ELSEVIER

Neuropsychologia 46 (2008) 426–433

NEUROPSYCHOLOGIA

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Modulation of hemispatial neglect by directional and numerical cues in the line bisection task

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Received 9 May 2007; received in revised form 24 July 2007; accepted 24 August 2007
Available online 31 August 2007

Abstract

We investigated the effects of arrows, eye gaze, and digits presented as irrelevant flankers in a line bisection task that was administered to 17 right brain damaged patients with or without left neglect. The rightward bias of neglect patients was selectively modulated by the direction of eye gaze and by the magnitude of two identical digits. The bisection error was shifted contralesionally by leftward-gazing eyes and "small" digits, whereas it was shifted ipsilesionally by rightward-gazing eyes and "large" digits. Therefore, the performance of neglect patients was influenced by task-irrelevant cues whose directional meaning was either explicitly represented (eye gaze) or related to the activation of a spatially oriented mental representation (digits). Regression analyses of the overall performance revealed that size of the rightward bias and error variability were predicted by neglect assessment scores across the entire sample of right brain damaged patients. The increased variability in line bisection performance is consistent with the "indifference zone" theory and it appears to be a subtle but stable marker of neglect.

Keywords: Neglect; Line bisection; Number processing; Eye gaze; Arrows

Neglect is an acquired multicomponential neuropsychological syndrome characterised by the impairment of conscious processing of stimuli in the contralesional hemispace (Halligan, Fink, Marshall, & Vallar, 2003; Parton, Malhotra, & Husain, 2004). Neglect has been described more frequently after damage to the right inferior parietal lobule or to the right temporoparietal junction and, consequently, the neglected hemispace is usually the left (Vallar, 2001).

The line bisection task is one of the most common clinical tests employed to assess neglect. It consists in marking the mid-point of a visually presented line (Bisiach, Capitani, Colombo, & Spinnler, 1976; Schenkenberg, Bradford, & Ajax, 1980). Neglect patients typically shift their subjective midpoint towards the ipsilesional hemispace as if they were not aware of the contralesional end of the line. Healthy participants, in contrast, show "pseudoneglect" that is a mild leftwards bias with respect to the true midpoint of the line (for a review see Jewell & McCourt, 2000).

The line bisection task can be "cued" in different ways (see Fischer, 2001a, for review). The first studies in the field employed relevant cueing (Nichelli, Rinaldi, & Cubelli, 1989; Riddoch & Humphreys, 1983). The aim of these studies was to assess whether shifting voluntary attention towards the neglected hemispace would have ameliorated bisection performance. Participants were usually required to read aloud a letter presented at one end (left vs. right) or at both ends of the to-be-bisected line. The rightward shift of neglect patients, observed in the uncued condition, decreased following left cueing, that is when bisection was performed after reading the letter placed on the left (Riddoch & Humphreys, 1983; but see also Heilman & Valenstein, 1979). A second cueing modality is to use cues that have a directional meaning. The most straightforward type of directional cue is one that explicitly represents a spatial orientation, such as pointing arrows or gazing eyes. Reaction time studies of healthy participants have shown that these cues automatically generate a spatial code (e.g., Zorzi, Mapelli, Rusconi, & Umiltà, 2003) and trigger reflexive shifts of spatial attention (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Gibson & Kingstone,

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doi:10.1016/j.neuropsychologia.2007.08.019

2006; Ristic & Kingstone, 2006). Cueing by arrows was also employed in several studies of line bisection in healthy participants. The most common finding is that arrow cueing shifts the subjective midpoint towards the direction opposite to the orientation of the arrows (Chieffi, 1999; Kashmere & Kirk, 1997; Macdonald-Nethercott, Kinnear, & Venneri, 2000). To the best of our knowledge, direction of eye gaze has never been used to cue the line bisection task. However, one would predict that gaze cues can modulate neglect performance; indeed, Vuilleumier (2002) reported that the extinction rate of right brain-damaged patients was ameliorated when a left target was cued by leftward gazing eyes.

One further type of cue that conveys directional meaning is a one-digit number. Directional meaning is not explicit in this case but it is related to the activation of a spatial representation of numbers in the form of a left-to-right oriented mental number line (for reviews see Fias & Fischer, 2005; Hubbard, Piazza, Pinel, & Dehaene, 2005). Reaction time studies of healthy participants have shown the association between response side and numerical magnitude, in the form of a left-small versus right-large correspondence (the SNARC effect; Dehaene, Bossini, & Giraux, 1993). More direct evidence for the spatial coding of numbers has been reported by Zorzi, Priftis, and Umiltà (2002), who asked left neglect patients to mentally bisect numerical intervals (e.g., "What number is halfway between 1 and 9?"). Neglect patients reported a number larger than the correct one (e.g., "7"), shifting the response towards the "right" end of the mental number line (also see Priftis, Zorzi, Meneghello, Marenzi, & Umiltà, 2006; Zorzi, Priftis, Meneghello, Marenzi, & Umiltà, 2006). Finally, centrally presented digits produce lateral shifts of spatial attention that are related to their numerical magnitude (Casarotti, Michielin, Zorzi, & Umiltà, 2007; Fischer, Castel, Dodd, & Pratt, 2003) and can influence the execution of pointing movements (Ishihara et al., 2006).

The effect of digit cueing upon line bisection performance has been studied with healthy participants only. Fischer (2001b) first reported that the bisection of lines made up by a string of digits (e.g., 111111111) was modulated by numerical magnitude. Fischer found a rightward deviation for lines composed of "large" numbers (8 and 9) and a leftward deviation for lines composed of "small" numbers (1 and 2). In a second experiment, two different digits (1 and 2 or 8 and 9) were placed at the extremities of each line. Results revealed a shift towards the larger of the two digits, that had to be reported before bisecting the line. Calabria and Rossetti (2005) also presented lines composed of digits but they did not find a deviation of the midpoint as a function of number magnitude. Nonetheless, the effect was present when the line was made up by a continuous sequence of written number words (e.g., the French translation of NINENINENINENINENINE). Finally, de Hevia, Girelli and Vallar (2006) did not replicate the findings of Fischer (2001b) with lines made from digits, whereas they found a more consistent shift towards the numerically larger of two digits presented as flankers at the ends of to-be-bisected lines or empty spaces, and interpreted this finding as an illusion of length induced by the larger digit.

In the present study, we directly compared the effects of gazing eyes, arrows, and Arabic digits used as task-irrelevant flankers in a line bisection task. The finding that these types of stimuli can influence spatial processing and produce shifts of attention in healthy participants leads to the question of whether they can modulate performance of neglect patients in the line bisection task. Notably, neglect patients seem to be more sensitive than brain damaged controls to task-relevant cues (e.g., Olk & Harvey, 2002) as well as to (task-irrelevant) illusions of length (e.g., Daini, Angelelli, Antonucci, Cappa, & Vallar, 2002). Thus, irrelevant visual cues might be particularly effective in the case of neglect patients. The use of different types of cue within the same patients allows us to compare the effect of social cues (eye gaze), symbolic cues (arrows), and numerical cues (digits). The directional meaning is explicitly represented in the case of eye gaze and arrows, whereas it is implicit in the case of digits (i.e., related to the activation of their mental representation). Both eye gaze and digits have not been used in previous studies of line bisection with neglect patients.

With regard to the effect of specific cues, the results of the studies reviewed above lead to the following set of predictions: (i) bisection error should be shifted towards the direction indicated by the gazing eyes; (ii) the effect of arrows should be very similar to that of gazing eyes, although the inconsistent results regarding arrow-cued line bisection in healthy participants do not allow us to use a directional hypothesis; (iii) small digits (i.e., 1-1) should shift the bisection error towards the contralesional hemispace, whereas the opposite shift should be observed for large digits (i.e., 9-9); (iv) two different digits placed at the ends of the line should induce a shift towards the larger number.

1. Method

1.1. Participants

Seventeen consecutive patients with right hemisphere lesion participated in the study. Patients were admitted to a rehabilitation centre for the treatment of their neuromotor deficits; patients' demographic, clinical, and neuropsychological data are reported in Table 1. None had a history of substance abuse or other neurological diseases. All participants gave written informed consent to take part in the study, according to the Declaration of Helsinki. The presence of a single right hemisphere lesion was confirmed by CT or MR scans. Participants were initially screened with the Mini Mental State Examination (Italian version of Magni et al., 1996) to exclude the presence of diffuse cognitive impairment.

To investigate the presence of peripersonal neglect, the conventional part of the Behavioural Inattention Test (BIT; Wilson, Cockburn, & Halligan, 1987) was administered. Participants were assigned to the two groups (neglect or controls) on the basis of their performance in the bisection subtest and in at least one of the other subtests of the BIT (see Table 1). In addition, all patients performed ecological tasks to assess the presence of neglect in personal or extrapersonal (i.e., beyond reaching) space. Nine patients showed left neglect (N+ group), whereas the remaining eight patients had no sign of left neglect (N− group). One neglect patient (LL) was later excluded from the N+ group (see Section 2). The remaining eight N+ patients did