e.g., within the right half, there does not appear to be differences between the right and left sides), nor does it appear that leftward and rightward bisectors have intrinsic preference for the left or right hemi-paintings. This further suggests that
the results of Studies 1 and 2 can be attributed to individual differences in visuospatial biases, as rightward and leftward bisectors do not perceive the left and right halves of paintings differently when they are centrally presented. Only when whole paintings are presented do differences begin to appear between left and right bisectors.

The results of Studies 1 and 2 are fairly consistent, suggesting the left half of asymmetrical non-mirrored paintings show more evocative impact, technique, and perhaps novelty and aesthetics (according to Study 1) than the right half. However, in the present study, the left asymmetrical hemi-paintings were not selected more frequently than the right when selecting for evocative impact, nor for novelty, aesthetics, or technique. In fact, the results for technique were in the opposite direction from what was predicted. Further, the left hemi-paintings were chosen more frequently for aesthetics than the right hemi-paintings, but only for the symmetrical paintings, which was unexpected. Thus, the results of the present study are not in line with what would be predicted based on the results of Studies 1 and 2.

It is important to note that the five attributes in the present study were those originally selected by Drago et al. (2008) based on prior studies investigating creativity and art; they were not specifically selected to investigate laterality. Although post-hoc investigation suggests that three of these attributes do appear to be associated with lateralized functions (emotional evocation, aesthetics, and novelty), they were not initially selected for this purpose. Thus, examination of variables that were specifically selected based on past laterality research is warranted.
4.6. Study 3b

The following study examined whether attributes that are known to rely on lateralized hemispheric processing are differentially represented in the left and right halves of paintings, to explore whether there is a possible biological explanation for where artists place these attributes within their paintings. In line with Study 2, these lateralised variables included positive valence, negative valence, logic, and evocative impact. Brightness was also examined because of its established asymmetrical placement in art that is thought to be related to visuospatial biases (Hutchison et al., 2011; McDine et al., 2011; Sun & Perona, 1998). It is not clear whether this leftward lighting/brightness bias is related to hemispheric asymmetries, though some researchers do suggest that it may be related to visuospatial biases (Hutchison et al., 2011; McDine et al., 2011). For this reason, it was an attribute of interest in the present study, even though the perception of brightness itself is not known to be associated with cerebral asymmetries. Further, given that asymmetries in brightness can be objectively verified, this variable served to validate the design.

4.6.1. Laterality of emotion and logic. The right hemisphere appears to be dominant for processing emotional evocation (Borod, 1992; Borod et al., 1998; De Renzi et al., 1994; Harciarek et al., 2006; Ley & Bryden, 1982). For example, studies have demonstrated that regions of the right hemisphere, such as the anterior temporal cortex (Lane, Chua, & Dolan, 1999), the superior and inferior parietal cortex (Junghöfer et al., 2001; Lang et al., 1998), and other temporoparietal regions (Aftanas et al., 2005; Heilman et al., 1975; Heller, 1993; Heller et al., 1997; Moratti et al., 2008) are particularly active during emotional arousal.
Moreover, according to the valence hypothesis, the right hemisphere is particularly adept at processing negatively-valenced emotions, whereas the left hemisphere can process positively-valenced emotions (Canli et al., 1998; Davidson, 1995; Kinsbourne, 1978; Reuter-Lorenz & Davidson, 1981; but c.f. Borod et al., 1988). Along this line, studies have demonstrated that negatively-valenced stimuli can be better processed when presented in a manner conducive to right hemisphere processing (e.g., presented in the left visual field), whereas positively-valenced stimuli are better processed when presented in a manner conducive to left hemisphere processing (Balconi & Pozzoli, 2003; Jansari et al., 2000; Reuter-Lorenz & Davidson, 1981; Rodway & Schepman, 2007; Shamay-Tsoory et al., 2008; Smith & Bulman-Fleming, 2005; Tapia et al., 2008). For example, Reuter-Lorenz and Davidson (1981) found that participants identified the presence of happy faces significantly faster than sad faces when the faces were presented in the right visual field (processed by the left hemisphere), whereas left visual field presentation of these faces (right hemisphere processing) resulted in faster identification of sad than happy faces. With this being the case, it is also possible that valence may bias the direction of attention based on which hemisphere is dominant for processing that valence. Support for this suggestion comes from an fMRI study by Canli et al. (1998) which demonstrated that the left hemisphere is indeed more highly activated than the right in response to positive pictures, which combined with the activation-orientation hypothesis, suggests that positive valence may draw attention to the right side of space. Furthermore, Canli et al. reported that the right hemisphere is more highly activated than the left in response to negative pictures, which may result in an attentional bias to the left side of space. Taken together, this suggests that emotional valence may
influence how individuals perceive and conceptualize emotional content, and thus how emotional content may be arranged within a painting by artists.

In terms of posing biases, as discussed earlier, a number of researchers have demonstrated that artists’ paintings of portraits display the left cheek more often than the right cheek (Bruno & Bertamini, 2013; Conesa et al., 1995; McManus & Humphrey, 1973; Nicholls, Clode, et al., 1999; Powell and Schirillo, 2011; Schirillo, 2000; Schirillo and Fox, 2006). Nicholls, Clode, et al. (1999; see also Cate, 2002; Duerksen et al., 2016) noted that this leftward bias is especially prevalent for portraits of females, less so for portraits of males, and nonexistent for portraits of scientists from the Royal Society.

Upon examining this phenomenon, Nicholls et al. demonstrated that participants tended to pose with more of their left side showing when they were asked to convey emotional content, and they chose to pose with more of their right side showing when asked to conceal emotional content or to appear scientific. Nicholls and colleagues suggested that this occurred due to the proficiency of the right hemisphere in emotion processing: the right hemisphere is more highly activated than the left during emotion processing, which could result in more attention to, and thus emphasis on, the contralateral half of the body when emotions are portrayed. In contrast, when asked to pose as a scientist, individuals may have wished to conceal emotions and thus presented the other half of their face. However, it is also possible that the rightward bias that was demonstrated when asked to pose as a scientist arose from the stereotypical idea of a scientist as logical and analytical (Cate, 2002). In this case, the left hemisphere may have been more highly activated than the right due to its analytical capabilities (e.g., Bever & Chiarello, 2009), leading to a contralateral right-side posing bias.
The research on valence and posing biases suggests that hemispheric dominances for different types of emotional and cognitive processing may lead to systematic asymmetries within artwork. To test this idea, participants selected whether the lateralized attributes of emotional evocation, positive valence, negative valence, and logic (in addition to brightness) were also asymmetrically placed within paintings by comparing the left and right halves and choosing which half better represented the attribute in question.

**4.6.2. Study 3b hypotheses.** As noted earlier, the fact that the artist of the asymmetrical paintings appeared to demonstrate typical hemispheric organization for visuospatial processing was especially important for this study, which examined whether well-known hemispheric functional asymmetries were related to asymmetries in the placement of attributes in the left or right halves of his paintings. Importantly, unlike Study 3a, attributes associated with left hemisphere processing were included in the present study, in addition to the right hemisphere attributes. This allowed for an investigation of whether asymmetrical placement of attributes in paintings corresponds with known left and right hemispheric processing, respectively, suggesting that the placement is not simply a result of left visual field (right hemisphere) spatial bias. Emotional evocation was examined a second time in the present study, due to the fact that emotional evocation has been associated with right hemisphere activation, and because it produced significant predicted results in Studies 1 and 2, but not in Study 3a. Because no effects were observed for this attribute in Study 3a, this served as a direct replication to see whether there was no effect to be found, or whether there are other
explanations (e.g., atypical sample in Study 3a). Similar to Studies 2 and 3a, symmetrical paintings were included as control stimuli.

4.6.2.1. Do left and right hemi-paintings intrinsically differ for the lateralized attributes? The hypotheses for the lateralized attributes examined in the present study are outlined below:

- Evocative impact and negative valence: It was expected that the left hemi-paintings would be selected more often than the right hemi-paintings for the attributes of evocative impact and negative valence, due to their association with right hemisphere processing.

- Logic and positive valence: These attributes are associated with left hemisphere processing, so it was expected that the right hemi-paintings would be selected more often as being more logical and more positively-valenced than the left hemi-paintings.

- Brightness: Because artwork typically displays a light source on the left side, it was predicted that participants would select the left hemi-paintings as the brighter halves more often than the right hemi-paintings.

Similar to Study 3a, these predictions were only expected to apply to the asymmetrical paintings, which have marked differences between the left and right halves. In contrast, it was expected that participants would select the left and right halves of the symmetrical paintings an equal number of times when judging the attributes, indicating no significant asymmetries in the placement of content related to these attributes.
4.6.2.2. Are visuospatial biases related to selection of hemi-paintings?

Similar to study 3a, line bisection was used to determine if visuospatial biases were related to intrinsic preferences for the left or right sides of paintings, independent of their spatial location.

- It was expected that line bisection bias would not be related to hemi-painting selections for each attribute, as the hemi-paintings were centrally presented.
- However, if for some reason an effect of visuospatial bias was to be observed, then line bisection performance would be associated with opposite patterns of results for mirrored and non-mirrored versions of the hemi-paintings, due to asymmetries within the hemi-paintings themselves (as discussed more fully in the Hypotheses for Study 3a).

4.7. Method

4.7.1. Participants. A total of 26 individuals participated in this study, 22 of whom were female. All participants were under 40 years of age ($M = 20.54$ years, $SD = 2.83$), had normal or corrected-to-normal vision, and were right handed ($M = 4.42, SD = 0.24$) as determined by the Waterloo Handedness Questionnaire–Revised (Elias et al., 1998).

4.7.2. Measures and procedure. The line bisection task and the hemi-painting attribute task were the same as described in Study 3a, except that participants were asked to determine which image appeared more logical, more positive, more negative, brighter, and evoked more emotion.

4.7.3. Scoring. The tasks were scored in the same way as described in Study 3a.
4.8. Results

4.8.1. Preliminary analyses. First, examination of boxplots revealed a few outliers in the line bisection task and the hemi-painting attribute task. Like Study 3a, to control for any undue influence these outlying values might have on the analyses, they were modified to be slightly larger than the second-largest value. In doing so, these values still maintained their rank as the largest, but no longer were abnormally larger than the rest of the values (Laerd Statistics, 2015a).

First, analyses were conducted to determine whether participants displayed typical leftward line bisection biases. Similar to Study 3a, and in-line with previous literature, one-sample t-tests revealed that participants displayed a significant leftward bisection bias for their left hand, \( t(25) = -5.61, p < .001, d = -2.24 (M = -1.76, SD = 1.60) \). Also like Study 3a, no significant bias was observed for line bisection using two-hands, \( t(25) = -0.70, p = .49, d = -0.28 (M = -.21, SD = 1.53) \), or the right hand, \( t(25) = 1.15, p = .26, d = 0.46 (M = 0.31, SD = 1.38) \), but it is noteworthy that the two-hands condition demonstrated a leftward bias and produced a mean that was intermediate to the left and right hand means, as also observed in Study 3a. Repeated measures ANOVAs comparing hand use showed that there was a difference between the hand-use conditions, \( F(2, 50) = 16.40, p < .001, MSE = 1.84, \eta^2_p = .40 \). Specifically, pairwise comparisons showed left hand line bisection produced significantly stronger leftward bisections than right hand line bisection, \( p < .001, SEM = .39 \), and two-hands line bisection, \( p < .002, SEM = .44 \). The right hand and two-hands condition did not significantly differ from each other, \( p = .08 \).
4.8.2. Main analyses.

4.8.2.1. Are lateralised attributes differentially represented in the right and left halves of paintings? One-sample t-tests were used to examine whether the hemi-painting bias scores for each of the attributes significantly differed from zero, indicating that the attribute is preferentially represented in the left or right half of the painting. These analyses showed that only asymmetrical paintings displayed significant selection biases, as predicted. As shown in Figure 7, the left half of paintings were selected more often as appearing more bright, \(t(25) = -18.42, p < .001, d = -7.37 (M = -.68, SEM = .04, SD = .19)\), and more positive, \(t(25) = -4.00, p = .001, d = -1.60 (M = -.31, SEM = .08, SD = .40)\), than the right hemi-paintings. In contrast, the right half of paintings were selected more often as appearing more logical, \(t(25) = 3.02, p = .006, d = 1.21 (M = .16, SEM = .05, SD = .27)\), and more negative, \(t(25) = 7.97, p < .001, d = 3.19 (M = .38, SEM = .05, SD = .24)\), than the left hemi-painting. The results for brightness and logic matched the predictions, but the results for positive and negative valence were opposite to what was predicted. No other hemi-painting selection biases were significant, including those for symmetrical paintings (see Figure 8, all \(ps > .07\)).

Although any potential influence of orientation on the results was primarily examined in the next section, it should be noted that re-running the above analyses separately for the non-mirrored and mirrored conditions showed the same pattern of

---

8 Post-hoc sign tests were also run to examine whether there were significant differences in the number of times the left and right hemi-paintings were selected. Results were similar to those produced by the correlations: for the asymmetrical paintings the left hemi-art was selected as showing more brightness \((p < .001)\) and positive valence \((p = .01)\), whereas the right hemi-art was selected as showing more negative valence \((p < .001)\). When examining non-mirrored and mirrored paintings separately, the same pattern of results was also found, with the addition of the right non-mirrored hemi-paintings selected as appearing more logical \((p = .02)\).
Figure 7. Mean hemi-painting selection scores (±SEM) of lateralized attributes for asymmetrical paintings.
Figure 8. Mean hemi-painting selection scores (±SEM) of lateralized attributes for symmetrical paintings.
significant results for both orientations. Further paired sample t-tests comparing whether the hemi-painting selections differed in the mirrored and non-mirrored conditions were run to see if there was an unexpected influence of orientation. As expected, results did not demonstrate an effect of orientation, all ps > .26.

4.8.2.2. Are visuospatial biases related to hemi-painting attribute selections?

Visuospatial biases were not expected to relate to hemi-painting selections because each hemi-painting pair was presented centrally. Nevertheless, to determine whether visuospatial biases had an unexpected influence on the results, Pearson correlations were run to examine the relationship between line bisection biases and hemi-painting selections (collapsed over mirrored and non-mirrored conditions). For asymmetrical paintings, right hand line bisection was negatively correlated with hemi-painting selections for positive valence, $r = -.46, p = .02$, suggesting that leftward bisectors were more likely than right bisectors to demonstrate a right hemi-painting preference, while rightward bisectors were more likely to demonstrate a left hemi-painting preference. Also, two-hand line bisection was positively correlated with asymmetrical hemi-painting selections for brightness, $r = .42, p = .03$; although all participants selected the left hemi-art as brighter, leftward bisectors demonstrated a stronger left hemi-painting preference than rightward bisectors. Surprisingly, for symmetrical paintings, left hand line bisection was negatively correlated with selections for brightness, $r = -.42, p = .03$, such that the most leftward bisectors were more likely to perceive the right hemi-paintings as brighter.
compared to those with relatively rightward biases.9

It appears as though visuospatial biases can influence hemi-painting selections of both asymmetrical and symmetrical artworks, despite symmetrical paintings not displaying any significant results in the first portion of the main analyses (See Figure 8). This was further investigated with Pearson Correlations, to determine if visuospatial biases were related to hemi-painting selections in a predictable fashion for mirrored and non-mirrored orientations. If hemi-painting selections are influenced in this fashion, correlations in opposite directions would be expected for mirrored and non-mirrored pairings for each attribute. As discussed in the hypotheses, these correlations would be expected for the asymmetrical paintings only.

Pearson correlations produced five out of 60 significant correlations (Table 8), none of which were consistent across the above-described mirrored/non-mirrored pairings. Two of these correlations were for asymmetrical paintings: right hand line bisection was negatively correlated with mirrored painting selection biases for positive valence (the most leftward bisectors demonstrated a right hemi-painting preference for mirrored asymmetrical paintings, whereas relatively rightward bisectors preferred the left hemi-paintings); also, two-hand line bisection was positively correlated with mirrored painting selection biases for brightness (all participants selected the left half of paintings as more bright, though it appears that the stronger the leftward bisection bias, the

9To test whether one half of symmetrical paintings is brighter than the other, the paintings were converted into 1-bit black and white images using GNU Image Manipulation Program (GIMP), and the percentage of white pixels in the left and right halves was calculated and then compared using a paired samples t-test (as was done for symmetrical paintings in Study 1). Consistent with asymmetrical paintings, the means suggest that there are a slightly greater percentage of white pixels in the left half (left M = 49.51%, SD = 32.66; right M = 47.89%, SD = 33.41), though this difference was not statistically significant: t(6) = 1.83, p = .12. Overall, it appears as though the left and right halves of symmetrical art did not differ in brightness.
Table 8. Pearson correlations between line bisection bias scores and hemi-painting bias scores for asymmetrical and symmetrical paintings in mirrored and non-mirrored orientations for Study 3b.

<table>
<thead>
<tr>
<th></th>
<th>Asymmetrical Paintings</th>
<th>Symmetrical Paintings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-mirrored</td>
<td>Mirrored</td>
</tr>
<tr>
<td><strong>Brightness</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = -.002$</td>
<td>$r = .03$</td>
</tr>
<tr>
<td></td>
<td>$p = .99$</td>
<td>$p = .87$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = .04$</td>
<td>$r = .07$</td>
</tr>
<tr>
<td></td>
<td>$p = .84$</td>
<td>$p = .75$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = -.20$</td>
<td>$r = .42 \ast$</td>
</tr>
<tr>
<td></td>
<td>$p = .32$</td>
<td>$p = .03$</td>
</tr>
<tr>
<td><strong>Evocative Impact</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = -.19$</td>
<td>$r = -.06$</td>
</tr>
<tr>
<td></td>
<td>$p = .33$</td>
<td>$p = .77$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = .03$</td>
<td>$r = -.16$</td>
</tr>
<tr>
<td></td>
<td>$p = .90$</td>
<td>$p = .44$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = -.18$</td>
<td>$r = -.22$</td>
</tr>
<tr>
<td></td>
<td>$p = .38$</td>
<td>$p = .28$</td>
</tr>
<tr>
<td><strong>Logic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = -.03$</td>
<td>$r = .15$</td>
</tr>
<tr>
<td></td>
<td>$p = .87$</td>
<td>$p = .46$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = -.07$</td>
<td>$r = .02$</td>
</tr>
<tr>
<td></td>
<td>$p = .74$</td>
<td>$p = .92$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = -.15$</td>
<td>$r = .12$</td>
</tr>
<tr>
<td></td>
<td>$p = .48$</td>
<td>$p = .56$</td>
</tr>
<tr>
<td><strong>Negative Valence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = .07$</td>
<td>$r = .16$</td>
</tr>
<tr>
<td></td>
<td>$p = .74$</td>
<td>$p = .42$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = .37$</td>
<td>$r = -.004$</td>
</tr>
<tr>
<td></td>
<td>$p = .13$</td>
<td>$p = .98$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = .10$</td>
<td>$r = -.17$</td>
</tr>
<tr>
<td></td>
<td>$p = .64$</td>
<td>$p = .42$</td>
</tr>
<tr>
<td><strong>Positive valence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LLB</td>
<td>$r = .06$</td>
<td>$r = .17$</td>
</tr>
<tr>
<td></td>
<td>$p = .78$</td>
<td>$p = .41$</td>
</tr>
<tr>
<td>RLB</td>
<td>$r = -.23$</td>
<td>$r = -.59\ast\ast$</td>
</tr>
<tr>
<td></td>
<td>$p = .26$</td>
<td>$p = .002$</td>
</tr>
<tr>
<td>BLB</td>
<td>$r = .04$</td>
<td>$r = -.12$</td>
</tr>
<tr>
<td></td>
<td>$p = .84$</td>
<td>$p = .56$</td>
</tr>
</tbody>
</table>

* $p < .05$
** $p < .01$
stronger this left hemi-painting preference). The remaining three correlations were for symmetrical paintings: left hand line bisection was negatively correlated with selections of mirrored hemi-paintings for brightness (stronger left bisectors were more likely to select the right halves of mirrored symmetrical paintings as more bright, whereas those with weaker bissections were more likely to select the left hemi-paintings as more bright); left hand line bisection was negatively correlated with non-mirrored symmetrical painting selection biases for logic (the strongest left bisectors were likely to choose the right half of non-mirrored symmetrical paintings as more logical whereas those who were relatively more rightward bisectors selected the left hemi-paintings as more logical); and, also when selecting for logic, right hand line bisection was positively correlated with mirrored symmetrical painting selection biases (relatively leftward bisectors were more likely to choose the left half of mirrored symmetrical paintings as more logical, whereas relatively rightward bisectors were more likely to select the right hemi-paintings).

Whereas the latter two correlations were for the same attribute (logic), they were not for the same line bisection hand, nor were they in the predicted direction. Indeed, it should be noted that the observed correlations in Study 3b were for different hand use, were not in a consistent direction, and were vastly outnumbered by non-significant correlations (92% were not significant). Furthermore, consistent (and significant) opposite patterns were not observed for the non-mirrored and mirrored conditions when all else was the same (same attribute, same hand, and same painting type), as would be expected if visuospatial bias was truly having an effect on the results (see hypotheses sections, and Tables 6 and 7). However, when collapsing across mirrored and non-mirrored
conditions, results do appear to suggest that individual differences in visuospatial attention (as indexed by line bisection) can influence hemi-painting selection biases to some extent.

4.9. Discussion

In Study 3b, which examined attributes associated with known hemispheric asymmetries, asymmetrical paintings were found to have differences between the right and left halves, whereas symmetrical paintings did not. In particular, the right half of asymmetrical paintings was selected significantly more often as logical and negatively valenced, whereas the left half was selected more often as brighter and positively valenced. These results are in line with predictions for logic and brightness, but opposite to the predictions for positive and negative valence. For brightness, the results match other research demonstrating that paintings and other artwork are brighter on the left (Hutchison et al., 2011; McDine et al., 2011; Sun & Perona, 1998). For logic, the finding of a rightward hemi-painting bias is consistent with the idea that the left hemisphere is dominant and produces a rightward attentional bias (Cate, 2002), which may have led the artist of the asymmetrical paintings to place more logical material on the right. Similarly, it was predicted that right hemispheric processing of negative valence would lead to greater representation of that attribute in the left half of the paintings, and vice versa for left hemispheric processing of positive valence. However, the opposite pattern was found.

It may be the case that the placement and perception of emotionally-valenced content in asymmetrical paintings is not dependent on hemispheric processing, but on other attributes. For example, brightness may be perceived as more positive, thus producing a leftward bias, whereas darker tones could be perceived as more negative,
producing a rightward bias. To examine this idea, post-hoc Pearson correlation analyses were run to determine if there was a positive correlation between hemi-painting bias scores for brightness and positive valence, and a negative correlation between hemi-painting bias scores for brightness and negative valence, but no significant correlations were found (both $p_s > .49$). Thus, it appears that participants in the present study did not equate positive valence with greater brightness, nor negative valence with lesser brightness, so this cannot explain the unexpected results for valence.

Another possible explanation for the unexpected pattern of results for positive and negative valence is that amygdala processing, rather than cortical processing, was responsible for the placement of emotionally-valenced content within paintings. Relevant to this idea, some studies have demonstrated that amygdala activation in response to negative valence is lateralised to the left (Baas et al., 2004; Wager, Phan, Liberzon, & Taylor, 2003; but see Garavan, Pendergrass, Ross, Stein, & Risinger, 2001), in contrast to the typical finding that prefrontal regions of the right hemisphere are more responsive to negative emotional content and less responsive to positive emotional content (e.g., Canli et al., 1998; Grimshaw & Carmel, 2014). Furthermore, passive processing of emotional information has been associated with a higher probability of amygdala activation than following active task instructions (Costafreda, Brammer, David, & Fu, 2008). It is likely that artists do experience a more passive, intuitive process when painting (Edwards, 2012), rather than painting based on a particular a set of instructions, furthering support for the idea that amygdala activation and its associated lateralization may explain the observed results. However, there does not appear to be evidence that the right amygdala is more active than the left in response to positively valenced content, so
this explanation may only apply to negatively valenced content. As mentioned in the introduction of this study, it is important to note that the artist of the asymmetrical paintings was right handed and demonstrated pseudoneglect, both of which are typical of the general population (suggesting neurotypical hemispheric organization). As such, if the creation of these asymmetrical paintings was influenced by asymmetries in lateralization, then the results of Study 3b may indeed suggest that left amygdala processing of negative valence may result in the rightward placement of that element within a painting.

4.9.1. The influence of visuospatial biases. Unexpectedly, it appeared as though individual differences in visuospatial biases were related to whether participants selected the left or right halves of both asymmetrical and symmetrical paintings, to some extent. For asymmetrical paintings, participants who bisected relatively leftward when using their right hands were more likely to select the right half of paintings as more positively valenced, in contrast to relatively rightward bisectors who were more likely to select the left half as more positively valenced. Also for asymmetrical paintings, although all participants selected the left half as more bright, those who bisected relatively leftward when using two hands were more likely to select the left half of paintings as more bright, compared to relatively rightward bisectors. Finally, when it came to ratings of brightness for symmetrical paintings, those who were the strongest leftward bisectors when using their left hands more frequently selected the right hemi-paintings as more bright, compared to rightward bisectors. However, as the brightness analysis for the symmetrical paintings showed, there was a non-significant trend for left hemi-paintings to be brighter.
These results cannot be explained by asymmetries in the hemi-paintings, as visuospatial bias was not related to opposing selections for mirrored and non-mirrored conditions, suggesting that something other than asymmetries within the hemi-paintings was at play. That is, leftward and rightward bisectors likely did not differ in their selections because the left halves of the left hemi-paintings contained more of a given attribute than the right halves of the left hemi-paintings. If this was the case, mirroring the hemi-paintings should have switched where the attribute in question was best represented, in turn changing the preferences for the leftward and rightward bisectors. Without the effect of mirroring, it is unclear why leftward and rightward bisectors would have inherent differences in their perceptions of left and right hemi-paintings. The fact that these results only appeared for Study 3b, and not 3a, may suggest that opposing laterality of leftward and rightward bisectors holds some clue. Future research should focus on more clearly elucidating the functional, and perhaps structural (e.g., SLF II; see de Scshotten et al., 2011) differences between left and right line bisectors. It should also be noted that the individual differences in visuospatial biases did not affect perception of whole paintings, as no significant results were found in Study 2 for the attributes which reached significance in Study 3b.

4.10. General Discussion

While the results of Study 3a do not offer clear support for asymmetries in paintings, the results of Study 3b, which targeted attributes with known hemispheric lateralization, do in fact suggest that there are asymmetries in the paintings. Taken as a whole, the results of Studies 3a and 3b suggest that the left halves of asymmetrical paintings display greater brightness and positive valence, whereas the right halves of
asymmetrical paintings display greater technique, logic, and negative valence. For the most part there were no differences between the left and right halves of symmetrical paintings, with the exception of aesthetics, such that the left halves of symmetrical paintings were selected as more beautiful than the right. Most of these findings can be tied to the idea that lateralized processing of attributes will lead painters to place more of an attribute on the half of paintings contralateral to the more highly activated hemisphere (see Bultitude & Aimola Davies, 2006; Kinsbourne, 1993; Reuter-Lorenz & Posner, 1990), though there is not yet evidence that this laterality-based explanation would apply to technique or brightness.

Notably, in both of the present studies, there were no biases in the placement of emotionally evocative content within paintings. Because the right hemisphere is thought to be dominant for processing emotional evocation (Borod, 1992; Borod et al., 1998; De Renzi et al., 1994; Harciarek et al., 2006; Ley & Bryden, 1982), it was expected that this attribute would be more greatly represented in the left half of asymmetrical paintings. Also, in Studies 1 and 2, it appeared that evocative impact was leftward-biased in paintings, so these results do not support that hypothesis. It is possible that evocative impact is too vague of a concept, which can be interpreted in both a positively and a negatively valenced manner. If this is the case, then perhaps the leftward-biased positive valence and the rightward-biased negative valence came together to cancel each other out. The fact that Study 3b in particular showed a complete absence of bias for evocative impact, when participants were also explicitly asked to judge the hemi-paintings in terms of positive and negative valence, supports this idea. Alternatively, it is possible that emotional evocation is not consistently biased in paintings after all.
4.10.1. Composition and visual literacy in artists. A final consideration for the present study is how the results fit with what is known about how artists make their compositions. While the creation of art is a very personal and subjective process, there are many common principles that can be expressed and interpreted through what is known as visual literacy – the ability to express and understand concepts in a visual medium (e.g., paintings and photographs), in contrast to a linguistic medium (e.g., books and conversations). That is, a person with high visual literacy will be better able to identify and comprehend the ideas portrayed in an image, and will have an understanding of how to effectively convey meaning through a visual medium. Formally trained artists tend to have greater visual literacy than non-artists (Nodine, Locher, & Krupinski, 1993), which includes an understanding of composition, or how visual elements are positioned within art to best convey a desired meaning (Serafini, 2014).

In Western culture, wherein we typically read from left to right, the left half of an image is supposed to represent the old and familiar, whereas the right half is supposed to represent the new or possible (Serafini, 2014). Based on this visual principle, it would actually be expected that the right half of paintings would be perceived as more novel than the left. The results of Study 1 and 2 suggest the opposite, that the left halves of asymmetrical paintings are more novel. Further, in the present study, participants did not select one particular half of the paintings as more novel, though Figure 5 does show a trend towards selections of the left half. Thus, these results do not match with the principle of left-right/familiar-novel. However, it should also be noted that participants in Studies 1-3 were all recruited from undergraduate psychology courses, and the majority of participants were likely not formally trained in art. Thus, it is possible that
different results would be observed for a group of participants with greater visual literacy, such as formally-trained and experienced visual artists.

Further, relevant to emotion processing and valence, Bang (2000) outlined some elements of composition which affect emotional responses to artwork. For example, white backgrounds (perhaps related to brightness) are perceived as safer than black backgrounds; and pointed and angular shapes elicit more fear than rounded objects. Further to this, Dondis (1973) suggested that circles tend to represent comfort, protection, and endlessness; squares represent stability, honesty, and conformity; and triangles represent tension, conflict, and dynamism. She also described how vertical lines imply stability and division, whereas horizontal lines imply calmness and tranquillity. Colours may also convey emotional meanings in different ways; for example, in Western cultures, yellow is often related to happiness, caution, and warmth, whereas red is associated with power, energy, and anger (Serafini, 2014).

The specific composition of the paintings used in Studies 1-3 has not been objectively and systematically examined in any way, except in terms of brightness (see Study 1 section 2.6.1, and present study footnote 6) which was found to be more greatly represented in the left half of asymmetrical images than the right. However, for future research, it would be useful to analyse the composition in terms of colour, lines, and shapes to see if these are asymmetrically represented in a manner consistent with known hemispheric asymmetries in emotion processing and expression.

In sum, the results of the present study, when combined with the findings from Studies 1 and 2, suggest that there are verifiable asymmetries in paintings that may have a biological basis. Furthermore, these asymmetries can influence the perception of
paintings in different ways depending on the direction of the viewer’s visuospatial bias. However, the results were not completely consistent across the studies of this dissertation. The results of Study 1 and 2 suggest that the attributes examined in Study 3a (most notably, evocative impact and novelty) would be more prominently represented on the left half of the asymmetrical paintings (in light of left and right bisectors’ opposing preferences for non-mirrored and mirrored paintings, respectively), but Study 3a did not find results for these attributes, and instead found more *rightward* representation of technique. Furthermore, the attributes examined in Study 3b (particularly positive valence, negative valence, brightness, and logic) demonstrated significant differences between the left and right halves. Although the results of Study 2 also suggested that the hemi-paintings differed for positive valence, logic, and brightness, it was assumed that both positive valence and logic were biased to the right, and brightness to the left. However, whereas the results of the present study did show support for the predictions regarding logic and brightness, positive valence was actually biased to the left. It is possible that the inconsistent results regarding valence relate to the fact that emotion perception is less consistently associated with support for the valence hypothesis (e.g., see Borod, 1992; Borod et al., 1998) compared to emotion production and expression (Carson et al., 2000; Gainotti, 1972; Grajny et al., 2016; Lee et al., 1990; Starkstein et al., 1989). Further research is needed to clarify these inconsistent results.

It should be noted that the asymmetrical paintings in these studies were produced by a single artist, so the results may not be representative of other paintings and other artists. However, research on visual literacy in artists suggests that there may be some consistent principles in the expression of certain attributes such as emotion (Bang, 2000).
It would be interesting to examine whether the biases observed in the present study also appear in paintings by other artists, in other styles of paintings, and perhaps in different types of artwork altogether.
5. Verbal, Facial, and Emotional Influences on the Line Bisection Task (Study 4)\textsuperscript{10}

The line bisection task is a simple and effective measure of individual differences in visuospatial biases. Recently, a number of studies have reported that line bisection biases are influenced by other lateralized functions, such as emotion processing (e.g., Armaghani, Crucian, & Heilman, 2014; Cattaneo et al., 2014), leading to the suggestion that line bisection may be a simple means of assessing lateralized functions beyond visuospatial attention. However, inconsistencies have been reported (e.g., Leggett, Thomas, & Nicholls, 2016). Thus, further research is needed to clarify how lateralized functions affect line bisection biases. The present study uses a new approach to examine the influence of lateralized functions on line bisection biases, while addressing limitations in previous studies. Inspiration for this approach comes from Bryden and MacRae’s (1988) dichotic listening task that assesses both left hemispheric (verbal) and right hemispheric (emotion) processing within a single measure. Specifically, we examined the influence that emotional facial and verbal content had on line bisection performance, to assess the influence of relative right versus left hemispheric activation on visuospatial biases.

5.1. Line Bisection and Visuospatial Biases

In a clinical population, the line bisection task can be used to assess hemispatial neglect, which typically follows damage to the right inferior parietal lobe (Vallar &

\textsuperscript{10} This study has been peer-reviewed and published in a special issue on the legacy of M. P. Bryden, as follows: Hatin, B., & Sykes Tottenham, L. (2016). What’s in a line? Verbal, facial, and emotional influences on the line bisection task. \textit{Laterality: Asymmetries of Body, Brain and Cognition}, 21(4-6), 689-708.
Perani, 1986). Because the right parietal lobe is dominant for orienting spatial attention (Chambers, Payne, Stokes, & Mattingley, 2004), damage to this region results in a loss of the ability to attend to the contralateral side of space (Fink et al., 2000; Vallar & Perani, 1986). Patients with left hemispatial neglect bisect lines to the far right, as though the left halves of the lines do not exist (Heilman & Valenstein, 1979; Olk & Harvey, 2002; Urbanski & Bartolomeo, 2008).

In contrast, neurologically healthy individuals typically display pseudoneglect, a slight leftward bias on the line bisection task (Bowers & Heilman, 1980). Pseudoneglect may be explained by the activation-orientation hypothesis of attention, which states that attention is oriented in a direction contralateral to the more highly activated hemisphere (Bultitude & Aimola Davies, 2006; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990). Duecker and Sack (2015) provide evidence that suggests this attentional hypothesis applies specifically to the posterior parietal cortex, such that left and right parietal regions are in competition and directing attention contralaterally. Thus, when completing the line bisection task, which relies heavily on visuospatial processing of the right parietal cortex (Çiçek et al., 2009; Fink et al., 2000; Foxe et al., 2003), attention is subsequently oriented more leftward resulting in leftward bisections.

5.2. Line Bisection as an Index of Non-Visuospatial Biases

Recently, many have suggested line bisection can be used to assess relative left and right hemispheric activation that is independent of visuospatial processing, such as approach- and avoidance-motivation (e.g., Armaghani et al., 2014; Baumann, Kuhl, & Kazén, 2005; Cattaneo et al., 2014; Drake & Myers, 2006; Nash, McGregor, & Inzlicht, 2010; Shrirà & Martin, 2005). Relevant to the present study, Armaghani et al. (2014) and
Cattaneo et al. (2014) found that line bisection is influenced by emotional faces; Armaghani et al. found that both positive and negative faces drew bisections leftward relative to neutral faces, whereas Cattaneo et al. found that negative and neutral faces were associated with larger leftward bisections than were positive faces. To avoid potential confounding effects of hand-use (discussed below), Leggett et al. (2016) used landmark line bisection to determine how biases are influenced by positive and negative emotional primes; in the first of five studies, negative face primes were associated with leftward biases (neutral and positive face primes were not), but this pattern was not replicated in four studies that followed – the last of which was an exact replication of the first.

Because the above-noted studies each used different methodologies and produced differing results, it remains to be determined whether line bisection biases are predictably influenced by stimuli associated with lateralized processing. Leggett et al. (2016) used landmark line bisection to avoid potential motor effects, whereas Armaghani et al. (2014) and Cattaneo et al. (2014) used manual line bisection, but did not control for hand-use. Further, Leggett et al. presented their emotional stimulus as a prime, in advance of the line bisection task, whereas Armaghani et al. and Catteneo et al. used emotional faces at one or both ends of the line to be bisected, respectively, allowing the faces to be processed concurrently during line bisection.

5.3. Present Study

To determine whether line bisection can be used as a quick and simple measure of relative hemispheric activation, we used character line bisection tasks (e.g., Lee et al., 2004), which involve the bisection of lines of characters, such as letters or symbols.
Consistent with the majority of studies, ours involved manual bisections. To examine potential hand-use effects, participants completed the tasks with the right hand, left hand, and both hands concurrently. We manipulated line type (face versus word) in addition to line valence (positive, negative, and neutral), as verbal and facial content were expected to differentially activate the left and right hemispheres, respectively (explained below). Lastly, our tasks differed from previous studies in that the lines themselves were embedded with the emotional facial and verbal content, to ensure exposure to this content while the line was bisected. If the line bisection task can index the extent of activation of each hemisphere relative to the other, using this approach we should see different patterns of bisections when processing information that has been established to preferentially activate the left (e.g., words; Knecht et al., 2000) versus the right hemisphere (e.g., faces; Ley & Bryden, 1979).

5.3.1. Manipulated factors and hypotheses. It was expected that our sample would display the typical leftward bias on a solid line bisection task, because the task requires spatial processing involving the right parietal lobe (Çiçek et al., 2009; Fink et al., 2000; Foxe et al., 2003). This task served as the baseline against which performance on the novel line bisection tasks was compared.

5.3.1.1. Line type: faces versus words. Words and faces were used as characters within the lines because they are known to preferentially activate the left hemisphere (Bryden et al., 1983; Vigneau et al., 2006) and right hemisphere (Perrett et al., 1988), respectively. For example, processing written language involves left hemispheric regions, particularly the left fusiform gyrus (i.e., Visual Word Form Area [VWFA]; Cohen, Jobert, Le Bihan, & Dehaene, 2004; Harris, Rice, Young, & Andrews, 2016;
McCandliss, Cohen, & Dehaene, 2003; Price et al., 2003); faces typically activate the right fusiform gyrus (aka, Fusiform Face Area (FFA); Harris et al., 2016; Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Gore, & Allison, 1997). We hypothesized, relative to baseline, line bisection errors would be further left for face-line bisections and right for word-line bisections, due to differential activation of the right and left hemispheres, respectively.

5.3.1.2. Line valence. Character line bisection tasks are typically emotionally neutral, whereas ours contains words and faces conveying both neutral and emotionally valenced information. The Right Hemisphere Hypothesis of emotion posits that the right hemisphere is dominant for processing both positive and negative valence; it is supported by studies demonstrating that damage to the right hemisphere, but not the left, leads to disrupted emotion processing (e.g., Borod et al., 1998), and by those showing left visual field and left ear advantages for emotion processing (e.g., Bryden & MacRae, 1988). Of relevance to line bisection, Armaghani et al. (2014) found sad and happy faces at either end of a line resulted in greater leftward bisections compared to neutral faces, whereas Cattaneo et al. (2014) found happy faces placed at both ends of a line reduced leftward line bisection biases compared to those observed for neutral and sad faces. These findings suggest right hemisphere emotion processing can influence line bisection performance in a contralateral fashion, but the extent of this influence might differ depending on valence.

The Valence Hypothesis suggests both hemispheres process emotion, with the right hemisphere especially suited for processing negative emotion and avoidance-motivation (Bryden & MacRae, 1988; Reuter-Lorenz & Davidson, 1981), whereas the
left hemisphere is capable of processing positive emotion and approach motivation (Killgore & Yurgelun-Todd, 2007). In a review and comparison of the Right Hemisphere Hypothesis, the Valence Hypothesis, and the approach/avoidance model of emotion processing, Najt, Bayer, and Hausmann (2013) found that anger, fear, and sadness consistently produce a right hemisphere advantage, whereas other emotions do not consistently produce lateralized advantages.

In the present study, neutral, angry, and happy emotional faces and words were used to examine the influence of emotional information on line bisection bias. We hypothesized that, if positively valenced emotional information (happy faces and positive words) activates the left hemisphere to a greater extent than the right, positively valenced lines will be bisected further to the right than baseline and neutral lines. Similarly, if negatively valenced emotional information (angry faces and negative words) activates the right hemisphere to a greater extent than the left, then these lines will be bisected further to the left than baseline and neutral lines.

5.3.1.3. Hand-use. The hand used to make the bisection was manipulated to account for motor activation effects. Research suggests hand-use exerts a subtle, albeit significant, influence on spatial attention, such that left and right hand-use can increase and decrease the extent of pseudoneglect, respectively (Jewell & McCourt, 2000; McCourt et al., 2001). A two-hand line bisection condition was also added, in order to try to equalize the activation of the left and right hemispheres from motor activity and serve as a control for motor effects. We hypothesized that using the left hand (right hemisphere) to complete the line bisection tasks would draw line bisections leftward, using the right hand (left hemisphere) would draw bisections rightward, and use of both
hands simultaneously (both hemispheres) would result in a purer line bisection bias without the small but significant influence of unilateral motoric activation (McCourt et al., 2001).

**5.3.1.4. Interactions.** The manipulated factors were crossed in the novel line bisection tasks, in that each line contained emotionally valenced faces or words and was bisected with either the left or right hand, or both hands. As such, we consider the interactions among these factors. It was expected that the relative activation of each hemisphere caused by each condition would have additive or negating effects on line bisection bias, depending on whether one or both hemispheres were activated, respectively. For example, left hand bisection of angry face lines would preferentially activate the right hemisphere to a greater degree than any other condition (due to right hemisphere control of the left hand, and right hemisphere dominance for processing both faces and negative emotions), resulting in the largest leftward bisection errors. In contrast, when the stimuli promote competing activation of both hemispheres, the effects on line bisection biases would be negated.

**5.4. Method**

**5.4.1. Participants.** A total of 50 individuals (37 female) participated in the present study. Most were right-handed \((M = 4.41, SD = .52)\) and right-footed \((M = 3.94, SD = .75)\), as assessed by questionnaire (Elias et al., 1998); however one was left-handed, and three were left-footed. Participants had normal or corrected-to-normal vision, and were 18–26 years of age \((M = 20.40, SD = 1.75)\). Participants were recruited via a psychology department subject-pool.
5.4.2. Measures.

5.4.2.1. Computerized line bisection. Participants completed a novel computerized line bisection task. The lines were either solid or embedded with a series of faces or words (Figure 9). Unlike previous character line bisection tasks, in order to avoid inducing local processing we asked participants to bisect the character lines (instead of selecting the central character) and made the lines more coherent by placing a border around the stimuli (Figure 9a). The border was the same size as the edges of the thick solid control lines. These face and word lines differed by valence (positive, negative, and neutral). Happy, angry, and neutral human faces were selected from Matsumoto and Ekman’s (1988) JACFEE and JACNeuF photo databases, and positive, negative, and neutral words were chosen based on the “valence” dimension of Bradley and Lang’s (1999) Affective Norms for English Words (ANEW). The solid lines were included as a control. One set of solid lines was the same length and height as the word and face lines (hereafter referred to as “thick” lines; Figure 9b), whereas the other set was comparable to the pen-and-paper line bisection task used in Studies 1-3; hereafter referred to as “thin” lines. Line thickness was important to account for, because thicker lines have been found to reduce the magnitude of pseudoneglect (McCourt & Jewell, 1999). For each stimulus-type, five lines were bisected per hand condition (right, left, and both).

The face, word, and thick solid lines subtended a total of 9.96 degrees of visual angle (DVA) in length and 0.51 DVA in height. For the face lines, each face was repeated 17 times within the line, with some lines being offset such that half-faces were displayed at the ends of the lines. For the word lines, a total of 41 letters were embedded
Figure 9. (a) Examples of the negative, positive, and neutral word and face lines used in the character line bisection task. Humintell/David Matsumoto have granted permission to the authors to print the JACFEE and JACNeuF faces. (b) Screenshot of the solid thick line bisection page, demonstrating randomized line placement.
within each line, allowing for 6–8 words per line which were randomly ordered in one of
two sequences. Words were typed in a modified Courier font, which was selected for its
monospacing and print-like characters (script-like characters, rather than print-like
characters, may actually lead to unwanted right hemispheric activation; Bryden &
Allard, 1976). The thin solid lines were 9.96 DVA in length and 0.11 DVA in height,
which was calculated to be equivalent to 100 mm in length and 2 mm in height (same as
the pen-and-paper solid lines described in the following section) when displayed on a 19
inch monitor with a 1280 × 1024 screen resolution. Five lines were horizontally
presented on the monitor at a time, similar to the pen-and-paper task used in Studies 1-3.
The lines were randomly offset from centre by 0 DVA, ±2.95 DVA, and ±5.89 DVA.
Figure 9b shows the line placement in a random trial. This variant of the line bisection
task was used for its similarity to the pen-and-paper line bisection task used in the
present study and previous studies of this dissertation. The offset lines require
participants to evaluate each line independently, as the mark on one line cannot be used
as a guide for the next line, which would be the case for centrally presented lines.

The mouse’s cursor appeared as a thin vertical line on the screen. The starting
placement of this cursor was in the middle of the screen, which participants then had to
move to the top-most line which was offset from centre. Upon clicking both mouse
buttons on the perceived centre of the line, a red bisection line was stamped onto the
image at the cursor’s location. Lines were bisected in order from top to bottom, and all
five lines had to be bisected before moving on to the next condition.

5.4.2.2. Pen-and-paper line bisection. A solid line bisection condition was also
completed in pen-and-paper format, to allow us to determine whether the novel
computerized line bisection task would produce results similar to line bisection completed in the traditional paper format. Like Studies 1-3, each printed page consisted of 5 horizontal lines that were 9.88 DVA in length and 0.19 DVA in height. The lines were offset from centre by 0 DVA, ±1.98 DVA, and ±4.45 DVA, and were equally spaced vertically. Five lines were bisected per hand condition (right, left, and both).

5.4.2.3. Handedness and demographics questionnaire. Participants completed a handedness, footedness, and demographics questionnaire, which was adapted from Elias et al. (1998). This measure includes 15 questions that assess the degree of right or left handedness, and 10 questions that assess the degree of right or left foot preference. Other factors also reported to be related to performance on line bisection tasks (e.g., age and sex) were recorded. None of these factors influenced the pattern of results in the present sample, thus they are not examined further.

5.4.3. Procedure. After informed consent was obtained, participants completed the pen-and-paper line bisection task by using a pen to place a mark at the perceived midpoint of each line on a printed page. Three pages were completed, one for each hand condition: left, right, and both hands. This resulted in a total of 15 bisected lines. When using both hands, participants were shown how to hold the pen and instructed to use both hands equally when moving the pen around the page. Each page was secured in a clipboard and placed along the participants’ midlines, and participants were instructed to sit up straight and not to tilt or move the clipboard. Participants completed this task at their own pace, with no time restrictions. This portion of the experiment took approximately 3 min to complete, including time for instructions.
Next, the computerized line bisection task was completed, starting with the baseline solid line conditions. Three virtual “pages” were completed for both the thin and thick solid lines, one page per hand condition, for a total of 30 bisected lines. Following this, participants bisected the character lines. The positive, negative, and neutral valence conditions were presented in randomized blocks, and within each block, hand-use and line type were counterbalanced. Figure 10 represents the general structure of the computerized line bisection task. Because faces and words themselves are easier to distinguish between than emotions within the faces and words, the task was presented in blocks based on emotion in order to ensure that participants had the maximal chance of correctly observing the valence, thus ensuring relevant hemispheric activation. Eighteen virtual pages of character lines were completed for a total of 90 character lines bisected. Participants completed this task at their own pace, with no time restrictions placed on stimulus viewing time, and were allowed to take breaks between each block in order to reduce the potential for fatigue. The average completion time for the computerized line bisection task was 10 min and 48 sec. For the character line bisections, participants were instructed to briefly observe the content of each line and not to use any “cheating” techniques such as counting the number of characters. For all of the computerized line bisection trials, participants used a mouse to move the cursor to the perceived centre of each line, then clicked both mouse buttons to mark the bisection location. For the face and word lines, to ensure participants were attending to the content of the lines, after each block they indicated via keyboard button press what the lines had in common: positive emotional content, negative emotional content, or neutral emotional content.
Figure 10. Counterbalanced structure of the computerized line bisection task.
Within each block, participants were given written instructions accompanied by an image indicating which hand to use (left, right, or both).

Once participants finished the computerized line bisection task, they completed the demographics and handedness/footedness questionnaire (Elias et al., 1998), then received an educational debriefing.

5.4.4. Scoring.

5.4.4.1. Computerized line bisection. Bisection errors on the computerized line bisection task were calculated by measuring how far the perceived midpoint was from the true midpoint to the nearest pixel. Leftward deviations were multiplied by −1, so that negative scores indicated leftward errors and positive scores indicated rightward errors. Bisection bias scores were calculated by summing the error scores separately for the thick and thin solid line baselines, and for the positive, negative, and neutral word and face lines. Calculations were made separately for each hand condition. This resulted in a total of 24 bias scores calculated for each participant. All calculations were then transformed into DVA.

5.4.4.2. Pen-and-paper line bisection. Similarly, bisection errors on the pen-and-paper line bisection task were calculated by measuring how far the bisections were from the true midpoint. Digital vernier calipers were used to measure the bisection errors to the nearest 0.5 mm. Leftward deviations were multiplied by −1, so that negative scores indicated leftward errors and positive scores indicated rightward errors. Bisection bias scores were calculated by summing the error scores separately for each hand condition. A total of three bias scores were calculated for each participant. All calculations were then transformed into DVA.
5.5. Results

5.5.1. Valence identification.

For the computerized line bisection task, we examined participants’ accuracy when asked to determine what each block had in common: neutral, positive, or negative valence. Accuracy was generally high, with an average of 2.5 out of 3 correct identifications ($SD = 0.75$). However, because valence appears to have a small and highly variable effect on lateralized advantages, particularly positive valence (Najt et al., 2013), we decided to include only those participants who made correct identifications for all three blocks. As such, 33 participants were included in the following analyses. As a note, inclusion of all 50 participants in the same analyses did not change the pattern of results, with the exception of greater variability in terms of hand-use.

5.5.2. Solid lines.

5.5.2.1. Computerized line bisection. First, we examined whether hand-use and line thickness influenced line bisection performance. A three (hand-use: left, right, and both) by two (line type: thick and thin) repeated measures ANOVA revealed no main effects or interactions, all $p$s > .34. As such, these line bisection scores were averaged over line type and hand-use for the remaining analyses. Next, a one-sample t-test was run to determine whether our sample displayed pseudoneglect for the solid computerized line bisection task. A significant leftward bias was indeed observed, $t(32) = -5.67$, $p < .001$, $SEM = 2.97$, such that these lines were bisected an average of 0.46 DVA to the left of true centre ($SD = 0.46$).

5.5.2.2. Pen-and-paper line bisection. We also examined whether hand-use influenced pen-and-paper line bisection performance. A repeated measures ANOVA
demonstrated a main effect of hand, $F(2,64) = 17.51$, $MSE = 1.83$, $p < .001$, $\eta_p^2 = .35$. As confirmed with post hoc comparisons using a Bonferonni adjustment, bisecting the lines with the left hand resulted in a stronger leftward bisection bias ($M = -0.16$ DVA, $SD = 0.20$) than bisecting the lines with the right hand, $p < .001$ ($M = 0.03$ DVA, $SD = 0.14$), or with both hands, $p < .001$ ($M = -0.02$ DVA, $SD = 0.13$). One-sample t-tests were run to determine whether our sample displayed pseudoneglect, and a significant leftward bias was observed for the left hand condition, $t(32) = -.46$, $p < .001$, but not for the right or two-hand conditions, $ps > .28$.

5.5.2.3. Comparison. Next, we examined whether pen-and-paper and computerized solid line bisection performance was correlated. Pearson’s correlations revealed that the two task formats were not correlated for left hand, $r = .005$, $p = .98$, right hand, $r = .34$, $p = .06$, and both hand, $r = .18$, $p = .39$, conditions. However, when collapsing over hand, performance on the two solid line bisection tasks was significantly correlated, $r = .53$, $p = .001$. As such, we can infer that hand-use has an effect on manual solid line bisection, but not computerized solid line bisection, and that the computerized solid line bisection task is a suitable replacement for the pen-and-paper version of the task as long as hand-use is not a variable of interest. The scores on the computerized solid line bisection task served as baseline values against which performance on emotional and neutral verbal and facial lines were compared.

5.5.3. Emotional and neutral word and face lines.

5.5.3.1. Does valence, line type, and hand-use influence bias magnitude? A three (valence: positive, negative, and neutral) by three (hand-use: left, right, and both) by two (line type: word and face) repeated measures ANOVA was run to examine
whether the valence of the line, the type of line, and hand used to bisect the line influenced bisection performance (Table 9). A main effect of hand-use was revealed such that the both hands condition ($M = -0.42$ DVA, $SD = 0.64$) and left hand condition ($M = -0.39$ DVA, $SD = 0.59$) resulted in more leftward bisections than the right hand condition ($M = -0.29$ DVA, $SD = 0.58$). However, post-hoc comparisons of the three hand conditions with a Bonferonni adjustment demonstrated that they did not significantly differ from each other, all $ps > .06$. A main effect of line type was also observed, with word lines producing stronger leftward bisection errors ($M = -0.52$ DVA, $SD = 0.62$) than face lines ($M = -0.21$ DVA, $SD = 0.62$). No main effect of valence was observed.

In addition, there was a significant interaction between line type and valence, though the two-way and three-way interactions involving hand-use were not significant (Table 9). Paired sample t-tests were run to further examine the type by valence interaction. A Holm-Bonferonni sequential correction was performed (Gaetano, 2013; Holm, 1979) to control for error rates arising from the large number of comparisons. As seen in Figure 11, when examining line type, positively and negatively valenced word lines produced significantly more leftward bisections than positively and negatively valenced face lines, respectively, indicating that word lines produce stronger leftward biases than face lines in these conditions. Neutral face and word lines did not produce significant differences from each other. When examining valence, no influence was observed for performance on the face lines, but positive word lines were bisected furthest to the left compared to negative word lines.
Table 9. Results of the repeated measures ANOVA examining whether line valence, line type, and hand use influenced line bisection performance.

<table>
<thead>
<tr>
<th>Main Effects</th>
<th>df</th>
<th>F</th>
<th>p (2-tailed)</th>
<th>MSE</th>
<th>$\eta^2_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>2, 64</td>
<td>3.29</td>
<td>.04</td>
<td>9.72</td>
<td>.09</td>
</tr>
<tr>
<td>Type</td>
<td>1, 32</td>
<td>16.91</td>
<td>&lt;.001</td>
<td>31.46</td>
<td>.35</td>
</tr>
<tr>
<td>Valence</td>
<td>2, 64</td>
<td>2.14</td>
<td>.12</td>
<td>14.33</td>
<td>.06</td>
</tr>
<tr>
<td>Interactions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valence x Hand</td>
<td>4, 128</td>
<td>0.44</td>
<td>.78</td>
<td>10.77</td>
<td>.01</td>
</tr>
<tr>
<td>Valence x Type</td>
<td>2, 64</td>
<td>6.42</td>
<td>.003</td>
<td>9.24</td>
<td>.17</td>
</tr>
<tr>
<td>Hand x Type</td>
<td>2, 64</td>
<td>0.27</td>
<td>.77</td>
<td>8.52</td>
<td>.01</td>
</tr>
<tr>
<td>Valence x Hand x Type</td>
<td>4, 128</td>
<td>1.06</td>
<td>.38</td>
<td>6.78</td>
<td>.03</td>
</tr>
</tbody>
</table>
Figure 11. Differential influence of line type (face, word) and valence (neutral, positive, negative) on line bisection performance, as compared to baseline line bisection performance on solid lines.
5.5.3.2. Do character lines produce pseudoneglect? In order to determine whether the leftward line bisection biases on the face and word lines were significant, a series of one-sample t-tests were run. Because the preceding set of analyses showed that all hand conditions produced leftward errors that did not significantly differ from each other in post hoc comparisons, this variable was collapsed. As seen in Table 10, all word lines, along with neutral face lines, produced leftward errors that significantly differed from a score of 0, indicating that these conditions produced significant leftward biases. As such, all word lines produced pseudoneglect, regardless of valence. In contrast, face lines only produced pseudoneglect when neutral expressions, but not valenced expressions, were shown.

5.5.3.3. Comparison of character lines to solid line baseline performance.

Finally, we examined how these line bisection biases related to typical line bisection performance, as determined by the baseline information provided by computerized solid line bisection performance. Specifically, paired sample t-tests were run comparing the word and face-line bisection biases against solid line bisection biases. Again, because analyses showed that all hand conditions produced leftward errors that did not significantly differ from each other in post hoc comparisons, this variable was collapsed. Figure 11 provides a summary of the following results. The leftward line bisection bias was significantly reduced for negative face lines, $t(32) = -2.96$, $SEM = 3.59$, $p = .006$, and positive face lines, $t(32) = -2.66$, $SEM = 4.03$, $p = .01$. In contrast, positively valenced word lines shifted the bisections significantly farther left than baseline, $t(32) = 3.03$, $SEM = 2.76$, $p = .005$. No other significant deviations from baseline were observed, all $ps > .09$. 
Table 10. Results of one sample t-tests examining whether participants significantly deviated from true centre on the character line bisection task for each line type.

<table>
<thead>
<tr>
<th>Character Line Type</th>
<th>t</th>
<th>df</th>
<th>p (2-tailed)</th>
<th>M</th>
<th>SD</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Face</td>
<td>-1.45</td>
<td>32</td>
<td>.16</td>
<td>-0.17</td>
<td>0.67</td>
<td>0.11</td>
</tr>
<tr>
<td>Positive Face</td>
<td>-1.33</td>
<td>32</td>
<td>.19</td>
<td>-0.17</td>
<td>0.73</td>
<td>0.13</td>
</tr>
<tr>
<td>Neutral Face</td>
<td>-2.66</td>
<td>32</td>
<td>.01</td>
<td>-0.28</td>
<td>0.61</td>
<td>0.11</td>
</tr>
<tr>
<td>Negative Word</td>
<td>-3.56</td>
<td>32</td>
<td>.001</td>
<td>-0.43</td>
<td>0.69</td>
<td>0.12</td>
</tr>
<tr>
<td>Positive Word</td>
<td>-6.46</td>
<td>32</td>
<td>&lt;.001</td>
<td>-0.69</td>
<td>0.62</td>
<td>0.11</td>
</tr>
<tr>
<td>Neutral Word</td>
<td>-3.58</td>
<td>32</td>
<td>.001</td>
<td>-0.46</td>
<td>0.74</td>
<td>0.13</td>
</tr>
</tbody>
</table>
5.6. Discussion.

In line with past studies, the results of the present study show that participants generally demonstrated leftward biases on all line bisection conditions, which suggests overall right hemispheric activation (Çiçek et al., 2009; Fink et al., 2000; Foxe et al., 2003). However, our hypotheses were not supported regarding the effects that verbal, facial, and emotional content would have on the direction and extent of line bisection biases, nor was our hypothesis supported concerning differential effects of hand-use (except for the pen-and-paper task). Opposite to our predictions, word lines produced significantly greater leftward bisection biases than face lines; valence modulated this effect, but not as expected (discussed below). Because of these unexpected results, it is unclear whether relative activation of the left and right hemispheres had cumulative effects on the biases. If there were cumulative effects, they resulted from patterns of brain activity different from those predicted.

5.6.1. Emotional word and face lines. Face and word lines produced significant effects opposite to those predicted: word lines increased the extent of pseudoneglect, whereas face lines decreased it. This result was modulated by valence, but again not as expected. As predicted, neutral lines did not differ from baseline. However, positive word lines resulted in a significant leftward shift (increasing pseudoneglect) and both positive and negative face lines produced a significant rightward shift (negating pseudoneglect), relative to baseline.

These results add to the already inconsistent findings in this area, in which unilateral positive and negative faces have been found to produce larger leftward biases than bilateral neutral faces (Armaghani et al., 2014), bilateral negative and neutral faces
produced larger leftward biases than positive faces (Cattaneo et al., 2014), and centrally
presented negative face primes produced leftward biases compared to both neutral and
positive primes (in just 1 of 5 studies by Leggett et al., 2016). Because each study
(including ours) used methods that differ from the others in important respects, such as
the lateral/non-lateral placement of the faces, the temporal presentation of the faces and
lines (e.g., prime versus concurrent), and the characteristics of the line bisection tasks
(e.g., landmark versus motor), it cannot be determined at present if the inconsistent
findings are due to methodological differences or inconsistent effects of emotional faces
on visuospatial biases.

Duecker and Sack’s (2015) hybrid model of attentional control may shed light on
these inconsistent findings. Their model suggests frontal regions involved in the fronto-
parietal attentional network direct attention in a different manner than posterior parietal
regions. Specifically, instead of the interhemispheric competition that characterizes the
parietal lobes, the right frontal lobe is dominant for spatial processing and capable of
directing attention towards both visual fields, whereas the left frontal lobe only directs
attention to the right visual field. They also suggest that the time-course of frontal and
parietal activation may be important to consider. Because emotionally salient stimuli are
likely to activate frontal regions more than posterior parietal regions (Kawasaki et al.,
2001), they may produce bilateral activation, making them unlikely to have a lateralized
influence on visuospatial attention. Thus, the inconsistent findings regarding the effects
of emotional stimuli on visuospatial attention may result from other stimulus and task
characteristics that differ among studies.
Along a similar vein, because word and face stimuli may predominantly activate non-parietal regions (e.g., VWFA and FFA), the verbal and facial characteristics of our tasks may not be the factors that are underlying the observed leftward and rightward laterally biasing effects in the present study. Other characteristics of our lines, or the fashion in which the lines were examined, may have influenced the processing of them in a lateralized fashion.

5.6.1.1. Alternative explanations for results. An important difference between our study and previous studies was that our emotional facial and verbal stimuli were embedded within the bisection lines themselves, allowing the stimuli to be processed while the lines were bisected. In turn, the words may have induced global processing whereas faces may have induced local processing, leading to differential activation of the right and left occipital and temporo-parietal regions, respectively (Han et al., 2002). Lee et al. (2004) found letter and symbol character line bisection demonstrated reduced and non-significant leftward bisection biases, which they attributed to local processing of the characters. Thus, left hemisphere activation associated with local processing may explain the significantly reduced leftward bias (relative to baseline) observed for face lines in the present study, as participants had to focus attention rather intently to the emotional expression on the small faces in order to judge valence. Our word lines may have induced right hemisphere activation associated with global processing, as the characters in the word lines formed entire words, rather than existing as isolated units.

Similarly, another consideration is that the word and face lines may differ in terms of spatial frequency. It is likely that the face lines were of higher spatial frequency than the word lines, particularly due to the high level of detail in such a small amount of
space. The left hemisphere is specialised for high spatial frequency processing, in contrast to right hemispheric specialisation for processing low spatial frequencies (Prete et al., 2015). Thus, the face lines may have induced left hemisphere activation, and the word lines right hemisphere activation, which could explain the pattern of observed results.

Alternatively, scanning direction may have influenced biases, particularly for the word lines (Chokron et al., 1998). Because all participants spoke English and the lines consisted of English words, participants likely scanned the lines from left to right, which may explain the increased leftward bias (Brodie & Pettigrew, 1996; Chokron & Imbert, 1993; Nicholls & Roberts, 2002; though see: Hurwitz et al., 2011; Sosa & McCourt, 2011). However, neither the local/global or scanning direction hypothesis can account for why only the positive valence condition of the word lines produced significantly increased pseudoneglect.

One possible explanation for why positive word lines, in particular, significantly increased the extent of pseudoneglect is that the word lines differed not just in valence, but also arousal. The words in the present study were selected based on the “valence” dimension of ANEW (Bradley & Lang, 1999). However, the positive words that were selected were also rated the highest in arousal. High arousal has been associated with leftward attentional biases regardless of valence (Robinson & Compton, 2006), which may have played a role in the observed leftward bias for the positive word condition.

5.6.2. Hand-use. Counter to our prediction, hand-use (right, left, and both) did not influence performance on the computerized character and solid line bisection tasks, but did influence the extent of bias on the pen-and-paper task. Congruent with past
research (e.g., Jewell & McCourt, 2000), we found that left hand line bisection produced significantly larger leftward biases compared to right hand line bisection on the pen-and-paper task; in addition, the left hand bias was significantly greater than the bias obtained with the both hands condition. Based on these findings, it may be that pen-and-paper line bisection is associated with greater cerebral activation due to increased motor demands (e.g., those involved with holding a pen upright) compared to computerized line bisection using a mouse, leading to greater lateralized effects of hand-use. As our computerized line bisection task did not produce significant effects of hand-use, and was correlated with the pen-and-paper task when collapsed across hand, it may be a suitable replacement for pen-and-paper tasks in future, especially since extraneous lateralized motoric effects caused by hand-use appear minimal.

5.6.3. Limitations and future directions. As discussed above, the stimuli in the present study may have inadvertently resulted in right hemispheric global processing of words, and left hemispheric local processing of facial features. While this interpretation fits with the activation-orientation hypothesis of attention, it was not the intended focus of the study. Future studies should separate out the effects of facial and verbal processing from local and global processing. Furthermore, the word lines in the present study likely encouraged left-to-right scanning, possibly contributing to the observed leftward bisections, which may have over-ridden any other effects resulting from left hemispheric activation of language regions.

Further, unlike Bryden and MacRae’s (1988) dichotic listening task which used a single set of stimuli to demonstrate opposing effects of laterality, the present study used separate sets of stimuli (emotional face lines and emotional word lines). This leaves
room for varying interpretations regarding the differences found for bisecting different line types. In the future, lines that combine words and faces may help overcome this limitation, whereby – similar to Bryden and MacRae’s dichotic listening task – participants could be encouraged to attend solely to the faces or solely to the words when bisecting the lines.

5.7. Conclusion

Although emotional facial and verbal stimuli may influence the extent of pseudoneglect, they did so in unexpected directions in the present study. Further research is needed to determine whether other factors, such as visual scanning, local or global processing, or arousal, can account for the pattern of results. It is clear, however, that our results (along with inconsistent results from previous studies) suggest that caution is needed when using biases on the line bisection task to make inferences about other lateralized processes beyond visuospatial attention.

While a great deal of information is known about processes that demonstrate cerebral asymmetries, discovering how these lateralized processes impact behaviours is still an area of fruitful research. The present study was inspired by the work of M.P. Bryden, who was a pioneer in this area. His work on functional lateralities, and how they can influence human behaviours, continues to spark questions and curiosities – indeed, his legacy lives on.

6.1. Review of Studies 1-4

The studies in this dissertation were conducted in order to investigate how differences in visuospatial attention and other lateralized attributes can affect the perception of artwork and other aspects of our environments. In Study 1, participants viewed asymmetrical paintings and were asked to rate them on evocative impact, aesthetics, technique, novelty, and closure. It was found that leftward bisectors generally gave higher ratings to paintings when they were non-mirrored, whereas rightward bisectors gave higher ratings to mirrored paintings. Further, leftward bisectors gave higher ratings when using an ascending rating scale, whereas rightward bisectors gave higher ratings when using a descending rating scale. These results suggest that individual differences in line bisection performance may reflect general traits in visuospatial attention, which in turn can influence the stimuli that are processed and perceived – in this case, affecting responses to asymmetrical paintings and responses on asymmetrical rating scales in an opposite fashion.

Study 2 was designed to examine whether the results of Study 1 could indeed be attributed to individual differences in visuospatial bias (which involves preferential right hemisphere processing in neurotypical individuals), or instead could be explained by hemispheric differences related to processing of the specific attributes examined (most of which also involve preferential right hemisphere processing in neurotypical individuals). Attributes related to left hemisphere processing (logic, positive valence) were introduced to distinguish between these two possibilities, along with other attributes associated with right hemispheric asymmetries and/or leftward asymmetries in art (negative valence,
brightness); the previously-investigated attributes were also examined again. Further, a forced-choice paradigm was employed instead of a rating scale, to avoid the influence of visuospatial bias on ratings. The asymmetrical paintings used in Study 1 were examined, in addition to symmetrical paintings which served as control stimuli. Results showed that leftward bisectors more frequently selected the non-mirrored paintings as more emotionally evocative, whereas rightward bisectors selected the mirrored paintings more frequently for this attribute, which partially replicated the findings in Study 1. A similar, though non-significant, trend was observed for selections of novelty. The results of further post-hoc tests also suggested that left bisectors perceived the non-mirrored paintings as more logical, positively valenced, and bright compared to the mirrored paintings. These findings support the idea that hemispheric differences in processing left and right hemisphere attributes played a greater role in the results of Study 1, beyond hemispheric differences related to visuospatial processing alone.

The results of Studies 1 and 2 together suggested that leftward and rightward bisectors differed in how they perceive the paintings, while also suggesting that there were asymmetries within the paintings themselves. Attributes such as evocative impact and brightness appeared to be more present in the left half of non-mirrored paintings than the right, whereas attributes such as logic and positive valence seemed to have greater representation on the left. Study 3 examined whether the attributes used in the previous studies were biased within the paintings in a manner consistent with Studies 1 and 2, and with the hemispheric asymmetries underlying the processing of these attributes. That is, instead of examining how individuals perceive art, this study examined how painters themselves might create their art by having participants compare the left and right halves
of the paintings in a spatially separate, midline manner. Study 3a examined the five attributes first used in Study 1 (evocative impact, aesthetics, technique, novelty, and closure), and showed that participants chose the right half of asymmetrical paintings more frequently than the left half as expressing better technique (opposite to what was predicted). Study 3b examined the attributes chosen for their established lateralized patterns, namely logic, positive valence, negative valence, brightness, and evocative impact. Results showed that the right half of asymmetrical paintings was chosen more frequently than the left as appearing more logical and negatively valenced, whereas the left half was selected more often than the right as brighter and more positively valenced. These results were in line with predictions for logic and brightness, but opposite to predictions for positive and negative valence, perhaps as a result of limbic rather than frontal lobe activation when creating art (as discussed in Study 3b).

Studies 1-3 all examined how visuospatial biases (and other attributes associated with lateralized processing) can influence how one perceives or interacts with information in their surroundings. In contrast, Study 4 was designed to examine how attributes associated with lateralized processing can influence visuospatial biases themselves. The line bisection task was manipulated with different line types (face, word, solid), and emotional valences (positive, negative, neutral). Results indicated that participants displayed pseudoneglect in general, but line type and valence affected the strength of these leftward biases. In general, when the lines were embedded with facial stimuli, the extent of pseudoneglect decreased, and when the lines were embedded with words, the extent of pseudoneglect increased (particularly when positive words were used). These results were opposite to what was predicted based on known hemispheric
asymmetries, perhaps due to an unforeseen influence of other lateralized processes such as local and/or global processing.

Overall, the studies in this dissertation showed how individual differences in visuospatial attention work with other aspects of lateralized processing in order to influence the way we perceive and process information in our environments. Indeed, the results suggest asymmetries in the brain can lead to asymmetries in behaviour.

6.2. Line Bisection Across the Studies: Post-Hoc Comparisons

The studies in this dissertation were compared to each other with the assumption that the samples were similar in composition (all participants were undergraduate students enrolled in undergraduate psychology courses at the University of Regina). In order to determine if they were indeed similar with regard to visuospatial biases, a cross-study comparison of line bisection bias scores for pen-and-paper line bisection was conducted to determine whether the samples were comparable in their performance on this measure. First, a two by five mixed design ANOVA comparing left and right hand line bisection scores across all of the studies revealed a main effect of hand, \( F(1, 208) = 97.35, p < .001, \eta_p^2 = .32 \); a main effect of study, \( F(4, 208) = 4.76, p = .001, \eta_p^2 = .08 \); and an interaction between hand and study, \( F(4, 208) = 3.01, p = .02, \eta_p^2 = .06 \).

For the main effect of hand use, pairwise comparisons confirmed that left hand use (\( M = -1.58, SE = .14 \)) and right hand use (\( M = -0.07, SE = .12 \)) significantly differed from each other, \( p < .001 \). For the main effect of study, participants in Study 2 were more leftward biased (\( M = -1.55, SE = .19 \)) than the participants in the remaining studies (\( M = -.45 \) to \( -.73; SE = .17 \) to \( .29 \)), and pairwise comparisons confirmed that only Study 2 significantly differed from all other studies, all \( ps \leq .02 \).
Figure 12. Comparison of left and right hand line bisection bias scores (±SEM) across all studies.

* $p < .001$
To decompose the interaction, the effect of hand-use within each study was first examined. As visible in Figure 12, left handed line bisection produced a leftward bias and right handed line bisection bias produced a slight rightward bias, with the exception of Study 2. Even so, paired-samples t-tests confirmed that left handed line bisection produced a significantly larger leftward bisection bias compared to right handed line bisection in all studies, including Study 2, all ps < .001. Next, to examine between-study differences, univariate ANOVAs were conducted on each hand separately. These analyses revealed that only right hand line bisection performance significantly differed across studies, $F(4, 208) = 6.87, p < .001, \eta_p^2 = .12$, while left hand performance did not ($p = .09$). Pairwise comparisons showed that right hand performance in Study 2 differed from all other studies, all ps ≤ .001, whereas right hand performance did not differ between studies 1, 3a, 3b, and 4, all ps > .35.

Studies 2-4 also introduced a novel two-hand line bisection condition, and further cross-study analyses were run to examine how this condition compared to the left and right hand conditions across these studies. A three (hand: left, right, both) by four (study: 2, 3a, 3b, 4) mixed design ANOVA showed a main effect of hand, $F(2, 280) = 64.24, p < .001, \eta_p^2 = .32$; a main effect of study, $F(3, 140) = 4.49, p = .005, \eta_p^2 = .09$; and an interaction between hand and study, $F(6, 280) = 2.77, p = .01, \eta_p^2 = .06$. In terms of the main effect of hand use, the two-hands condition ($M = -.40, SE = .15$) fell between the left hand ($M = -1.73, SE = .17$) and the right hand ($M = -.06, SE = .15$) condition, with pairwise comparisons showing that all conditions significantly differed from each other, all ps ≤ .002. This result suggests that the two-hand line bisection task may indeed control for asymmetrical motor effects that arise from single-hand use. The results for
the main effect of study again demonstrate that participants in Study 2 were more
leftward biased as a whole ($M = -1.30, SE = .17$) than the participants in the remaining
studies ($M = -.50$ to -.62; $SE = .23$ to .25); pairwise comparisons confirmed that only
Study 2 significantly differed from all other studies, all $ps \leq .01$.

To examine the interaction between hand use and study for Studies 2-4, paired-
samples t-tests were run first to examine the effect of hand-use within each study. As
visible in Figure 13, left hand use produced significantly stronger leftward biases than
right and two-hands use, and that right hand use did not significantly differ from the use
of both hands within each study. Next, to examine between-study differences, univariate
ANOVA were run separately for each hand
condition. Results indicated that the extent
of line bisection bias did not differ across the studies for left hand use, $p > .83$, but did
differ for right hand use, $F(3, 140) = 9.21, p < .001, \eta^2_p = .17$, and two-hand use, $F(3, 140) = 3.85, p = .01, \eta^2_p = .08$; post-hoc comparisons once again showed that line
bisection performance differed in Study 2 only, compared to the other studies, when the
right hand was used, all $ps < .001$, and when two hands were used, all $ps \leq .04$.

Taken together, the interaction between hand use and study shows that left hand
use for the line bisection task produces the strongest leftward biases, followed by weaker
leftward biases for both hands, and mostly-rightward biases for the right hand (with the
exception of Study 2). Right hand and two-hand line bisection performance did not differ
within studies, but when collapsed across studies this difference became significant.
Further, right hand and two-hand line bisection performance in Study 2 was significantly
different than right and two-hand line bisection performance in the other studies,
suggesting that the sample in Study 2 was atypical.
Figure 13. Comparison of left hand, two-hand, and right hand line bisection bias scores (±SEM) across Studies 2-4.
*p < .001
Notably, Study 2 was the one which introduced left hemisphere attributes to
distinguish between two competing explanations for the results of Study 1. However, no
significant findings were observed for the left hemisphere attributes. Perhaps no such
results were observed because the sample in this study displayed strong pseudoneglect,
which may suggest high right hemisphere relative to left hemisphere activation when
completing a spatially-relevant task such as comparing mirrored and non-mirrored
images (even when the judged attribute typically involves left hemisphere activity).
Indeed, the results of Study 3 do suggest that the right half of paintings appears more
logical than the left, so the fact that results were not found in Study 2 could be
attributable to something other than a definite lack of that attribute within the painting.
While different participant characteristics may be one explanation, another could be
different painting judgement task characteristics, because this task was presented in
different ways across Studies 1-3. A replication of Study 2 would be useful with a
sample that is more comparable to the samples in the other studies in terms of
visuospatial bias (as indexed by line bisection performance). In addition, the
methodology used in Study 1 could be adapted to Study 2, while bearing in mind the
limitations of using rating scales that were demonstrated in Study 1.

6.3. The Influence of Painting Judgement Task Characteristics

The idea that different task characteristics may have influenced the results was
initially discussed in Study 2. In Study 1, participants viewed single images of paintings
and rated how much, if any, of an attribute was present. This rating likely involved
global processing (a right hemisphere function; Han et al., 2002), because participants
had to consider and rate the paintings in their entirety. Results of Study 1 showed that
leftward bisectors preferred non-mirrored variations of the paintings when considering evocative impact, aesthetics, novelty, and technique; this would make sense if non-mirrored paintings contained more of the attribute of interest in the left half. The opposite was shown for right bisectors, who preferred mirrored versions of the paintings, which presumably would contain more of the attribute in the right half (i.e., the mirrored left half). In Study 2, participants simultaneously viewed the paintings in non-mirrored and mirrored orientations and were asked to select which image displayed more of the attribute in question. This likely involved local, analytical processing (a left hemisphere function; Han et al., 2002) because participants now needed to consider each image separately from the other and make a single selection. The results of Study 2 showed that more leftward bisectors were more likely to select non-mirrored paintings as emotionally evocative, and perhaps more novel, but no results were found for the attributes of technique, aesthetics, and closure. It is possible that left hemispheric activation from the task characteristics competed with the right hemispheric activation from processing the attributes, reducing the overall effect. However, it should be noted that the pairs of images in this study were the same, except that one was mirrored, and this was likely obvious to the participants. As such, they may have been less motivated to make genuine comparisons between the two images, which may also explain the reduced number of significant results compared to Study 1 (i.e., no findings for aesthetics or technique, and no findings for the right hemisphere attributes).

In contrast to Studies 1 and 2, Study 3 was likely untied from the influence of unintentional left or right hemispheric activation of the participants due to changes in task characteristics. The left and right halves of the paintings were presented one above
the other, so even if the left hemisphere was more highly activated than the right, this would not affect whether the top or bottom image (i.e., the left or right hemi-painting) was selected more often. Even if attention was drawn to the right, this does not mean that the right hemi-painting was on the right side of the screen. As such, the explanation for the results of Study 3 must relate to whether the left or right hemi-painting has an attribute inherent in it, due to the artist putting it there, whether consciously or not, when he or she painted it. Because the results of Study 3 likely were not influenced by local or global processing, it is possible that the asymmetrical paintings truly were right-biased in terms of technique, and that this was masked in Study 1 because of global processing, and in Study 2 because of motivational factors.

Finally, the results of Study 4 may also be understood in terms of local processing of face lines and global processing of word lines. As detailed in section 5.6.1.1., honing in on a facial expression within a small face embedded within a line could produce unexpected left-hemispheric processing due to the need to focus attention in a local, detail-oriented manner. Also, reading a series of words embedded within a line that together convey a particular valence could result in the recruitment of additional right hemisphere resources due to the distribution of attention in a more global manner. This could explain the finding that the extent of pseudoneglect was generally reduced for face lines, and increased for word lines.

Of particular relevance, Jackson, Hobman, Jimmieson, and Martin (2012) also demonstrated that local and global processing is an important consideration for individuals with different patterns of laterality. In their studies, individuals with a right-ear preference actually performed better at local (left-hemisphere) tasks, whereas
individuals with a left-ear preference performed better at global (right-hemisphere) tasks. In the future, it would be interesting to examine how individuals with leftward and rightward biases in visuospatial attention might also differ on tasks which clearly require local and/or global processing.

6.4. The Big Picture.

The behavioural asymmetries observed in the present dissertation likely developed as a “side effect” of functional laterality, which is observed in nearly all vertebrate life (Vallortigara, Rogers, & Bisazza, 1999). The hemispheric organization of lateralized functions is fairly consistent across species (Ghirlanda & Vallortigara, 2004); for example, spatial functions are generally lateralized to the right hemisphere, whereas categorization of stimuli is typically lateralized to the left, with this pattern reported in fish, amphibians, reptiles, birds, and mammals (Ghirlanda & Vallortigara, 2004; Rogers & Andrew, 2002; Vallortigara, Pagni, & Sovrano, 2004; Vallortigara et al., 1999). This consistent organization across different taxonomies suggests that functional laterality is evolutionarily advantageous. Indeed, researchers have found that the lateralization of functions to different hemispheres allows for parallel processing of separate tasks (Lust, Geuze, Groothuis, & Bouma, 2011), which is cognitively efficient (e.g., allows for faster reaction time and enhanced skill performance; Rogers, 2000).

The lateralization of spatial processing to the right hemisphere of the brain thus allows for animals to efficiently navigate their environment while simultaneously processing other important information. However, behavioural biases arise as a consequence of this laterality. For example, animals react faster to predators approaching from the left (De Santi, Sovrano, Bisazza, & Vallortigara, 2001; Evans, Evans, & Marler,
1993; Lippolis, Bisazza, Rogers, & Vallortigara, 2002), and they display left-side biases when interacting with members of their own species (Casperd & Dunbar, 1996; Deckel 1995; Peirce, Leigh, & Kendrick, 2000; Robins, Lippolis, Bisazza, Vallortigara, & Rogers, 1998; Sovrano, Bisazza, & Vallortigara, 2001; Vallortigara, 1992; Vallortigara, Cozzutti, Tommasi, & Rogers, 2001; Vermeire, Hamilton, & Erdmann, 1998; Weiss, Ghazanfar, & Hauser, 2002). Further, research with avians reveals that chicks and pigeons prefer to peck at grains positioned to the left of centre (Wilzeck & Kelly, 2013), and when trained to peck at the middle-most bead in a line of beads, they tend to err to the left for longer lines (essentially demonstrating a leftward line bisection bias; Regolin 2006).

Thus, it is likely that the existing mechanisms which underlie directional behavioural asymmetries are what allowed for the development of asymmetries in the perception and creation of art, as observed in the present studies. However, one cannot discount the role that social and cultural influences also play in such complex behaviours. For example, colours and shapes are ascribed different meanings and associations according to one’s culture (Gage, 2003; Madden, Hewett & Roth, 2000; Ou, Luo, Woodcock, & Wright, 2003), which may influence one’s interpretation of coloured paintings. Further, different patterns of eye gaze and strength of attentional asymmetries can be observed in cultures where language is written and read from right to left, such as Arabic and Japanese, compared to cultures where language is written and read from left to right, such as English (Adams et al., 2010; Friedrich & Elias, 2014; Girelli, Marinelli, Grossi, & Arduino, 2017; Jordan et al., 2014). Overall, these cultural influences interact
with the biological mechanisms underlying behavioural asymmetries, together producing interesting and complex spatially-relevant behaviours.

The results of this dissertation may be of particular interest to artists and art educators, as it adds new considerations related to the composition of paintings. For example, knowing that the majority of people focus attention towards the left, and fewer to the right, can help inform how to best convey meaning to a larger target audience, or contrarily, to appeal more to individuals with a rightward spatial bias. The results also add to the body of research discussing additional “side effects” of functional laterality in humans. Other studies have found behavioural asymmetries in relation to navigational tasks such as walking through doorways (Hatin et al., 2012; Kitayama, Fujikake, Kokubu, & Higuchi, 2015; Nicholls, Loftus, Mayer, & Mattingley, 2007; Nicholls, Loftus, Orr, & Barre, 2008; Thomas et al., 2009; Turnbull & McGeorge, 1998) and driving or simulated driving (Bendetto, Pardrotti, Bremond, & Baccino, 2013 Jang, Ku, Na, & Lee, 2009; Nicholls et al., 2010). Leftward behavioural asymmetries have also been observed when holding infants (Harris, Almerigi, Carbary, & Fogel, 2001; Harris et al., 2010; Manning & Chamberlain, 1991; Vauclair & Donnot, 2004), selecting seats in classrooms (Harms, Poon, Smith, & Elias, 2015), and expressing emotions (e.g., Sackeim et al., 1978). Taken together, this field of research demonstrates that functional laterality has far-reaching influences on the behaviour of humans and other animals.

6.5. Conclusion

The present dissertation contributed new and interesting insights into how asymmetries in the human brain can influence the way paintings and lines are interacted with and perceived. Moreover, individual differences in the way lateralised functions are
processed, such as visuospatial attention, emotion, and logic, can result in different patterns of behaviour. This is intriguing, because it is also possible that other aspects of our world are differently perceived based on, at least in part, inherent biological differences in visuospatial processing. The environments we encounter are rarely symmetrical, so individuals with differing visuospatial biases may in fact have quite different experiences of how the world looks. For future research, it would be interesting to move beyond static images to see how the dynamic, living world that surrounds us can be differently perceived and interpreted by those with differing patterns of laterality.
References


doi:10.1016/j.bandc.2007.07.001

and eye movements. *Neuron*, 21(4), 761-773. doi:10.1016/S0896-6273(00)80593-0


De Renzi, E., Perani, D., Carlesimo, G. A., Silveri, M. C., & Fazio, F. (1994). Prosopagnosia can be associated with damage confined to the right hemisphere—
An MRI and PET study and a review of the literature. *Neuropsychologia*, 32(8), 893-902. doi:10.1016/0028-3932(94)90041-8


electrical mapping and source analysis. *NeuroImage, 19*(3), 710-726.

doi:10.1016/s1053-8119(03)00057-0


doi:10.1007/s40167-014-0019-3


doi:10.13140/RG.2.1.3920.0481


doi:10.1080/13576500903064018


doi:http://dx.doi.org/10.1093/brain/awl164


doi:10.3758/BF03206096


doi:10.1093/beheco/arh107


Appendix 1. Non-mirrored asymmetrical paintings used in Studies 1-3

Images not to scale. Printed with permission from the artist Stephen Duren.
Appendix 2. Supplementary Tables A and B for Study 1

Supplementary Table A
Results of the $z$ test of the difference between Pearson Correlations of left- and right-hand line bisection bias scores with each of the five attributes.

<table>
<thead>
<tr>
<th>LLB and RLB bias compared on this attribute:</th>
<th>Visual Analogue</th>
<th>Numeric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional Evocation</td>
<td>$z$-score</td>
<td>-3.04*</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.002</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>$z$-score</td>
<td>-2.30*</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.02</td>
</tr>
<tr>
<td>Novelty</td>
<td>$z$-score</td>
<td>-1.88</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.06</td>
</tr>
<tr>
<td>Technique</td>
<td>$z$-score</td>
<td>-2.28*</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.02</td>
</tr>
<tr>
<td>Closure</td>
<td>$z$-score</td>
<td>-1.88</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.06</td>
</tr>
</tbody>
</table>
Supplementary Table B

Results of the $z$ test of the difference between Pearson Correlations of the visual analogue and numeric ratings with each of the five attributes.

<table>
<thead>
<tr>
<th>Visual Analogue and Numeric compared on this attribute:</th>
<th>LLB Bias</th>
<th>RLB Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional Evocation</td>
<td>$z$-score</td>
<td>.69</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.49</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>$z$-score</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.98</td>
</tr>
<tr>
<td>Novelty</td>
<td>$z$-score</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.31</td>
</tr>
<tr>
<td>Technique</td>
<td>$z$-score</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.92</td>
</tr>
<tr>
<td>Closure</td>
<td>$z$-score</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td>$p$ (2-tailed)</td>
<td>.18</td>
</tr>
</tbody>
</table>
Appendix 3. Non-mirrored symmetrical paintings used in Studies 2 and 3.

Images not to scale. Printed with permission from the artists Holly Fay and Ernest Klinger, and under public domain usage rights for Wassily Kandinsky and Paul Klee.
Appendix 4. University of Regina Research Ethics Board approvals

DATE: July 13, 2011

TO: Bianca Hatin
Psychology Department

FROM: Dr. David Senkow
Acting Chair, Research Ethics Board

Re: Are Judgements of Faces and Art Related to Visual Attention? (File # 10551011)

Please be advised that the University of Regina Research Ethics Board has reviewed your proposal and found it to be:

☑ 1. APPROVED AS SUBMITTED. Only applicants with this designation have ethical approval to proceed with their research as described in their applications. For research lasting more than one year (Section 1F), ETHICAL APPROVAL MUST BE RENEWED BY SUBMITTING A BRIEF STATUS REPORT EVERY TWELVE MONTHS. Approval will be revoked unless a satisfactory status report is received. Any substantive changes in methodology or instrumentation must also be approved prior to their implementation.

☐ 2. ACCEPTABLE SUBJECT TO MINOR CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB. **Do not submit a new application.** Once changes are deemed acceptable, ethical approval will be granted.

☐ 3. ACCEPTABLE SUBJECT TO CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB. **Do not submit a new application.** Once changes are deemed acceptable, ethical approval will be granted.

☐ 4. UNACCEPTABLE AS SUBMITTED. The proposal requires substantial additions or redesign. Please contact the Chair of the REB for advice on how the project proposal might be revised.

Dr. David Senkow

cc: Dr. Laurie Sykes Tottenham - Psychology

**supplementary memo should be forwarded to the Chair of the Research Ethics Board at the Office of Research Services (Research and Innovation Centre, Room 109) or by e-mail to research.ethics@uregina.ca**
Research Ethics Board
Certificate of Amendment & Renewal Approval

PRINCIPAL INVESTIGATOR
Bianca Hatin

DEPARTMENT
Psychology

REB# 10551011

SUPERVISOR
Dr. Laurie Sykes Tottenham - Psychology

TITLE
Are Judgments of Faces and Art Related to Visual Attention?

AMENDMENT APPROVAL
OF
Increase the number of participants to 100

ORIGINAL DATE of APPROVAL
July 13, 2011

NEXT RENEWAL DATE
July 13, 2015

Date of Amendment Approval
June 17, 2014

Full Board Meeting □

Delegated Review ☑

AMENDMENT CERTIFICATION
The University of Regina Research Ethics Board has reviewed the changes to the above-named research project as outlined in your memo dated June 6 and they are approved.

The project is also renewed for an additional 12 months beginning July 13, 2014.

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.uregina.ca/research/reib/main.shtml

Dr. Lerena Hoeber, Chair
University of Regina
Research Ethics Board

Please send all correspondence to:
Office for Research, Innovation and Partnership
University of Regina
Research and Innovation Centre 109
Regina, SK S4S 0A3
Telephone: (306) 585-4775 Fax: (306) 585-4833
research.ethics@uregina.ca
DATE: May 15, 2012

TO: Bianca Hatn
Psychology

FROM: Dr. Bruce Plouffe
Chair, Research Ethics Board

Re: Emotions in Art and in Lines (File # 6851112)

Please be advised that the University of Regina Research Ethics Board has reviewed your proposal and found it to be:

☐ 1. APPROVED AS SUBMITTED. Only applicants with this designation have ethical approval to proceed with their research as described in their application. For research lasting more than one year (Section 1F), ETHICAL APPROVAL MUST BE RENEWED BY SUBMITTING A DETAILED STATUS REPORT EVERY TWELVE MONTHS. Approval will be revoked unless a satisfactory status report is received. Any substantive changes in methodology or instrumentation must also be approved prior to their implementation.

☐ 2. ACCEPTABLE SUBJECT TO MINOR CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB. **Do not submit a new application.** Once changes are deemed acceptable, ethical approval will be granted.

☐ 3. ACCEPTABLE SUBJECT TO CHANGES AND PRECAUTIONS (SEE ATTACHED). Changes must be submitted to the REB and approved prior to beginning research. Please submit a supplementary memo addressing the concerns to the Chair of the REB. **Do not submit a new application.** Once changes are deemed acceptable, ethical approval will be granted.

☐ 4. UNACCEPTABLE AS SUBMITTED. The proposal requires substantial additions or redesign. Please contact the Chair of the REB for advice on how the project proposal might be revised.

Dr. Bruce Plouffe

cc: Dr. Laurie Sykes Tottenham

**supplementary memo should be forwarded to the Chair of the Research Ethics Board at the Office of Research Services (Research and Innovation Centre, Room 323) or by e-mail to research.ethics@uregina.ca**
Principal Investigator
Bianca Hatim

Department
Psychology

REB#
651112

Supervisor
Dr. Laurie Sykes Tottenham - Psychology

Title
Emotions in Art and in Lines

Amendment Approval of

<table>
<thead>
<tr>
<th>Original Date of Approval</th>
<th>Next Renewal Date</th>
<th>Date of Amendment Approval</th>
</tr>
</thead>
</table>

- Separate the tasks into multiple sub-studies as they are too time consuming for a single study
- Extend participant recruitment to the community and university through university mail system and use of posters

Full Board Meeting

Delegated Review

Amendment Certification
The University of Regina Research Ethics Board has reviewed the changes to the above-named research project as outlined in your memo dated June 6, 2014 and they are approved.

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.uregina.ca/research/iteb/main.shtml

Dr. Larosa Hooban, Chair
University of Regina
Research Ethics Board

Please send all correspondence to:
Office for Research, Innovation and Partnership
University of Regina
Research and Innovation Centre 109
Regina, SK S4S 0A2
Telephone: (306) 585-4775 Fax: (306) 585-4993
research.ethics@uregina.ca