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Age-related changes in visual pseudoneglect

Rémy Schmitz, Philippe Peigneux *

UR2NF [Unité de Recherches en Neuropsychologie et Neuroimagerie Fonctionnelle], Université Libre de Bruxelles, Campus du Solbosch CP191, Avenue F.D. Roosevelt 50, B-1050 Brussels, Belgium

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ABSTRACT

Pseudoneglect is a slight but consistent leftward attentional bias commonly observed in healthy young populations, purportedly explained by right hemispheric dominance. It has been suggested that normal aging might be associated with a decline of the right hemisphere. According to this hypothesis, a few studies have shown that elderly tend to exhibit a rightward attentional bias in line bisection. In the present study, we tested this hypothesis in young and older participants using a perceptual landmark task. Results yield evidence for an age-related shift, from a strong attentional leftward bias in young adults toward a suppressed or even a reversed bias in the elderly. Right hemisphere impairment coupled to a left hemispheric compensation might explain the perceptual shift observed in older adults. However, a decline in corpus callosum function cannot be excluded. Alternatively, these results may be in agreement with the hypothesis of an age-related specific inhibition of return dysfunction, an overt attentional orienting mechanism, and/or a decrease of dopamine.

1. Introduction

Visual spatial fields are not symmetrically represented within the two cerebral hemispheres. Indeed, when asked to bisect lines or rods in two equal parts, young healthy subjects tend to err slightly on the left, misplacing the transection on the left side of the objective midpoint. Since Bowers and Heilman (1980), this natural leftward bias in line bisection (LB) tasks has been named pseudoneglect. This bias is also apparent using an alternative version, the landmark (LDM) task in which subjects are asked to estimate the symmetry of the two sections of pre-bisected lines (Milner, Brechmann, & Pagliarini, 1992; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990). On average in LDM tasks, evenly bisected lines are estimated longer (vs. shorter) on their left (vs. right) side, and unevenly bisected lines are more correctly perceived when the landmark is right-shifted. Although performance in LB tasks involves both perceptual and motor components, and may be influenced by various factors such as the hand in use, the size and the position of the line, or the direction of the visual scanning (see Jewell & McCourt, 2000, for a review), motor load is minimized in LDM tasks. In addition, the LDM task facilitates the dissociation between perceptual and response biases (Bisiach, Ricci, Lualdi, & Colombo, 1998; Toraldo, McIntosh, Dijkerman, & Milner, 2002; Toraldo, McIntosh, Dijkerman, & Milner, 2004).

In clinical practice, LB tasks are widely used to assess the degree of neglect in neuropsychological patients. Neglect can be defined as a failure to report, respond to, or orient towards novel or meaningful stimuli presented to the side opposite to a brain lesion, providing this state cannot be explained by primary sensory or motor deficits (Heilman & Valenstein, 1979; Heilman, Watson, & Valenstein, 2002). Contrary to healthy subjects, neglect patients considerably err to the right side when asked to bisect lines in LB tasks. Because the phenomenology is complementary, neglect and pseudoneglect are proposed to represent two sides of a coin (McCourt & Jewell, 1999). Neuropsychological studies consistently indicate that neglect is mostly present after right brain damage, underlying a right cerebral dominance for visuospatial processing (e.g. see Bartolomeo, 2006; Heilman et al., 2002). At the regional neuroanatomical level, lesions studies have underlined the important role played by the temporo-parietal junction and the inferior parietal lobule in neglect (for a review see Bartolomeo, Thiebaut de Schotten, & Doricchi, 2007), together with a possible role of superior temporal regions (Karnath, Ferber, & Himmelbach, 2001; Karnath, Fruhmann Berger, Kuker, & Rorden, 2004), dorsolateral prefrontal cortex, thalamus and basal-ganglia (Karnath, Himmelbach, & Rorden, 2002; Vallar, 2001). Additionally, electrical inactivation either of the right inferior parietal lobule or of the caudal temporal gyrus during a LB task in a brain surgery setting evokes a rightward bias (Thiebaut de Schotten et al., 2005). Interestingly, inactivation of the white matter pathway superior occipitofrontal fasciculus elicits the strongest rightward bias, yielding evidence for the importance of the integrity of subcortical fiber connections between parietal and frontal regions. Involvement of both (sub)cortical regions and white matter pathway in neglect

* Corresponding author. Fax: +32 0 2 650 22 09.
E-mail address: philippe.peigneux@ulb.ac.be (P. Peigneux).

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syndromes has been corroborated by a large-scale neuroanatomical study in patients (Karnath, Rorden, & Ticini, 2009).

The functional neuroanatomical correlates of performance in LB and LDM tasks have been investigated in healthy participants using positron emission tomography (PET, Weiss et al., 2000), functional magnetic resonance imaging (fMRI, Cicek, Deouell, & Knight, 2009; Fink, Marshall, Weiss, Toni, & Zilles, 2002; Fink, Marshall, Weiss, & Zilles, 2001; Fink, Marshall, Shah, et al., 2000; Fink, Marshall, Weiss, et al., 2000; Fink et al., 2003; Weiss, Marshall, Zilles, & Fink, 2003) and high-density electrical mapping of visual event-related potentials (Foxe, McCourt, & Javitt, 2003). These studies have consistently evidenced the implication of a predominantly right-lateralized occipito-parieto-frontal network in LB and LDM tasks (Cicek et al., 2009; Fink, Marshall, Shah, et al., 2000; Fink Marshall, Weiss, et al., 2000; Foxe et al., 2003; Weiss et al., 2003). In this network, besides early visual processes in the peristriate cortex, spatial judgment seems to be associated with right parietal cortex activity (Cicek et al., 2009), whereas anterior cingulate and prefrontal cortices might subtend executive supervision systems needed to perform the task. Premotor cortex activations are additionally observed in the LB task, where a motor component is involved (Weiss et al., 2003). Consistently, lesions in the right occipito-parieto-frontal network in neglect patients are associated with a strong rightward perceptual bias in the LDM task (Vossel, Eschenbeck, Weiss, & Fink, 2010). Additionally, right subcortical caudate lesions have been evidenced in patients showing a specific rightward response bias, suggesting an anatomical dissociation between perceptual and response biases in the LDM task.

Repetitive transcranial magnetic stimulation (rTMS) studies have confirmed the crucial involvement of the right posterior parietal cortex (PPC) in neglect symptoms (Bjoertomt, Cowey, & Walsh, 2002; Brighina et al., 2002; Ellison, Schindler, Pattison, & Milner, 2004; Fierro, Brighina, Piazza, Oliveri, & Bisiach, 2001; Fierro et al., 2000; Fierro Brighina, Giglia, et al., 2006; Ghacibeh, Shenker, Winter, Triggs, & Heilman, 2007; Kim et al., 2005; Pourtois, Vandermeeren, Olivier, & de Gelder, 2001). Indeed, transient inhibition of neural activity in this area leads to an inverted leftward bias that mimics the rightward bias typically observed in neglect patients. Another study (Ghacibeh et al., 2007) showed that right PPC inhibition reversed the leftward perceptual bias in LB, whereas right motor frontal cortex inhibition enhanced the rightward motor bias (i.e. deviating toward one specific side for each line irrespective of the visual feedback), further dissociating perceptual and motor processes in LB (for a similar dissociation in neglect patients see Na et al., 1998). It is worth noticing that rTMS over the right superior temporal region impacts the leftward bias in a visual features searching task but not the LDM (Ellison et al., 2004), suggesting a weakest involvement of temporal regions in left pseudoneglect as probed using the LDM task. It also indicates that notwithstanding the fact that both tasks are clinically relevant for the diagnostic of neglect, different brain networks are recruited depending on the task demands. Besides its effects in healthy populations, rTMS also exerts long term effects on neglect symptoms and therefore presents direct clinical applications (Fierro, Brighina, & Bisiach, 2006a). Indeed, disruption of the unaffected PPC enhances response accuracy in a LDM task and significantly reduces the patients' perceptual bias (Oliveri et al., 2001), even 15 weeks after rTMS treatment (Brighina et al., 2003).

Because left brain disruptions are less susceptible to be associated with neglect symptoms, several models have hypothesized that the right hemisphere (RH) spatially represents both the contralateral and ipsilateral sides of the visual scene, whereas the left hemisphere (LH) only represents the half right (contralateral) side (e.g. see Heilman & Valenstein, 1979; Mesulam, 1981). According to the activation/orientation model (Kinsbourne, 1970), attentional orienting biases are the result of an imbalance in hemispheric cerebral activation and inhibition of the less activated hemisphere by its homologous. In this framework, pseudoneglect might arise in healthy subjects because the spatial nature of LB/LDM tasks activates more the RH that inhibits the LH. As a consequence of RH activation, healthy subjects might automatically focus more on the left visual field and misperceive the objective midline, the left side being subjectively perceived larger than the right side. In line with this proposal, Kim et al. (2005) recently showed that rTMS on the right (vs. left) PPC enhances (vs. reduces) the leftward bias in the LDM task. Moreover, although rTMS over both right and left PPC facilitates the processing of the contralateral visual hemifield, left but not right PPC stimulation inhibits ipsilateral processing. Nonetheless, it remains disputable whether pseudoneglect arises due to an overrepresentation and/or an underrepresentation of the left or right visual hemifields respectively. Indeed, failure in the disengagement of attentional orienting might as well explain a neglect syndrome (Bartolomeo & Chokron, 2002). In other words, contralateral neglect in patients might be due to an irrepressible attraction of attention towards the elements and details of the ipsilateral scene, thus resulting in a magnification of the contralateral visual hemifield. This interpretation might apply to pseudoneglect in healthy individuals as well. Indeed, it has been shown that the perceived subjective midpoint can be rightward shifted in participants performing the LDM task under specific experimental conditions, artificially inducing such an attentional magnification towards one side of the visual field (Toba, Cavanagh, & Bartolomeo, 2011). Finally, it is worth mentioning that other, non attentional factors may modulate the pseudoneglect effect, such as the hand used, the direction of scanning (with eyes or hand), and sex or age of participants (Jewell & McCourt, 2000).

Nowadays, pseudoneglect has been seldom investigated in the context of aging. Studies using the LB task initially disclosed a shift toward a rightward bias in participants aged over 60 years (Fujii, Fukatsu, Yamadori, & Kimura, 1995; Fukatsu, Fujii, Kimura, Saso, & Kogure, 1990; Stam & Bakker, 1990), a result consistent with the hypothesis of a specific RH impairment during normal aging (Dolcos, Rice, & Cabeza, 2002). This model was initially based on empirical evidences showing that elderly participants obtained lower scores for the spatial performance component in the Wechsler Adult Intelligence Scale (WAIS), and that their neuropsychological profile somehow mimicked right brain damage patients' performance (see Hellige, 1993, pp. 293–299). In the framework of pseudoneglect, given the putative brain network lateralization during LB and LDM tasks in young adults, a rightward bias in aging might reflect a RH dysfunction as well. Furthermore, it was shown later that a hand effect might interact with pseudoneglect according to the participants' age (Failla, Sheppard, & Bradshaw, 2003). Indeed, a rightward inversion was present only when older participants (age range: 60–70) used their right hand. This hand effect might suggest an additional decrease in corpus callosum efficiency in the elderly, concomitant with a specific RH impairment. However, Beste, Hamm, and Hausmann (2006) failed to replicate this hand effect looking both at age and gender of participants. When asked to bisect lines with the left hand, all participants irrespective of age (range 20–79 years) presented a leftward bias, except 50–59 year old women who failed to show a bias. Moreover, only the oldest women above 70 years exhibited a statistical trend ($p = .08$, see p. 760) towards a rightward bias when the right hand was required. Notwithstanding the paucity of available data, the results suggest the abolition or even an inversion of pseudoneglect with age, fitting with the hypothesis of an age-related reduction in RH efficiency. To the best of our knowledge, however, the effect of aging on visual pseudoneglect has never been probed using a perceptual LDM task.

In this context, the aim of the present study was to investigate the hypothesis of a pseudoneglect suppression or inversion using a