



Reading direction shifts visuospatial attention: An Interactive Account of attentional biases



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ABSTRACT

A growing amount of evidence confirms the influence of reading and writing habits on visuospatial processing, although this phenomenon has been so far testified mainly as a lateralized shift of a single behavioral sign (e.g., line bisection), with lack of proof from pure right-to-left readers. The present study contributed to this issue by analyzing multiple attentional and motor indexes in monolingual Italian (i.e., reading from left-to-right), and monolingual (i.e., reading from right-to-left) and bilingual Israeli (i.e., reading from right-to-left in Hebrew but also from left-to-right in English) participants' visuospatial performance. Subjects were administered a computerized standard star cancellation task and a modified version in which English letters and words were replaced by Hebrew ones. Tasks were presented on a graphics tablet, allowing recording of both chronometric and spatial parameters (i.e., measured in (x, y) vector coordinates). Results showed that reading direction modulated the on-line visuomotor performance (i.e., left-to-right vs. right-to-left shifts) from the beginning (i.e., *first mark*) to the end of the task (i.e., spatial distribution of *omissions* and *subjective epicenter*). Additionally, the spatial bias observed in a computerized line bisection task was also related to the participants' habitual reading direction. Overall, the results favor the proposal of an *Interactive Account* of visuospatial asymmetries, according to which both cultural factors, such as the directional scanning associated with language processing, and biological factors, such as hemispheric specialization, modulate visuospatial processing. Results are discussed in light of recent behavioral and neuroanatomical findings.

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1. Introduction

Neurobiological determinants have been commonly offered to account for the spatial biases in human performance. Right hemisphere dominance for spatial cognition (e.g., Bradshaw, Nathan, Nettleton, Wilson, & Pierson, 1987; Kinsbourne, 1970) along with the asymmetry in the neural mechanisms involved in attention (Nicholls & Roberts, 2002) have been suggested to underlie such biases. However, there is increasing evidence for cultural modulation of visuospatial performance (Chokron, 2002; for a review, see Chokron, Kazandjian, & De Agostini, 2011). The present study: 1) investigated the role of cultural factors in visuospatial exploration, by comparing three groups with different reading habits, and 2) manipulated language (e.g., English and Hebrew letters) to examine effects of context.

A prototypical example of asymmetries in spatial performance is represented by the slight leftward bias, known as *pseudoneglect* (Bowers & Heilman, 1980), generally shown by healthy participants in bisection tasks, in both the visual and haptic modalities (for a review, see Jewell & McCourt, 2000), resulting from the overestimation of the

left side of space. This pattern mimics the rightward bias characterizing bisection performance of neglect patients. Neglect patients show difficulties in reporting, orienting, and responding to stimuli in the contralesional hemispace more frequently after damage to the right than left brain hemisphere (Halligan, Fink, Marshall, & Vallar, 2003; Heilman, Watson, & Valenstein, 1993). Both behavioral and neuropsychological evidence, thus, converge in pointing to an imbalanced hemispheric activation in spatial tasks, partially resulting from the predominant role of the right fronto-parietal network in visuospatial and attentional functions (Bartolomeo, Thiebaut de Schotten, & Chica, 2012; Corbetta & Shulman, 2011). In support of a pure neurobiological account of spatial asymmetries, pseudoneglect-like effects have been reported in non-human species such as in the pecking activity of birds (Diekamp, Regolin, Güntürkün, & Vallortigara, 2005) and in the bisection performance of chickens (Diekamp, Manns, Güntürkün, Vallortigara, & Regolin, 2005; Regolin, 2006), suggesting a common evolutionary lateralization of spatial attention.

On the other hand, over the years, it has been found that cultural practices, such as reading habits, broadly influence the cognitive system, inducing spatial biases at both perceptual and representational levels. For example, opposite reading routines correlated with directional differences in perception of facial effect (Vaid & Singh, 1989), aesthetic

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judgment (Chokron & De Agostini, 2000), and direction of stroke movement in free-hand figure drawing (Vaid, Singh, Sakhuja, & Gupta, 2002). Moreover, cross-cultural differences linked to the reading and writing system characterize the mental representation of temporal, spatial, action (i.e., semantic) and preference relations (Dobel, Diesendruck, & Bölte, 2007; Maass & Russo, 2003; Ouellet, Santiago, Israeli, & Gabay, 2010; Tversky, Kugelmass, & Winter, 1991). Critically, these patterns seem to emerge over school years suggesting the impact of cultural practices in the complex origin of spatial–representational biases (Dobel et al., 2007; Kebbe & Vinter, 2013; see also Fagard & Dahmen, 2003).

Accordingly, evidence for the cultural shaping of visuospatial performance is not lacking. Comparing English, Hebrew and Arabic readers, Nachson (1985) first reported that directional preferences in visual tasks might be a function of either reading and writing habits, or hemispheric asymmetry, or both. Moreover, Abed (1991) reported that in Western, East Asian and Middle Eastern participants, saccades direction, but not location of fixation, was fully predicted by reading habits. More critical for our purpose, reading habits have been found to influence line bisection. Chokron and Imbert (1993) showed that Hebrew readers bisected lines to the right of the true center, while native French readers bisected lines to the left of the center (see also, Kazandjian, Cavézián, Zivotofsky, & Chokron, 2010). Similar patterns have been detected also in preschoolers, where directional asymmetries might originate by observational learning and by trained eye scanning habits in visual-perception, indirectly related to reading habits (Chokron & De Agostini, 1995). Language-dependent effects have been reported also in line extension (Chokron, Bernard, & Imbert, 1997) and line partition (Zivotofsky, 2004) tasks, although their consistency has been challenged by controversial results (Nicholls & Roberts, 2002). Importantly, previous studies focusing on reading direction effects involved mainly Israeli participants who can hardly be considered monolingual, due to their experience with left-to-right material (i.e., English learning) throughout their education (Chokron et al., 2011). Overall, evidence for a culturally based or a neurobiologically based account of visuospatial asymmetries is both available and debatable.

The present study used a classic line bisection task and a computerized cancellation task to examine the role of reading habits in perceptual asymmetries. Cancellation tasks have long been used in the neurological assessment of visuospatial functions and selective attention, both in healthy subjects and in neuropsychological patients (Parton, Malhotra, & Husain, 2004). Recent investigations on the cancellation task suggest a highly organized exploration of the visual scene (Manly et al., 2009; Mark, Woods, Ball, Roth, & Mennemeier, 2004; Woods & Mark, 2007). Interestingly, the searching strategy has been shown to change over written language acquisition (Brucki & Nitrini, 2008) and over the school years (Woods et al., 2013), shifting the distribution of visuospatial attention asymmetrically. To the best of our knowledge, only one study investigated cancellation performance in right-to-left readers and reported no spatial asymmetry in the distribution of omissions (Geldmacher & Alhaj, 1999). However, because language competence was not systematically assessed and control reading groups were not considered, these results remain suggestive.

The classic paper-and-pencil version of the cancellation task presents limitations that have been overcome by the recent development of computer-assisted evaluation, which is more sensitive to attentional mechanisms and visuospatial performance in healthy adults (Di Luca, Pesenti, Vallar, & Girelli, 2013), neglect patients (Rabuffetti et al., 2012) as well as in school-children (Wang, Huang, & Huang, 2006). Specifically, it allows for a variety of indexes to analyze behaviors that are hardly registered in the paper-and-pencil cancellation test. Additionally, the computerized techniques are less time-consuming and labor-intensive than other procedures as, for example, the video recording method (Manly et al., 2009; Mark et al., 2004).

In the present study, we used a computerized version of the line bisection task and two versions of the star cancellation task (Wilson,

Cockburn, & Halligan, 1988), performed with the help of a graphics tablet. This equipment allows us to record both visuospatial and visuomotor parameters of performance. Participants were monolingual left-to-right, monolingual right-to-left and bilingual readers (i.e., reading in both directions). The star cancellation task is composed of verbal and non-verbal stimuli. It comprises 56 small stars (targets) pseudo-randomly distributed among distractors (large stars, letters and words). Expanding on the original star cancellation task (Wilson et al., 1988), a new version with Hebrew letters and words as distractors was adopted. Participants performed a computerized line bisection task that constrained visuospatial processing by minimizing the impact of visuomotor performance.

Overall, the present study allowed us to contrast two alternative accounts of the asymmetries in visuospatial performance. According to a *Laterality Account* (or *Activation Orientation Account*; Kinsbourne, 1970; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990), we should expect no group difference in the indexes associated to the visual search due to the right hemisphere dominance in task execution; thus, a leftward bias (associated to a rightward-oriented visual search) would emerge regardless of reading habit. Moreover, biomechanical factors related to the preferential direction of hand movements (i.e., outward vs. inward hand movements) might contribute to making the leftward bias in right-handed subjects more consistent (Dreman, 1974). According to an *Interactive Account*, neurobiological determinants of visuospatial asymmetries are critically modulated by directional oculo-motor routines associated to reading and writing exploration. Thus, we do not expect opposite directional readers to show mirrored patterns, that is, a leftward bias in left-to-right readers and a similar rightward bias in right-to-left readers. Instead, the rightward deviation should be attenuated in right-to-left readers compared with left-to-right readers. Bidirectional readers would show an intermediate, more symmetrical exploration of visual space. Additionally, this group might be sensitive to the manipulation of the alphabetic context related to the Hebrew or English distractors.

2. Materials and methods

2.1. Participants

A total of 67 participants took part in the study: 23 Italian students (9 males), average age 21.7 ± 1.8 years, from the University of Milano-Bicocca (Italy); 21 Israeli Orthodox Jewish participants (15 males), average age 20.7 ± 2.5 years, who were enrolled in religious colleges for Jewish studies; and 23 bilingual Israeli subjects (5 males), with an average age of 25.7 ± 2.7 years, from the Ben-Gurion University of the Negev (Israel). The bilingual right-to-left reading participants (i.e., Bi group) were native-born Israelis with Hebrew as their mother tongue, and with good English skills; they were all familiar with a left-to-right language, and had started to learn English from the fifth grade of primary school. Italian (i.e., MoLR group) and Israeli Orthodox Jewish (i.e., MoRL group) subjects were all monolinguals and therefore constituted a monodirectional group. We assessed the English literacy of the latter group with a letter and single-words reading and comprehension test; only participants with no knowledge of English were included in the study (i.e., those who failed to read simple letters and words). Additionally, no subject of the MoRL group reported being familiar with any other left-to-right languages and no one in the MoLR group reported familiarity with a Semitic language. The average age differed significantly in the three groups, $F(2, 64) = 29.63, p < .001, \eta = .48$, with the Bi group significantly older than both the MoLR ($p < .001$) and the MoRL group ($p < .001$). This difference was due to mandatory military service, which delayed the beginning of university courses for most non-Orthodox Israelis students for a minimum of two years. However, all groups were comparable in terms of years of education.

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