Effects of Reading Direction on Visuospatial Organization: A Critical Review

Sylvie Chokron, *Laboratoire de Psychologie & NeuroCognition, CNRS and ERT TREAT Vision, Service de Neurologie, Fondation Ophtalmologique A. de Rothschild, France,* sylvie.chokron@gmail.com

Seta Kazandjian, *Laboratoire de Psychologie & NeuroCognition, CNRS and ERT TREAT Vision, Service de Neurologie, Fondation Ophtalmologique A. de Rothschild, France*

Maria De Agostini, *Laboratoire d'Epidémiologie et Biostatistique, France*

Over the past decades, a growing literature on perceptual bias has investigated the factors that determine normal performance in simple visuospatial tasks, such as line bisection and aesthetic preference. Normal right-handed participants may exhibit spatial asymmetries in these tasks with a tendency to bisect to the left of the objective middle in line bisection and a preference for images with the center of interest in their right half in aesthetic preference tasks. These patterns of performance have mostly been attributed to hemispheric imbalance. Other explanations have also been put forth to explain the spatial asymmetries seen in the normal population. Here we review studies that target the role of reading direction on visuospatial tasks. In addition to presenting several of our studies that investigated differences in line bisection and aesthetic preference performances between left-to-right readers (French) and right-to-left readers (Israeli), we present a discussion of the existing literature on reading direction, culture and visuospatial processing. The findings are discussed regarding the interaction between cultural factors, such as reading habits, and biological factors, such as cerebral lateralization, in visual perception.

It is by now well established that the right and left cerebral hemispheres of healthy humans differ in the psychological functions they subserve. Clinical evidence for this assertion comes from studies on the effects of unilateral cerebral lesions (Hecaen, 1972) and from corpus callosotomy studies (the surgical separation of the hemispheres by sectioning the fibres of the corpus callosum) (Sperry, Gazzaniga & Bogen, 1969). Studies reporting hemispheric differences in healthy participants have employed brief presentations of stimuli to the left and right visual fields (White, 1972), presentation to the left and right ears under binaural (Kimura, 1961) or monaural (Young, 1983) conditions, or, less commonly, presentation to the left and right hands (Hermelin & O'Connor, 1971; Oscar-Berman, Rehbein, Porfest, & Goodglass, 1978; Witelson, 1976). These studies converge on the conclusion that in the great majority of right-handers, the left hemisphere is specialized for a number of language-related functions, while the right hemisphere is specialized for a number of spatial and motor skills (Kimura, 1973). Functional asymmetries in verbal and non-verbal visual perception tasks have been generally interpreted only in terms of a hemispheric specialization framework. This is particularly the case for perceptual biases that have been described in normal participants.

Functional and perceptual asymmetry

Since the 1960s, a growing literature on perceptual bias has investigated the factors that determine normal performance in simple visuospatial tasks, such as line bisection. The line bisection task involves the presentation of a series of straight, horizontal lines of varying lengths, of which the participant is asked to mark the center (or bisect it with a hatch mark) (Manning, Halligan, & Marshall, 1990). Judging the center of horizontally oriented linear

stimuli, either in the visual or tactile modality, is a task that has been used widely to explore lateralization of perceptual and attention factors in normal participants (for a review, see Brodie & Pettigrew, 1994). Line bisection is often used as a screening test for hemispatial neglect, thus the knowledge of how any person performs this kind of task seems mandatory. Several of these studies have shown that normal, healthy participants tend to judge the center of a visually inspected line, or of a rod felt tactually, to be to the left of the objective center. This phenomenon has been interchangeably termed pseudoneglect or Left Side Underestimation (LSU), referring to the asymmetric perception of space which is found in the absence of neural pathology, and which is usually, but not always, opposite in direction to asymmetries found among neglect patients. This shift of the objective center seen among normal participants has led to a debate regarding its cause. Is the shift a result of hemispheric imbalance and/or is it dependent on other factors, such as scanning or attention?

The majority of perceptual asymmetry findings in line bisection tasks have initially been interpreted solely in terms of hemispheric activation (Bowers & Heilman, 1980; Bradshaw, Nathan, Nettleton, Wilson, & Pierson, 1987). According to the hemispheric activation theory, the spatial nature of the line bisection task induces a preferential activation of the right hemisphere leading to an overestimation of the left hemispace and, therefore, to a displacement of the subjective center to the left of the objective center. This theory is a corollary of Kinsbourne's activation theory, which states that the distribution of attention in space is biased in the direction contralateral to the more activated hemisphere (Kinsbourne, 1970).

A review of the literature reveals that bias in visuo-motor line bisection cannot be explained only in terms of hemispheric activation (for a review, see Jewell & McCourt, 2000). For example, in several studies, no significant difference between left and right hand use was reported (Dellatolas, Vanluchene, & Coutin, 1996; Harvey, Milner, & Roberts, 1995; Mefferd, Wieland, & Dufiho, 1969), gaze deviation to one side did not induce a deviation of the subjective middle to the same side, as the activation hypothesis predicts (Chokron, Bartolomeo, Colliot, & Auclair, 2002; Chokron & Imbert, 1993a), and finally the majority of studies examining the influence of sex (known to affect cerebral lateralization) on line bisection performance report non-significant effects (Jewell and McCourt, 2000). Taking these findings into consideration, Nicholls and Roberts (2002) hypothesized that perceptual-attention bias may be reflecting an asymmetry in the neural mechanisms that control attention, rather than reflecting a hemispheric asymmetry driven by unilateral activation. According to the perceptual-attention hypothesis, various factors that can increase saliency of the right side of the line leads to an underestimation of the left side of an object or the line, and thus a shift of the objective center to the left, also termed LSU.

However, this framework is neither the only one available nor the one that was initially considered in early studies of visual hemifield presentation of words. Interestingly, the original interpretation of visual field asymmetries was in terms of post-exposure directional scanning tendencies arising from reading and writing experience (Heron, 1957). Visual field asymmetries, in this view, predominantly reflect a tendency to scan information in the direction in which one reads. Thus, a reader of English, who is fixating at center, will show a right visual field advantage for unilaterally presented words and a left visual field advantage for bilaterally presented words.

Indeed, the suggestion has been raised that directional bias arising from reading direction may even generalize to non-verbal material in the visual modality (Corballis, 1994) or even in the auditory modality (Bertelson, 1972). It is reasonable to expect that features of the languages used in a culture may affect various aspects of behavior of the members of that culture.

Effect of reading direction on lateral bias: position of the problem

An effect of reading direction on perceptual skills had been described both for school children (Abed, 1991; Braine, 1968; Kugelmass & Lieblich, 1970) and pre-school

children (Chokron & De Agostini, 1995; Shannon, 1978) who exhibited scanning of non-directional visual material related to reading direction before learning how to read. Some studies have emphasized the fact that children as young as four years old have the capability to produce graphics which exhibit some of the characteristics of writing such as directionality: from left to right for French pre-school children (Gombert & Fayol, 1992) and from right to left for Israeli pre-school children (Tolchinsky-Landsman & Levine, 1985). This effect of reading direction on space perception and exploration has thus challenged the well-known link between cerebral lateralization and bias described both in normal and brain-damaged patients.

In respect to spatial asymmetry, reading direction has been proven to be influential on perceptual exploration within the normal population (Kugelmass & Lieblich, 1970). The same way, the effect of reading direction on directional preferences in reproducing visual stimuli has been shown by various authors, corroborating other findings concerning the environmental influences on the regulation of perceptual scanning (Shannon, 1978).

The initial scanning direction was found to have a significant influence on the position of the subjective middle in line bisection (Brodie & Pettigrew, 1994). In fact, the bias displayed by normal right-handed participants when bisecting a visually presented line, was found to be a function of the hand and of the initial scan strategy used to perform the task. Using the left hand, or initially scanning from the left, will result in a significant leftward deviation, whereas initially scanning from the right with the right hand will normally result in no significant deviation from the objective midpoint. We subsequently replicated this finding in a proprioceptive straight ahead pointing task in normal and brain-damaged patients suffering from left neglect, in which we demonstrated that the direction of the motor exploration significantly affects the position of the subjective middle (Chokron & Bartolomeo, 1997). These results indicate the role of scanning direction on visuospatial organization and reveal how the position of the subjective middle in space may depend upon the scanning direction used to reach it. The experiments we present below were designed to thoroughly study these effects.

Effect of reading direction on visuospatial asymmetry: an experimental approach

In a series of studies conducted with children and adults with opposing reading direction modes, we aimed at measuring the extent to which reading direction may affect the position of the subjective middle in line bisection (Chokron & De Agostini, 1995; Chokron & Imbert, 1993b). Exclusively left-to-right reading, French monolinguals and right-to-left reading, Israeli monolinguals were tested with the line bisection task. Although our Israeli participants were born and raised in Israel and identified themselves as monolingual Hebrew speakers, it is probable that they had been exposed to some left-to-right directional material over the course of their education, e.g., math and music, their daily exposure to English language road signs and bulletin boards, and, most possibly, English language courses. However, comparing the two groups, we were able to demonstrate that the participants' reading direction modes may influence the position of the subjective middle in line bisection, with a leftward deviation for left-to-right adults and a rightward one for right-to-left. The greatest effect was seen between the Israeli and French 8 year olds $F_{1, 56} = 27.38$, $p<.0001$, followed by the adults, $F_{1, 56} = 14.38$, $p<.0001$. Notably, a significant difference was also seen between the French and Israeli pre-school children (i.e., 4.5 years old; see also Figure 1), who had not yet received formal reading instruction, $F_{1, 56} = 7.17$, $p<.01$. In this task, a score of 0 defines the objective center, therefore, leftward deviation is defined as any score below 0 (negative scores), and rightward deviation is defined by scores above 0 (positive scores). The high sensitivity of this task results in significant leftward or rightward deviation following only a few millimeters deviation to either side.

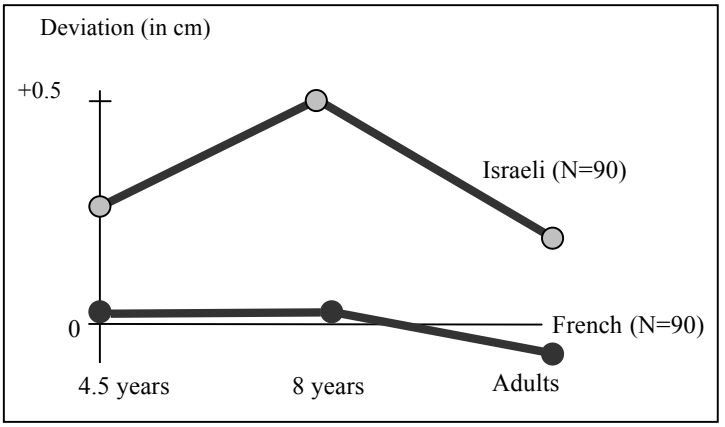

Figure 1. Effect of reading direction on bisection.

In another experiment (Chokron, Bernard & Imbert, 1997), we confirmed our previous findings showing that there is also an effect of reading direction on the performance on a line extension task where the participants had to construct the missing half of a line from a given one (left or right). Results ruled out any attempt to explain these perceptual asymmetries among normal adults only in terms of cerebral activation.

While some authors have postulated that the deviation in bisection occurs in the hemispace contralateral to the most activated hemisphere (Bradshaw, Bradshaw, Nathan, Nettleton, & Wilson, 1986; Bradshaw et al., 1987), our results show an opposite pattern between French and Israeli participants and suggest an opposite cerebral organization relative to the opposing reading direction. Rather than reasoning in terms of level of hemispheric activation, one can imagine that the scanning direction of the line, relative to reading direction may influence the orientation of attention along the line and, in this way, the length representation and the position of the bisection.

More recently, we attempted to study the extent to which aesthetic preference, previously attributed to cerebral dominance (Beaumont, 1985), can be influenced by reading direction (Chokron & De Agostini, 2000). One hundred and sixty-two normal participants were presented with pairs of images, one being the mirror-image of the other (i.e., a cat facing to the right and then to the left), and were asked for their aesthetic preference. The images consisted of directional mobile images (i.e., a truck or cat), directional static images (i.e., a road sign or statue pointing either to the left or the right), or landscape images with salient elements lateralized to the left or the right side of the page (i.e., a sidewalk image with a bench on the left side of the page). Half of the samples were left-to-right readers (French) and the other half were right-to-left readers (Israeli). We found a significant effect of reading direction on aesthetic preference with left-to-right readers showing a preference for stimuli depicting objects with a rightward directionality (the cat facing right) while right-to-left readers preferred stimuli depicting objects with a leftward directionality (the cat facing left). For the landscape images, however, both groups showed a rightward directionality preference (a mountain chain lateralized to the right of the page), with the Israeli participants showing a stronger preference than the French participants. This result (Figure 2) might be a function of an interaction between right-to-left reading and hemispheric specialization in right-handed participants that accounts for the higher right preference for landscapes in Israeli participants as compared to the French participants. These findings raise the question of an interaction between cultural factors and cerebral dominance in visuospatial organization and stress the need to more thoroughly disentangle these two factors.

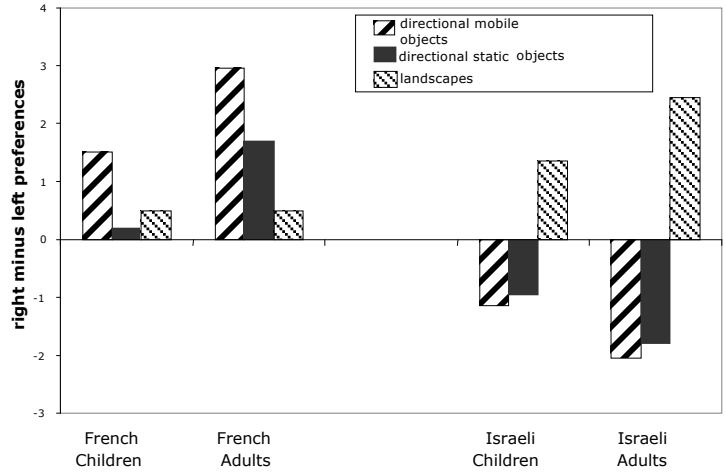

Figure 2. Effect of reading modes on aesthetic preference.

Results are expressed as left minus right preferences with 'left' preference corresponding to a preference for a picture with a right-to-left directionality whereas 'right' preference corresponds to a picture with a left-to right directionality.

Effect of reading direction on visuospatial asymmetry: Discussion and perspectives

Innate and/or acquired determination of preferential directional scanning?

First, there is the question about the origin of preferential directional scanning. Is it innate, depending on cerebral maturation (Braine, 1968; Chen, 1981; Nachson, Shefler, & Samocha, 1977), or is it acquired, depending on reading direction and environmental cues (Abed, 1991; Gibson, 1966; Harsel & Wales, 1987)? Abed (1991) was able to demonstrate that when exploring non-directional visual stimuli patterns, Western, East Asian, and Middle Eastern participants fixate more often on the top and left of the visual display independent of their reading direction mode. Concomitantly, the study on the direction of saccades revealed significant differences, which reflect the reading direction of the different cultures. Thus, it appears that the location of fixations on a neutral visual stimulus does not differ significantly for various cultural groups, but the scanning strategies used to arrive at the fixation points are nonetheless influenced by cultural factors.

Reading direction and attention

Heron (1957) proposed that scanning habits are comprised of two distinct mechanisms. The first is the scan in the direction in which the language is read (to the right in English and many other languages, to the left in Hebrew or Arabic, from top to bottom in Chinese, Japanese and other languages, and so forth). The second is the scan for the first element of the text (i.e., to the left in English, to the right in Hebrew or Arabic). Eviatar (1995) has shown that the second mechanism seems to bias movement of covert attention of left-to-right readers to the left side, and right-to-left readers to the right side. Thus, as this author pointed out, it may be useful to delimit the conditions under which reading scanning directions will affect performance asymmetries in non-language tasks, and the factors (i.e., hemispheric specialization for the task, presentation of attention cues, and unilateral or bilateral hemifield presentation) which modulate these effects.

Biological and cultural interaction

As we have discussed above, some perceptual or attention bias, such as pseudoneglect, have been initially attributed to hemispheric specialization without having tested normal readers with opposite reading directions. However, reading direction has been shown to influence visuospatial performance, such as line bisection (Chokron &, De Agostini, 1995; Chokron et al., 1997; Chokron & Imbert, 1993b), straight-ahead pointing (Kazandjian, Dupierrix, Gaash, Love, Zivotofsky, De Agostini, & Chokron, 2009), facial affect perception (Vaid & Singh, 1989), aesthetic judgement (Chokron & De Agostini, 2000), problem solving (Harsel & Wales, 1987) and apparent movement perception (Morikawa & McBeath, 1992; Tse & Cavanagh, 2000). Frith (1998), discussing the possibility of an influence of culture on brain anatomy, asked the following question: "Is it possible that learning to read has an effect on processes underlying visual perception and thinking?" Indeed, regarding the findings of the above-mentioned studies, and given the fact that the majority of hemispheric research is based on interpretations of performance asymmetries, it seems urgent to study to what extent directional modes, developed as a result of reading direction, can affect performance asymmetries for non-language tasks.

Currently, a growing interest in neuroanthropology has begun to revisit the role of culture on the brain. Language and reasoning are considered culturally determined cognitive tools by cognitive psychologists (Perez-Arce, 1999). Although a controversial theory, according to the Sapir-Whorf hypothesis from the 1930s and 1950s, the cognitive framework through which we interpret, classify, and organize perceptions and information is determined by language (Perez-Arce, 1999). In most cultures, thought is linguistically based. Therefore, the language in which the child interacts with, and the society and the cultural boundaries the child is exposed to, create the cognitive framework of the individual (Kolers, 1978). Universal aspects of cognition exist, such as perception, categorization, retention, reasoning, and problem-solving (Segall, 1979). However, this functional universality does not suggest that cultural differences do not exist within them. The process, content, and contexts in which these basic cognitive abilities are conducted, as well as the complex abilities that arise from the combination of these basic cognitive processes can vary between and across cultures. Wexler (2006) supports this view and theorizes a more direct influence on culture on neural networks.

Interestingly some free-viewing asymmetries cannot be explained in terms of reading direction effects. Abed (1991) showed that reading direction did not influence the top-left preferential location of visual fixation, while Chokron and De Agostini (2000) found that the normal population, independent of their reading modes (from left to right or from right to left), prefer pictures where a landscape is represented on the right part of the page, compared to its mirror-image. Nicholls and Roberts (2002) showed that the leftward bias in the grey scale task seems to be unaffected by the participant's reading mode. These dissociations favor the view of an interaction between culture and brain function (Paulesu, E., McCrory, E., Fazio, F., Menoncello, L., Brunswick, N., Cappa S.F., et al. (2000)). As Eviatar (1997) pointed out, the finding that a cognitive skill related to language (reading scanning direction) can affect performance asymmetry for non-language tasks believed to be subserved by the right hemisphere (Chokron & De Agostini, 1995; 2000; Chokron & Imbert, 1993a, 1993b; Vaid & Singh, 1989) might possibly reflect large scale interactions between cognitive functions and hemispheric asymmetries which are not covered by a general model. It seems that studies, such as that of Nicholls and Roberts' (2002), investigating perceptual and cognitive skills among literate adults with opposite reading directions, but also illiterate adults from different countries, are required in order to offer a dynamic brain model in which cognitive skills and culture interact with hemispheric specialization.

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