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BRIEF REPORT

Unstable world: Recent experience affects spatial perception

Emily Rosenich[1] · Samuel Shaki[2] · Tobias Loetscher[1]

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Abstract

An accurate perception of the space surrounding us is central for effective and safe everyday functioning. Understanding the factors influencing spatial perception is therefore vital. Here, we first confirm previous reports that our cultural reading habits shape the perception of space. Twenty-four left-to-right readers (tested in Australia) and 23 right-to-left readers (tested in Israel) over-attend to information presented on the left and right side of space, respectively. We then show that this cultural bias is highly malleable. By employing a simple mirror-reading task prior to the spatial judgments, we demonstrate that the supposed cultural bias can be easily overridden. These findings question hardwired, lateralisation models of spatial-attentional biases and highlight the need for a dynamic model that takes into account hemispheric lateralisation, cultural habits and situational context.

Keywords Culture · Reading habits · Lateralisation · Spatial perception

Introduction

Our spatial perception is biased. Left-to-right readers tend to pay more attention to spatial information presented on the left side of space (Jewell & McCourt, 2000). This phenomenon, dubbed 'pseudoneglect' (Bowers & Heilman, 1980), is commonly explained as the result of a laterality in brain functioning. The processing of visuo-spatial information yields stronger activation in the brain's right than its left hemisphere (Foxe, McCourt, & Javitt, 2003; Kinsbourne, 1970). This asymmetric activation is thought to cause a slight attentional bias towards the left side of space (Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990). The magnitude of this spatial attentional bias has also been linked to structural brain asymmetries (Cazzoli & Chechlacz, 2017; De Schotten et al., 2011). Larger leftward attentional biases, for example, are associated with larger volumes of right- compared to left-sided white matter tracts connecting parieto-frontal brain networks (De Schotten et al., 2011).

✉ Tobias Loetscher
tobias.loetscher@unisa.edu.au

[1] School of Psychology, University of South Australia, GPO Box 2471, Adelaide, SA 5001, Australia

[2] Department of Behavioural Studies, Ariel University, Ariel, Israel

Studies involving participants with right-to-left reading habits, however, yield results that conflict a pure lateralisation account of spatial asymmetries. Instead of showing the characteristic leftward bias of left-to-right readers, right-to-left readers demonstrate no or a slight rightward asymmetry in perceptual tasks such as line bisection (Chokron & Imbert, 1993; Rinaldi, Di Luca, Henik, & Girelli, 2014), face judgments (Vaid & Singh, 1989), and aesthetic preference judgments (Friedrich & Elias, 2016; Nachson, Argaman, & Luria, 1999). These findings have led to suggestions that participants' habitual script direction is a key factor underlying observed spatial biases (Kazandjian & Chokron, 2008; Maass & Russo, 2003; but see Nicholls & Roberts, 2002, for conflicting findings).

Observed differences in readers with opposite reading habits are incorporated in cultural accounts of spatial asymmetries, which propose that spatial biases are the result of learned behaviour. According to these accounts, everyday exposure to a reading and writing direction induces the development of a learnt spatial attentional bias that is capable of spilling over to tasks unrelated to script (Maass, Suitner, & Deconchy, 2014). The bias is not only shaped by many hours spent actively scanning text with eyes and fingers (ocular or motor biases), but also by reading observation as shown in preliterate children (Göbel, McCrink, Fischer, & Shaki, 2018; McCrink, Caldera, & Shaki, 2018).

Many contemporary views therefore suggest that spatial perceptual asymmetries are the result of an interaction between the lateralisation of brain function and cultural reading habits (Girelli, Marinelli, Grossi, & Arduino, 2017; Maass et al., 2014; Rinaldi et al., 2014). A hard-wired, hemispheric lateralisation of spatial attentional processes may be the brain's default setting that causes a leftward orienting bias. Experiences throughout the lifetime, such as cultural reading habits, might then shape the default setting in a way consistent with native script direction. In the case of right-to-left readers, continuous and frequent exposure to their script may override or, at the very least, weaken the default leftward bias.

While habitual reading direction is known to influence visuospatial biases (Chokron & Imbert, 1993; Maass et al., 2014), it is poorly understood how immediate prior experiences shape perceptual asymmetries. Studies on how people conceptualise abstract concepts suggest that the bias might be highly malleable. Habitual reading habits shape how we think about numbers, time and language comprehension with the left (right) being associated with smaller, earlier and the location of the actor in left-to-right readers (right-to-left readers). However, immediate prior spatial experiences, such as a few minutes of reading in the opposite direction or mirror reading, reverses these spatial conceptual asymmetries (Casasanto & Bottini, 2014; Román, Flumini, Lizano, Escobar, & Santiago, 2015; Shaki & Fischer, 2008). This raises the question of whether such flexibility observed in spatial conceptual asymmetries as a result of recent spatial experiences can also be demonstrated for spatial perceptual asymmetries.

The current study tests the influence of a mirror-reading manipulation on perceptual asymmetry within two groups with opposite long-term reading direction habits. Demonstrating a highly flexible and adaptive attentional system will have important implications for current theories of spatial biases, which do not currently consider the influence of recent experience (Bowers & Heilman, 1980; Chokron & Imbert, 1993; Kazandjian & Chokron, 2008; Reuter-Lorenz et al., 1990).

Method

Participants

Twenty-five native English readers (left-to-right) aged between 18 and 33 years of age (M = 23.12, SD = 4.48), and 24 native Hebrew readers (right-to-left) aged between 20 and 43 years of age (M = 24.96, SD = 4.60) participated in the study. All participants were right-handed (Nicholls, Thomas, Loetscher, & Grimshaw, 2013) University students and tested in their home country (Adelaide, Australia and Ariel, Israel). None of the Australian participants were able to read right-to-left scripts. Israeli participants were native Hebrew speakers, with habitual daily use of right-to-left script and reported only minimal exposure to left-to-right script.

The required sample size was based on the assumption of a moderate to large effect size of the reading manipulation (e.g., Shaki & Fischer, 2008). To achieve a power of .8 in a paired t-test with alpha =.05 and d = .65, a minimum of 21 participants were required per group; however, we aimed for 24 participants per group to account for possible issues during data collection.

The study was granted ethical approval from the University of South Australia's Human Research Ethics Committee, as well as from Ariel Institutional Review Board. Participants received an honorarium of $15 (Australian) or a credit in their psychology classes. All participants provided informed consent prior to participation.

Materials

Reading material Two non-fiction English travel recounts written by Tremblay and sourced from a travel adventure book titled 'Riding Sky High' were used (Tremblay, 2015). Each recount was roughly 1,200 words and contained Standard English vocabulary. Text was translated from English into Hebrew for the experiment conducted with native Hebrew readers. Text was presented in a standard (left-to-right/right-to-left) or mirror-reversed (right-to-left/left-to-right) format for English and Hebrew readers, respectively. All words were capitalised, and displayed in 15-point Helvetica font, with 1.15-point spacing. The text occupied four pages and was separated into roughly six paragraphs consisting of around four to six lines of text each. The protocol for the reading task (text length, font conditions and presentation) was adapted from Román et al. (2015), a study that successfully altered mental representations after mirror reading.

Landmark task stimuli The presentation of pre-bisected lines and the subsequent judgments of the length of the line's two segments is a common measure of spatial attentional biases (e.g., Harvey, Milner, & Roberts, 1995; McCourt & Jewell, 1999). The pre-bisected line stimuli in this study were modelled on McCourt (2001) and Nicholls et al. (2014). Stimuli were presented individually against a uniformly grey background. Two black and two white horizontal bars were arranged diagonally to form opposite pairs (see Fig. 1 for an example). The point at which the inner edge of the bars intersects was shifted 0.5, 1 or 2 mm to either the left or the right of the objective centre, such that one segment was always longer than the other. All lines remained 25 cm long. The entire position of the pre-bisected lines was jittered horizontally on a trial-by-trial basis between two locations located 2 mm from either left or right of true centre, or in the centre itself, in order to prevent participants from using external landmark cues to assist task completion. Despite horizontal jittering, the line was always placed in the vertical centre.

A series of 144 horizontal lines per condition was presented per participant, derived from four repetitions of 36 unique combinations of the four factors (polarity: top left horizontal bar

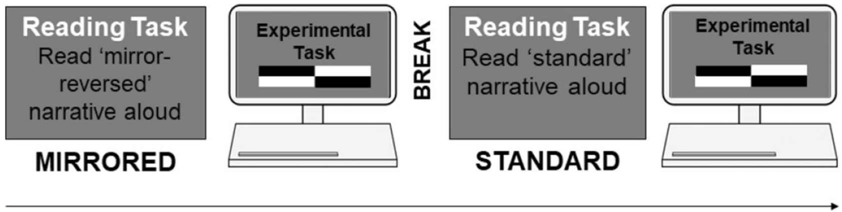

Fig. 1 Horizontal schematic illustrating the within-subjects experimental manipulation. Participants indicated whether a series of horizontal lines was longer on the left or longer on the right immediately after reading a text of a particular directionality (standard, mirrored). Order of conditions and texts were counterbalanced

(black); top left horizontal bar (white), jitter: left (2 mm); centre (0 mm); right (2 mm), longer side: first (left); second (right), and deviation: first (0.5 mm); second (1 mm); third (2 mm).

Procedure

Each participant read aloud travel recounts presented once in standard and once in mirror-reversed format. The order of the two conditions was counterbalanced and the text script was presented in participants' native language. After reading a text in either condition, participants performed the landmark task (see Fig. 1).

Participants were seated in a chair parallel to the experimenter and were given the travel recount to read. The experimenter recorded the number of errors and text reading time. Immediately after the text was read, participants were positioned in front of an LCD monitor. The monitor was positioned relative to the individuals' fronto-parallel plane and centred with respect to the sagittal-body middle. Participants were instructed to rest their chin on an adjustable chin rest that ensured head and eye positioning remained consistent with the centre of the monitor, at a viewing distance of 60 cm. After participants read on-screen experimental instructions (presented in a standard or mirror-reversed format, depending on condition), the landmark task began. On completion of the first condition, participants were given a short break before completing the opposite condition.

Whereas reading was manipulated via mirror-reversal, the landmark task itself remained unchanged, with the exception of on-screen experimental instructions, which were presented in a standard or mirror-reversed format to avoid effect contamination. This is unlike other studies, which sought to manipulate the bisection task itself by changing the direction from which scanning is initiated when judging the lines (cf. Jewell & McCourt, 2000). The landmark task required participants to make a forced-choice judgement as to whether the 144 randomly sequenced horizontal lines (displayed one at a time) were longer on the left or longer on the right. Participants indicated their response by pressing a left- or right-designated button. For example, if participants believed the left segment of the line was longer, the left button was pressed with the index finger on the left hand, with the opposite true for the right. Stimuli presentation and response timing were based on Nicholls et al. (2012), with stimuli shown for 500 ms and a response period of 2,000 ms. Participants were instructed to respond only after the prebisected line was removed. If participants failed to respond within the designated response window, an alert (presented in standard or mirror-reversed format, applicable to the test condition) appeared to remind participants to respond quickly. Missed trials were disregarded and replaced with an identical trial on next presentation.

Analyses

Reading performance was assessed by noting the number of reading errors and reading time (seconds) in the standard and mirror-reading condition. In addition, the cognitive cost of mirror reading relative to standard reading was calculated as mirrored reading time divided by standard reading time.

To assess spatial asymmetries in the landmark task, a response bias was calculated for each condition by subtracting the number of left responses from the number of right responses and converting the difference to a percentage of the total number of trials (Nicholls et al., 2014). The bias scores could range from −100 to +100, with negative and positive scores indicating a bias towards the left and right side, respectively. A score of −100 indicates that a participant always responded 'left segment longer'.

Results

One English participant was excluded from the analyses on the basis that their overall accuracy score did not significantly differ from chance (accuracy score M = 53.13%). The pattern of results did not change with the exclusion of this participant. Additionally, one Hebrew participant was excluded from the analyses because of a technical error whereby no data were recorded for one of the conditions.

The exclusion of the two participants reduced the sample size to 47 participants. Demographics and reading performance data split by Group are provided in Table 1.

Table 1 Details on reading performance

	Participants (f/m)	Reading time in seconds (SD)		Number of reading errors (SD)		Mirrored/standard reading time (SD)
		Standard	Mirrored	Standard	Mirrored	
Hebrew	23 (18/5)	323 (57)	1295 (292)	2.7 (1.6)	15.0 (5.9)	4.1 (1.1)
English*	24 (18/6)	410 (35)	1065 (274)	4.3 (3.1)	12.2 (7.0)	2.6 (0.6)
Total	47 (36/11)	367 (64)	1180 (303)	3.5 (2.6)	13.6 (6.5)	3.4 (1.2)

Note: Mirrored reading time divided by standard reading time indicates how much longer it took participants to read the mirrored text relative to the standard text. * One English participant missed large parts of text in the mirror-reading condition (totaling 223 reading errors). Their mirror-reading data were excluded when calculating the average reading time and mean errors

Overall accuracy in the landmark task was 71.7% (SD = 6.2) and 72.8% (SD = 7.9) for Hebrew and English readers, respectively. A repeated-measures ANOVA with reading direction (standard, mirror-reversed) as within-subject factor and native language (English, Hebrew) as between-subject factor revealed no main effect of native language ($F(1,45) = 0.01$; $p > 0.93$). There was a significant main effect of reading direction ($F(1,45) = 15.77$; $p < 0.001$; Partial $Eta^2 = .26$) with a smaller response bias after mirror reading (M = −9.40, SD = 26.30) than after standard reading (M = 2.54, SD = 28.01). Importantly, there was a significant interaction between reading direction and native language ($F(1,45) = 47.85$; $p < 0.001$; Partial $Eta^2 = .52$). Employing Holm-Bonferroni corrections for multiple comparisons, post hoc tests revealed opposing spatial biases in the two groups' standard reading condition ($t = -2.75$, $p = 0.009$, Cohen's $d = 0.8$) and significant effects of reading direction within both native language groups: Mirror reading shifted the response bias leftward compared to standard reading in native Hebrew readers ($t = 7.58$, $p < 0.001$, Cohen's $d = 1.6$), whereas mirror reading in English readers lead to a rightward response bias shift ($t = -2.12$, $p = 0.045$, Cohen's $d = 0.4$, see Fig. 2). One-sample t-tests against 0 revealed a significant bias in the standard ($t(22) = 3.62$, $p = 0.002$, $d = 0.76$) and mirror-reversed condition ($t(22) = -4.34$, $p < 0.001$, $d = -0.90$) for the Hebrew readers. The corresponding one-sample t-tests for the English readers were not significant (standard ($t(23) = -1.17$, $p = 0.25$, $d = -0.24$); mirror-reversed ($t(23) = 0.28$, $p = 0.78$, $d = 0.06$).

Exploratory analyses revealed no relationship between the cognitive cost of mirror reading (mirror-reading time divided

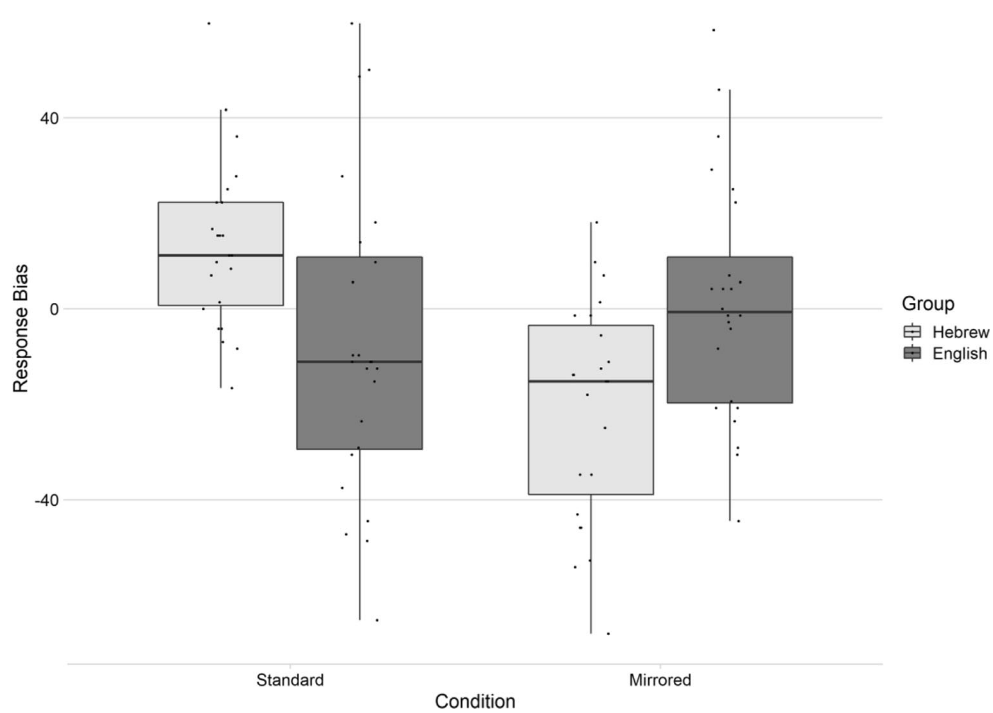

Fig. 2 Interaction between condition (standard, mirrored) and participant group (English, Hebrew). Negative and positive response biases indicate a bias towards the left and right side of space, respectively. Dots indicate individual participant data

by standard reading time) and change in spatial bias (calculated as Mirrored Bias minus Standard Bias): Pearson's r Hebrew participants = .01, p = .98; Pearson's r English participants = .03, p =.90.

Discussion

The findings of this study provide clear evidence against an exclusively hardwired account of spatial perceptual asymmetries (i.e. pseudoneglect as the result of a laterality in brain functioning). The opposing spatial biases observed in English and Hebrew readers highlights that cultural reading habits play an important role in how space is perceived and judged (Kazandjian & Chokron, 2008). The biases in the direction of their native reading directions serve as an important reminder that even low-level cognitive processes such as perception can be shaped by the culture in which we live and that cross-cultural studies are critical to gathering a complete understanding of brain functioning (Han & Northoff, 2008).

While cultural reading habits seem to shape the default setting of spatial perception with biases aligning with one's native script direction, this default setting seems highly plastic and mouldable. Briefly manipulating reading direction was enough to override native perceptual tendencies in both groups. The mirror-reading condition forced Hebrew and English readers to read in the opposite direction of their habitual script, and this was sufficient to reverse the direction of native spatial biases (see Fig. 2). The malleability of spatial biases demonstrated in response to immediate prior spatial experience ties in nicely with research that describes similar effects for the spatial conceptualisation of abstract domains, such as thinking about numbers (Shaki & Fischer, 2008) and time (Casasanto & Bottini, 2014). We show here that prior spatial experiences affect not only mental representation (Casasanto & Bottini, 2014; Román et al., 2015; Shaki & Fischer, 2008), but also simple perceptual judgments. The fact that a simple manipulation like reading is enough to change spatial judgements may be surprising given the importance of accurate spatial judgements in everyday life.

An interesting observation is that the mirror-reading manipulation worked better in Hebrew than in English participants. We can only speculate about the reasons for these group differences. However, it could be that the Hebrew participants demonstrate more malleability, as they are better accustomed to switching from right-to-left to left-to-right scripts, whereas none of the English participants were able to read a right-to-left script. A possible argument against this reasoning is that Hebrew participants were slower than English participants in the mirror-reading task (note that direct comparisons of reading time should be treated cautiously as we do not know whether the text difficulty and complexity differed between the original and translated texts).

An alternative explanation for the group differences is based on the interaction between the lateralisation of brain function and the mirror-reading direction. In Hebrew participants, hemispheric lateralisation and the reading direction in mirror reading could be additive, as they both pull in the same direction (leftward). In English participants, however, the mirror-reading manipulation needs to overcome the hardwired leftward bias, hence resulting in a smaller mirror-reading effect in English rather than Hebrew participants. Perhaps against this account speaks the observed bias in the standard reading condition. It could be argued that English participants should show a stronger leftward bias (additive effects of hardwired lateralisation and reading direction), but we did not observe pseudoneglect in our sample.

Irrespective of the explanation for stronger effects in Hebrew participants, the current findings complement recent studies demonstrating that *prior acquaintance with the stimuli* used in the experiment can bias the allocation of spatial attention, even if they are irrelevant to the task (e.g., Anderson & Halpern, 2017; Kyllingsbæk, Schneider, & Bundesen, 2001; Le Pelley, Mitchell, Beesley, George, & Wills, 2016). We expand on this previous work and show that prior experiences *unrelated to task stimuli* also can affect the allocation of attention.

While this study demonstrated the malleability of spatial biases, future research is needed to refine our understanding of these findings and their underlying mechanisms. A no-reading control condition was deemed unnecessary for the purpose of this study, but the lack of such a control condition means we cannot determine whether the default bias (i.e., bias in the absence of any prior reading) is similar to the bias observed after standard reading or located somewhere between the standard and mirror-reading conditions. The current study design can also not answer questions regarding the temporal aspects of the reading manipulation. An interesting next step would be to determine whether a longer reading duration would enhance the effects and how quickly these effects decay after reading. Finally, the use of eye-tracking in future studies would allow pinpointing the mechanism underlying the effect. For example, eye tracking could determine whether the reading manipulation changes participants' horizontal scanning behaviour and whether this effect was driven by saccadic eye movements, as our stimuli presentation was relatively long (500 ms) for a landmark task and may have allowed eye movements.

In conclusion, we demonstrate that a brief exposure to mirror reading can affect a subsequent spatial perceptual judgment. Our working hypothesis is that spatial perceptual asymmetries are the result of an interplay between biological, hemispheric specialisations (i.e., a default setting), experiences throughout the lifetime (e.g. cultural habits) that shape the default setting, and immediate experiences (e.g. recent spatial activities, situational context), which overwrite both the default setting and lifetime experiences under certain circumstances. If true, manipulating recent spatial activity and employing a perceptual task such as the landmark task in populations with opposing reading habits may provide an interesting strategy to disentangle the contributions of nature, nurture (lifetime experiences) and immediate prior experiences on brain functioning (Han & Northoff, 2008).

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Open Practices Statements The data for the experiments reported are available on Open Science Framework. The experiment was not preregistered.

Author Contributions TL and ER conceived and developed the experiment. ER and SS performed testing and collected the data. ER and TL analyzed the data. ER and TL drafted the paper with SS providing critical input. All authors approved the final version of the manuscript.

Compliance with ethical standards

Declaration of Interests The authors declare no competing interests.

References

Anderson, B. A., & Halpern, M. (2017). On the value-dependence of value-driven attentional capture. *Attention, Perception, & Psychophysics, 79*(4), 1001-1011.

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

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General, 143*(2), 473.

Cazzoli, D., & Chechlacz, M. J. C. (2017). A matter of hand: Causal links between hand dominance, structural organization of fronto-parietal attention networks, and variability in behavioural responses to transcranial magnetic stimulation. *86*, 230-246.

Chokron, S., & Imbert, M. (1993). Influence of reading habits on line bisection. *Cognitive Brain Research, 1*(4), 219-222. doi:https://doi.org/10.1016/0926-6410(93)90005-P

De Schotten, M. T., Dell'Acqua, F., Forkel, S. J., Simmons, A., Vergani, F., Murphy, D. G., & Catani, M. J. N. n. (2011). A lateralized brain network for visuospatial attention. *14*(10), 1245.

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 [star, open]. *Neuroimage, 19*(3), 710-726.

Friedrich, T. E., & Elias, L. J. (2016). The write bias: The influence of native writing direction on aesthetic preference biases. *Psychology of Aesthetics, Creativity, and the Arts, 10*(2), 128-133. doi:https://doi.org/10.1037/aca0000055

Girelli, L., Marinelli, C. V., Grossi, G., & Arduino, L. S. (2017). Cultural and biological factors modulate spatial biases over development. *Laterality: Asymmetries of Body, Brain and Cognition, 22*(6), 725-739. doi:https://doi.org/10.1080/1357650X.2017.1279623

Göbel, S. M., McCrink, K., Fischer, M. H., & Shaki, S. (2018). Observation of directional storybook reading influences young children's counting direction. *Journal of Experimental Child Psychology, 166*, 49-66. doi:https://doi.org/10.1016/j.jecp.2017.08.001

Han, S., & Northoff, G. (2008). Culture-sensitive neural substrates of human cognition: A transcultural neuroimaging approach. *Nature Reviews Neuroscience, 9*(8), 646-654.

Harvey, M., Milner, A. D., & Roberts, R. C. (1995). An investigation of hemispatial neglect using the Landmark Task. *Brain and Cognition, 27*(1), 59-78.

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: a review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia, 38*(1), 93-110.

Kazandjian, S., & Chokron, S. (2008). Paying attention to reading direction. *Nature Reviews Neuroscience, 9*(12), 965.

Kinsbourne, M. (1970). Cerebral basis of lateral asymmetries in attention. *Acta Psychologica, 33*, 193-201.

Kyllingsbæk, S., Schneider, W. X., & Bundesen, C. (2001). Automatic attraction of attention to former targets in visual displays of letters. *Perception & Psychophysics, 63*(1), 85-98.

Le Pelley, M. E., Mitchell, C. J., Beesley, T., George, D. N., & Wills, A. J. (2016). Attention and associative learning in humans: an integrative review. *Psychological Bulletin, 142*(10), 1111.

Maass, A., & Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychological Science, 14*(4), 296-301.

Maass, A., Suitner, C., & Deconchy, J.-P. (2014). *Living in an asymmetrical world: How writing direction affects thought and action*: Psychology Press.

McCourt, M. E. (2001). Performance consistency of normal observers in forced-choice tachistoscopic visual line bisection. *Neuropsychologia, 39*(10), 1065-1076.

McCourt, M. E., & Jewell, G. (1999). Visuospatial attention in line bisection: stimulus modulation of pseudoneglect. *Neuropsychologia, 37*(7), 843-855. doi:https://doi.org/10.1016/S0028-3932(98)00140-7

McCrink, K., Caldera, C., & Shaki, S. (2018). The Early Construction of Spatial Attention: Culture, Space, and Gesture in Parent–Child Interactions. *Child Development, 89*(4), 1141-1156. doi:https://doi.org/10.1111/cdev.12781

Nachson, I., Argaman, E., & Luria, A. (1999). Effects of directional habits and handedness on aesthetic preference for left and right profiles. *Journal of Cross-Cultural Psychology, 30*(1), 106-114. doi:https://doi.org/10.1177/0022022199030001006

Nicholls, M. E. R., & Roberts, G. R. (2002). Can free-viewing perceptual asymmetries be explained by scanning, pre-motor or attentional biases? *Cortex, 38*(2), 113-136.

Nicholls, M. E. R., Roden, S., Thomas, N. A., Loetscher, T., Spence, C. J., & Forte, J. D. (2014). Close to me: the effect of asymmetrical environments on spatial attention. *Ergonomics, 57*(6), 876-885. doi:https://doi.org/10.1080/00140139.2014.899633

Nicholls, M. E. R., Thomas, N. A., Loetscher, T., & Grimshaw, G. M. (2013). The Flinders Handedness survey (FLANDERS): A brief measure of skilled hand preference. *Cortex, 49*(10), 2914-2926. doi:https://doi.org/10.1016/j.cortex.2013.02.002

Nicholls, M. E. R., Thomas, N. A., Loetscher, T., Wignall, S., Yates, M. J., Forte, J. D., & Spence, C. J. (2012). The relationship between vertical stimulation and horizontal attentional asymmetries. *Quarterly Journal of Experimental Psychology, 65*(12), 2384-2396.

Reuter-Lorenz, P. A., Kinsbourne, M., & Moscovitch, M. (1990). Hemispheric control of spatial attention. *Brain and Cognition, 12*(2), 240-266.

Rinaldi, L., Di Luca, S., Henik, A., & Girelli, L. (2014). Reading direction shifts visuospatial attention: An Interactive Account of attentional biases. *Acta Psychologica, 151*, 98-105. doi:https://doi.org/10.1016/j.actpsy.2014.05.018

Román, A., Flumini, A., Lizano, P., Escobar, M., & Santiago, J. (2015). Reading direction causes spatial biases in mental model construction in language understanding. *Scientific Reports, 5*, 18248. doi:https://doi.org/10.1038/srep18248

Shaki, S., & Fischer, M. H. (2008). Reading space into numbers – a cross-linguistic comparison of the SNARC effect. *Cognition, 108*(2), 590-599. doi:https://doi.org/10.1016/j.cognition.2008.04.001

Tremblay, P.-Y. (2015). *Riding Sky High: A Bicycle Adventure Around the World*: Skyhorse Publishing.

Vaid, J., & Singh, M. (1989). Asymmetries in the perception of facial affect: Is there an influence of reading habits? *Neuropsychologia, 27*(10), 1277-1287.

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