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The Relationship Between Line Bisection Performance and Emotion Processing: Where Do You Draw the Line?

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Abstract

A recent study demonstrated that higher accuracy on a line bisection task related to greater ratings of evocative impact from paintings (Drago et al., 2008). The authors suggested that line bisection accuracy may act as a "barometer" for both visuospatial and emotion processing, likely as a function of overlapping neural correlates in the right temporoparietal region. We suggest and test an alternative explanation: that visuospatial bias interacted with asymmetries in the paintings and the rating scales to produce the apparent relationship between emotion and visuospatial functions. In the present study, using both visual-analogue and numeric rating scales, the relationship between line bisection performance and ratings of paintings (evocative impact, aesthetics, novelty, technique, and closure) was examined in a young adult sample. We demonstrate that left-hand line bisection bias direction, not line bisection accuracy, is related to most ratings, and that line bisection bias interacts with stimulus orientation (non-mirrored/mirrored) and rating scale direction (ascending/descending) in such a way that can explain the results of the previous study. We conclude that the line bisection task appears to be a sensitive measure of visuospatial attentional biases, which can influence ratings of asymmetrical paintings, and may affect how individuals perceive stimuli in their environment. (200 words)

Key Words: Line bisection, visuospatial attention, emotion processing, temporoparietal, art

The relationship between line bisection performance and emotion processing:

Where do you draw the line?

Visuospatial attention and emotion processing are distinct functions that both demonstrate right hemisphere dominance and have a number of shared neural correlates (Aftanas, Savotina, Makhnev, & Reva, 2005; Blonder, Bowers, & Heilman, 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.

Relationship between Line Bisection Performance and Emotion Processing

The right temporoparietal region is involved in both emotion processing (Aftanas et al., 2005; Moratti, Rubio, Campo, Keil, & Ortiz, 2008) and line bisection performance (Fink, Marshall, Weiss, & Zilles, 2001; Foxe, McCourt, & Javitt, 2003). The line bisection task is a simple measure of visuospatial attention that 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, Douell, & Knight, 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, Mantei, & Brugger, 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*=66years, *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 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 40-50years 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 46-82years (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 (Figure1a), 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.

An Alternative Approach: The Importance of Visuospatial Biases

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.

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, 1999b; 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 greater ratings for non-mirrored paintings (i.e., paintings with leftward asymmetries) than for mirrored paintings, whereas individuals with rightward biases will report greater ratings for mirrored paintings (i.e., paintings with rightward asymmetries) than non-mirrored paintings.

Ascending Versus Descending Scale Direction

A second factor considered in the present study is the scale type and format 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 format in 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 format 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.

Present Study

The present study aimed to: 1) determine whether the results from Drago et al.'s 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 are better explained by line bisection biases; and 3) examine the influence of rating scale type and format, and asymmetries in the painting stimuli, to further examine the alternative explanation that visuospatial biases, not line bisection accuracy, affect the ratings.

Method

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.

Painting judgement task. 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 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. 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 mirror-reversed orientation.

Participants had unlimited time to view each painting, but were asked to give their immediate impression in response to these 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 painting?" (Aesthetics); "How original or new is the painting?" (Novelty); "How much skill does the painting show?" (Technique); "How complete is the painting?" (Closure). Answers were provided in pen-and-paper format, using both visual-analogue and numeric scales (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 five response lines corresponding to the five questions; each response line was equally-spaced, left-aligned, and 100mm in length. The ascending visual-analogue lines were flanked by the numbers “1” and “10” on the left and right, respectively, as per Drago et al. (2008), and the descending visual-analogue 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, and “On a scale of 100-0, I would rate my response to be____” for the descending scale.

Line bisection. Four pen-and-paper line bisection pages were given to each participant. Each page contained five lines that were 100mm long and 2mm thick. The lines were equally spaced apart by 45mm, and staggered from the center of the page by 0mm, ±20mm, and ±45mm. 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).

Questionnaires. Participants completed a demographics and laterality questionnaire, the Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994a), 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 TAS-20 and CES-D were used to account for potential influence of depression and alexithymia. Scores on the handedness, TAS-20, and CES-D measures were not related to the overall results, and thus are not discussed further.

Procedure. After informed consent, participants completed the painting judgement task, in which paintings were presented in a random order. Responses were made using either a visual-analogue or numeric scale. Next, they completed one of the questionnaires, and then the second painting judgement task (using the scale format not previously used). After this, participants completed the line bisection task and the remaining questionnaires.

Scoring

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 0.5mm). 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 0mm-100mm, 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.

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 0.5mm). Line bisection accuracy scores were calculated by subtracting error scores from half the line length (50mm), as the maximum possible error score for bisection was 50mm. 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 0.5mm). 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 (Figure1b), therefore allowing us to decouple accuracy and bias in the following analyses, and determine which was related to the attribute ratings.

Results

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.

The accuracy analyses produced no significant correlations between line bisection accuracy and ratings (all *p*s>.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 (Table1), indicating that leftward bisectors gave higher ratings on the attributes (including emotional evocation) compared to rightward bisectors. No significant correlations were observed between right-hand line bisection bias scores and ratings.

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, 2015).

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.[1] 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; 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 (Table2). 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 (Figure2). 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 Figure2, and was observed for each of the significant interaction terms reported in Table2, 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).

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.[2] Hierarchical Multiple Regressions were 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 (Table3). 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 *ps*>.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 (Figure3).

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 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.

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, 1999a) and facial expressiveness (Luh, Rueckert, & Levy, 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, Lepore, Napolitano, & Trojano, 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.[3] 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.

Hand-use. Interestingly, all statistically significant effects were for left-hand line bisection biases, not right.[4] 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, Shulman, Miezen, & Petersen, 1995; Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Corbetta, Kincade, & Shulman, 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.

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.

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, Thut, Learmonth, & Harvey, 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, Keller, Carkassky, Minshew, & Just, 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.

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 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 (Table1). 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, Scholes, & Watson, 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/skill, along with the unrelated attribute of closure/completeness, are unknown.

Future fMRI research examining the Shared Neural Correlates hypothesis is needed to elucidate the neural correlates of perceived skillfulness and completeness, 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.

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 et al., 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.

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–affecting 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.

Footnotes

1. 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 *p*s > .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 nonmirrored stimuli. Taken together, there is sufficient evidence that our data meet the necessary assumptions.

2. 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 ps > .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.

3. 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, $t(7) = 4.01$, $SEM = 4.33$, $p = .005$

4. This was further supported by supplementary analyses using z difference scores between left- and right-hand line bisection correlations (Table1). Supplementary Table A demonstrates that

attribute rating correlations with left- and right-hand line bisection biases do significantly differ from each other, whereas Supplementary Table B 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.

References

Adair, H., & Bartley, S. H. (1958). Nearness as a function of lateral orientation in pictures. *Perceptual and Motor Skills, 8,* 135-141.

Aftanas, L. I., Savotina, L. N., Makhnev, V. P., & Reva, N. V. (2005). Analysis of evoked EEG synchronization and desynchronization during perception of emotiogenic stimuli: Association with autonomic activation processes. *Neuroscience and Behavioral Physiology, 35*(9), 951-957.

Bagby, R. M., Parker, J. D. A., & Taylor, G. J. (1994a). The twenty-item Toronto Alexithymia scale—I. Item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research, 38*(1), 23-32. doi: 10.1016/0022-3999(94)90005-1

Benwell, C. S. Y., Thut, G., Learmonth, G., & Harvey, M. (2013). Spatial attention: Differential shifts in pseudoneglect direction with time-on-task and initial bias support the idea of observer subtypes. *Neuropsychologia, 51*, 2747-2756. doi: 10.1016/j.neuropsychologia.2013.09.030

Bhushan, B., & Rai Sapru, S. (2008). Handedness, Hinduism and sculpture: Searching for evidence of lateralisation. *Laterality, 13*(4), 320-332. doi: 10.1080/13576500802000709

Blonder, L. X., Bowers, D., & Heilman, K. M. (1991). The role of the right hemisphere in emotional communication. *Brain, 114* (3), 1115-1127. doi: 10.1093/brain/114.3.1115

Bowers, D., & Heilman, K. M. (1980). Pseudoneglect: Effects of hemispace on a tactile line bisection task. *Neuropsychologia, 18*(4–5), 491-498. doi: 10.1016/0028-3932(80)90151-7

Bultitude, J. H., & Aimola Davies, A. M. (2006). Putting attention on the line: Investigating the activation-orientation hypothesis of pseudoneglect. *Neuropsychologia, 44*(10), 1849-1858. doi: 10.1016/j.neuropsychologia.2006.03.001

Çiçek, M., Deouell, L. Y., & Knight, R. T. (2009). Brain activity during landmark and line bisection tasks. *Frontiers in Human Neuroscience, 3*, 7. doi: 10.3389/neuro.09.007.2009

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). Outliers and multicollinearity: Diagnosing and solving regression problem II. *Applied multiple regression/correlation analysis for the behavioral sciences*, 390-430.

Conesa, J., Brunold-Conesa, C., & Miron, M. (1995). Incidence of the half-left profile pose in single-subject portraits. *Perceptual and Motor Skills, 81*, 920-922.

Cook, R. D., & Weisberg, S. (1982). *Residuals and influence in regression*. New York: Chapman and Hall.

Corbetta, M., Kincade, J. M., Ollinger, J. M., McAvoy, M. P., & Schulman, G. L. (2000). Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nature Neuroscience, 3*(3), 292-297.

Corbetta, M., Kincade, J. M., & Shulman, G. L. (2002). Neural systems for visual orienting and their relationships to spatial working memory. *Journal of Cognitive Neuroscience, 14*(3), 508-523.

Corbetta, M., Shulman, G. L., Miezin, F. M., & Petersen, S. E. (1995). Superior parietal cortex activation during spatial attention shifts and visual feature conjunction. *Science, 270*(5237), 802-805.

Dallenbach, K. (1923). Position vs. intensity as a determinant of clearness. *The American Journal of Psychology, 34*(2), 282-286.

De Schotten, M. T., Dell'Acqua, F., Forkel, S. J., Simmons, A., Vergani, F., Murphy, D. G. M., & Catani, M. (2011). A lateralized brain network for visuospatial attention. *Nature Neuroscience, 14*, 1245-1246.

Drago, V., Finney, G. R., Foster, P. S., Amengual, A., Jeong, Y., Mizuno, T., … Heilman, K. M. (2008). Spatial-attention and emotional evocation: Line bisection performance and visual art emotional evocation. *Brain and Cognition, 66*(2), 140-144. doi: 10.1016/j.bandc.2007.06.005

Elias, L. J., Bryden, M. P., & Bulman-Fleming, M. B. (1998). Footedness is a better predictor than is handedness of emotional lateralization. *Neuropsychologia, 36*(1), 37-43. doi: 10.1016/S0028-3932(97)00107-3

Failla, C. V., Sheppard, D. M., & Bradshaw, J. L. (2003). Age and responding-hand related changes in performance of neurologically normal subjects on the line-bisection and chimeric-faces tasks. *Brain and Cognition, 52*(3), 353-363. doi: 10.1016/s0278-2626(03)00181-7

Fink, A., Graif, B., & Neubauer, A. C. (2009). Brain correlates underlying creative thinking: EEG alpha activity in professional vs. novice dancers. *Neuroimage, 46*(3), 854-862. doi: 10.1016/j.neuroimage.2009.02.036

Fink, G. R., Marshall, J. C., Shah, N. J., Weiss, P. H., Halligan, P. W., Grosse-Ruyken, M., … Freund, H. J. (2000). Line bisection judgments implicate right parietal cortex and cerebellum as assessed by fMRI. *Neurology, 54*(6), 1324-1331. doi: 10.1212/wnl.54.6.1324

Fink, G. R., Marshall, J. C., Weiss, P. H., & Zilles, K. (2001). The neural basis of vertical and horizontal line bisection judgments: An fMRI study of normal volunteers. *NeuroImage, 14*(1), S59-S67. doi: 10.1006/nimg.2001.0819

Foster, P. S., Drago, V., Webster, D. G., Harrison, D. W., Crucian, G. P., & Heilman, K. M. (2008). Emotional influences on spatial attention. *Neuropsychology, 22*(1), 127-135. doi: 10.1037/0894-4105.22.1.127

Foxe, J. J., McCourt, M. E., & Javitt, D. C. (2003). Right hemisphere control of visuospatial attention: Line-bisection judgments evaluated with high-density electrical mapping and source analysis. *NeuroImage, 19*(3), 710-726. doi: 10.1016/s1053-8119(03)00057-0

Fujii, T., Fukatsu, R., Yamadori, A., & Kimura, I. (1995). Effect of age on the line bisection test. *Journal of Clinical and Experimental Neuropsychology, 17*(6), 941-944. doi: 10.1080/01688639508402443

Gaffron, M. (1950). Left and right in pictures. *Art Quarterly, 13*, 312-331.

Grossi, D., Lepore, M., Napolitano, A., & Trojano, L. (2001). On selective left-neglect during walking in a child. *Brain and Cognition, 47*(3), 539-544. doi: 10.1006/brcg.2001.1460

Harris, L. J., Cárdenas, R. A., Spradlin, M. P., & Almerigi, J. B. (2010). Why are infants held on the left? A test of the attention hypothesis with a doll, a book, and a bag. *Laterality: Asymmetries of Body, Brain and Cognition, 15*(5), 548-571. doi: 10.1080/13576500903064018

Heilman, K. M., Scholes, R., & Watson, R. T. (1975). Auditory affective agnosia: Disturbed comprehension of affective speech. *Journal of Neurology, Neurosurgery, and Psychiatry, 38*, 69-72.

Heller, W., Nitschke, J. B., & Lindsay, D. L. (1997). Neuropsychological correlates of arousal in self-reported emotion. *Cognition & Emotion, 11*(4), 383-402. doi: 10.1080/026999397379854

Hutchison, J., Thomas, N. A., & Elias, L. (2011). Leftward lighting in advertisements increases advertisement ratings and purchase intention. *Laterality*, *16*(4), 423-432. doi: 10.1080/13576501003702663

Ingalhalikar, M., Smith, A., Parker, D., Satterthwaite, T. D., Elliot, M. A., Ruparel, K., … Verma, R. (2014). Sex differences in the structural connectome of the human brain. *Proceedings of the National Academy of Sciences of the United States of America, 111*(2), 823-828. doi: 10.1073/pnas.1316909110

Jacobsen, T., Schubotz, R. I., Höfel, L., & Cramon, D. Y. (2006). Brain correlates of aesthetic judgment of beauty. *Neuroimage, 29*(1), 276-285. doi: 10.1016/j.neuroimage.2005.07.010

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia, 38*, 93-110.

Junghöfer, M., Bradley, M. M., Elbert, T. R., & Lang, P. J. (2001). Fleeting images: A new look at early emotion discrimination. *Psychophysiology, 38*, 175-178.

Kana, R.K., Keller, T.A., Cherkassky, V.L., Minshew, N. J., & Just, M. A. (2006). Sentence comprehension in autism: Thinking in pictures with decreased functional connectivity. *Brain, 129*, 2484–2493. doi: http://dx.doi.org/10.1093/brain/awl164

Kawashima, R., Matsumura, M., Sadato, N., Naito, E., Waki, A., Nakamura, S., . . . Yonekura, Y. (1998). Regional cerebral blood flow changes in human brain related to ipsilateral and contralateral complex hand movements: a PET study. *European Journal of Neuroscience, 10*, 2254-2260.

Kozbelt, A. (2001). Artists as experts in visual cognition. *Visual Cognition, 8*, 705-723.

Kozbelt, A., & Seeley, W. P. (2007). Integrating art historical, psychological, and neuroscientific explanations of artists' advantages in drawing and perception. *Psychology of Aesthetics, Creativity, and the Arts, 1*, 80-90.

Laerd Statistics. (2015). *Moderator analysis with a Dichotomous Moderator using SPSS Statistics: Enhanced Guide* [online]. Available at: https://statistics.laerd.com/spss-tutorials/dichotomous-moderator-analysis-using-spss-statistics.php [Accessed January 2015].

Lang, P. J., Bradley, M. M., Fitzsimmons, J. R., Cuthbert, B. N., Scott, J. D., Moulder, B., & Nangia, V. (1998). Emotional arousal and activation of the visual cortex: An fMRI analysis. *Psychophysiology, 35*(2), 199-210. doi: 10.1111/1469-8986.3520199

Levy, J., & Reid, M. (1978). Variations in cerebral organization as a function of handedness, hand posture in writing, and sex. *Journal of Experimental Psychology: General*, *107*(2), 119-144. doi: 10.1037/0096-3445.107.2.119

Luh, K. E., Rueckert, L. M., & Levy, J. (1991). Perceptual asymmetries for free viewing of several types of chimeric stimuli. *Brain and Cognition*, *16*(1), 83-103. doi: 10.1016/0278-2626(91)90087-O

Mattingley, J. B., Bradshaw, J. L., Phillips, J. G., & Bradshaw, J. A. (1993). Reversed perceptual asymmetry for faces in left unilateral neglect. *Brain and Cognition, 23*(2), 145-165. doi: 10.1006/brcg.1993.1052

McCourt, M. E., Freeman, P., Tahmahkera-Stevens, C., & Chaussee, M. (2001). The influence of unimanual response on pseudoneglect magnitude. *Brain and Cognition*, *45*(1), 52-63.

McDine, D. A., Livingston, I. J., Thomas, N. A., & Elias, L. J. (2011). Lateral biases in lighting of abstract artwork. *Laterality*, *16*(3), 268-279. doi: 10.1080/13576500903548382

McGeorge, P., Beschin, N., Colnaghi, A., Rusconi, M. L., & Della Sala, S. (2007). A lateralized bias in mental imagery: Evidence for representational pseudoneglect. *Neuroscience Letters, 421*(3), 259-263. doi: 10.1016/j.neulet.2007.05.050

McManus, I. C. (1979). *Determinants of laterality in man.* (Unpublished Doctoral Dissertation). University of Cambridge.

Moran, M. D. (2003). Arguments for rejecting the sequential Bonferroni in ecological studies. *Oikos, 100*(2), 403-405.

Moratti, S., Rubio, G., Campo, P., Keil, A., & Ortiz, T. (2008). Hypofunction of right temporoparietal cortex during emotional arousal in depression. *Archives of General Psychiatry, 65*(5), 532-541.

Nakagawa, S. (2004). A farewell to Bonferroni: The problems of low statistical power and publication bias. *Behavioral Ecology, 15*(6), 1044-1045. doi: 10.1093/beheco/arh107

Nelson, T. M., & MacDonald, G. A. (1971). Lateral organization, perceived depth and title preference in pictures. *Perceptual and Motor Skills, 33*, 983-986.

Nicholls, M. E. R., Bradshaw, J. L., & Mattingley, J. B. (1999a). Free-viewing perceptual asymmetries for the judgement of brightness, numerosity, and size. *Neuropsychologia, 37*, 307-314.

Nicholls, M. E. R., Clode, D., Wood, S. J., & Wood, A. G. (1999b). Laterality of expression in portraiture: Putting your best cheek forward. *Proceedings of the Royal Society B: Biological Sciences*, *266*(1428), 1517-1522.

Nicholls, M. E. R., Hadgraft, N. T., Chapman, H. L., Loftus, A. M., Robertson, J., & Bradshaw, J. L. (2010). A hit-and-miss investigation of asymmetries in wheelchair navigation. *Attention, Perception, & Psychophysics, 72*(6), 1576-1590. doi: 10.3758/APP.72.6.1576

Nicholls, M. E. R., Loftus, A., Mayer, K., & Mattingley, J. B. (2007). Things that go bump in the right: the effect of unimanual activity on rightward collisions. *Neuropsychologia, 45*(5), 1122-1126. doi: 10.1016/j.neuropsychologia.2006.07.015

Nicholls, M. E. R., Loftus, A. M., Orr, C. A., & Barre, N. (2008). Rightward collisions and their association with pseudoneglect. *Brain and Cognition, 68*(2), 166-170. doi: 10.1016/j.bandc.2008.04.003

Nicholls, M. E. R., Orr, C. A., Okubo, M. , & Loftus, A. (2006). Satisfaction guaranteed: The effect of spatial biases on responses to likert scales. *Psychological Science, 17*(12), 1027-1028.

Park, D.C., Lautenschlager, G., Hedden, T., Davidson, N.S. Smith, A.D., & Smith, P.K. (2002). Models of visuospatial and verbal memory across the adult life span. Psychology and Aging, 17(2), 299-320. doi: 10.1037//0882-7974.17.2.299

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments. *BMJ, 316*(7139), 1236-1238. doi: 10.1136/bmj.316.7139.1236

Radloff, L. S. (1977). The CES-D Scale. *Applied Psychological Measurement, 1*(3), 385-401. doi: 10.1177/014662167700100306

Rode, G., Rossetti, Y., & Boisson, D. (2001). Prism adaptation improves representational neglect. *Neuropsychology, 39*, 1250-1254.

Sun, J., & Perona, P. (1998). Where is the sun? *Nature Neuroscience, 1*(3), 183-184.

Tamagni, C., Mantei, T., & Brugger, P. (2009). Emotion and space: Lateralized emotional word detection depends on line bisection bias. *Neuroscience, 162*(4), 1101-1105. doi: 10.1016/j.neuroscience.2009.05.072

Thomas, N. A., Burkitt, J. A., Patrick, R. E., & Elias, L. J. (2008). The lighter side of advertising: Investigating posing and lighting biases. *Laterality*, *13*(6), 504-513. doi: 10.1080/13576500802249538

Tomasi, D., & Volkow, N. D. (2012). Laterality patterns of brain functional connectivity: Gender effects. *Cerebral Cortex, 22*(6), 1455-1462. doi: 10.1093/cercor/bhr230

White, A. M., & Dallenbach, K. (1932). Position vs. intensity as a determinant of the attention of left-handed observers. *The American Journal of Psychology*, *44*(1), 175-179.

Woelfflin, H. (1932). *Principles of art history*. New York: Dover.