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Neglect dyslexia: A matter of "good looking"

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ABSTRACT

Brain-damaged patients with right-sided unilateral spatial neglect (USN) often make left-sided errors in reading single words or pseudowords (neglect dyslexia, ND). We propose that both left neglect and low fixation accuracy account for reading errors in neglect dyslexia.

Eye movements were recorded in USN patients with (ND+) and without (ND−) neglect dyslexia and in a matched control group of right brain-damaged patients without neglect (USN−). Unlike ND− and controls, ND+ patients showed left lateralized omission errors and a distorted eye movement pattern in both a reading aloud task and a non-verbal saccadic task. During reading, the total number of fixations was larger in these patients independent of visual hemispace, and most fixations were inaccurate. Similarly, in the saccadic task only ND+ patients were unable to reach the moving dot. A third experiment addressed the nature of the left lateralization in reading error distribution by simulating neglect dyslexia in ND− patients. ND− and USN− patients had to perform a speeded reading-at-threshold task that did not allow for eye movements. When stimulus exploration was prevented, ND− patients, but not controls, produced a pattern of errors similar to that of ND+ with unlimited exposure time (e.g., left-sided errors).

We conclude that neglect dyslexia reading errors may arise in USN patients as a consequence of an additional and independent deficit unrelated to the orthographic material. In particular, the presence of an altered oculo-motor pattern, preventing the automatic execution of the fine saccadic eye movements involved in reading, uncovers, in USN patients, the attentional bias also in reading single centrally presented words.

1. Introduction

Unilateral spatial neglect (USN) is a neuropsychological disorder characterized by a deficit in detecting and identifying objects or executing movements in the portion of space contralateral to the lesion (Halligan, Fink, Marshall, & Vallar, 2003). The disorder is most frequently associated with right-hemisphere brain lesions. The most common anatomical correlates of left-sided neglect are the right inferior parietal lobule (supramarginal gyrus) and the temporo-parietal junction. Lesions involving the premotor cortex or confined to subcortical structures may also cause neglect (Vallar, 2001). Neglect dyslexia (ND) is a reading disorder often associated with other manifestations of the USN syndrome. When patients with ND read single words, pseudowords or sentences and lines of text they may misread some elements that occupy the controlesional side. Errors in single-word reading are considered markers of ND and are characterized by different types of errors (Ellis, Flude, & Young, 1987). The most common errors are omissions [e.g., the target word *orologio* (clock) read as *logio*] and substitutions [e.g., the target word *tavolo* (table) read as a non-word like *sevolo* or another word like *cavolo* (cabbage)].

The relationship between the reading disorder and the more general USN syndrome is controversial (see the review by Vallar, Burani, & Arduino, 2010). In fact, in USN reading abilities show associations and dissociations with other visuo-spatial tasks. In a large recent survey of neglect impairments, Lee et al. (2009) showed that the reading deficit co-occurred with other spatial deficits in 40% of patients. However, few cases of double dissociations between left ND and right USN have been described (Katz &

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Sevush, 1989; Cubelli, Nichelli, Bonito, De Tanti, & Inzaghi, 1991; Costello & Warrington, 1987), suggesting that the disorders may be due to different mechanisms. But, as noted by Vallar et al. (2010), these double dissociations and cases of ND without USN are generally associated with a lesion involving at least the left hemisphere or both hemispheres (Patterson & Wilson 1990; Warrington, 1991; Cohen & Dehaene 1991; Binder et al., 1992; Haywood & Coltheart, 2001; Arduino, Daini, & Silveri, 2005), which casts doubts about whether these cases should really be considered as neglect dyslexia (see the review of Vallar et al., 2010 for a discussion).

In a study of patients with ND and USN, Martelli, Arduino, and Daini (2011) suggested that in neglect dyslexia omission errors are associated with the USN deficit and that substitutions might arise from a more perceptual impairment. The authors showed that the number of letters omitted in reading single words and pseudowords correlated positively with the number of errors in line and letter cancellation tasks. Omission errors seem to be a characteristic marker of the unilateral spatial neglect disorder in reading. Weinzierl, Kerkhoff, van Eimeren, Keller and Stenneken (2012) compared the types of errors (omissions and substitutions) made by neglect patients with those of healthy controls whose performance was equated for accuracy by reducing exposure duration. They found that omissions were dominant in patients and that substitutions characterized controls' performance at threshold (with brief exposure durations).

Nevertheless, it is still unclear why only a fraction of patients with USN make reading errors. The reading pattern in ND might be due to impairment of one or more cognitive components involved in USN (e.g. Ptak, Di Pietro, & Schnider, 2012). Or, similarly to the interpretation of line bisection tasks, reading errors might arise as an epiphenomenon of the interaction between USN and an independent deficit. In line bisection tasks, it has been shown that hemianopic patients without USN compensate for their visual deficit by fixating toward the blind field (Ishiai, Furukawa, & Tsukagoshi, 1989; Barton, Behrmann, & Black, 1998) and that USN patients are unable to compensate for hemianopia because of their attentional deficit (Chedru, Leblanc, & Lhermitte, 1973; Girotti, Casazza., Musicco, & Avanzini, 1983; Ishiai et al., 1989; Karnath & Fetter, 1995; Barton et al., 1998). Thus, in line bisection tasks they show a larger bias than USN patients without visual field defects and their errors are opposite to those of hemianopic patients (D'Erme, De Bonis, & Gainotti, 1987; Doricchi & Angelelli, 1999; Daini, Angelelli, Antonucci, Cappa, & Vallar, 2002). This example shows that, due to the composite nature of the USN syndrome, a concomitant deficit may result in qualitative and quantitative behavioral differences between patients. Our working hypothesis is that the eye movement pattern of non-hemianopic USN patients with and without ND may help clarify the nature of the reading deficit.

The role of eye movements is particularly important in studying reading. Eye movements are influenced by many perceptual and semantic aspects of orthographic material and can indicate the cognitive processes involved in reading. Oculomotor behavior is influenced by early perceptual factors such as stimulus length, letter size, spatial layout of the text and lexical factors (Inhoff, Radach, Eiter, & Juhasz, 2003; Juhasz, 2008; O'Regan, 1979, 1980; Rayner, 1979; White, Rayner, & Liversedge, 2005, for a review see Rayner, 2009).

Eye movements have been extensively investigated in neglect patients (Chedru et al., 1973; Girotti et al., 1983; Johnston & Diller, 1986; Hornak, 1992; Behrmann, Watt, Black, & Barton, 1997; Ptak, Golay, Müri, & Schnider, 2009). Studies with USN patients have focused on tasks such as global scene description, visual search and object detection, and have shown impaired behavior on the neglected side. When a visual search task was adopted, studies showed that USN patients began exploring stimuli from the right hemifield. Furthermore, their exploration was mostly limited to the right side (Chedru et al., 1973; Hornak, 1992; Ptak et al., 2009) and when they explored the left hemifield their reaction times increased (Girotti et al., 1983). Coherently, Johnston and Diller (1986) found a strong negative correlation between an index of USN severity (derived from letter cancellation and visual matching task scores) and amount of exploration in the left hemifield. Behrmann et al. (1997) reported that in a letter detection task patients with USN made fewer fixations and engaged in shorter inspection time on the controlesional left side. These results demonstrated that in exploratory tasks omitted items were not fixated.

To our knowledge, very few studies have investigated eye movements during reading in patients with neglect dyslexia. In a single word and pseudoword reading aloud task, Di Pellegrino, Làdavas, & Galletti (2002) analyzed an ND patient's (FC) first landing positions after the stimulus appeared and number of fixations. They found that the patient's probability of reporting the left-sided letters could not be predicted by the amount of time spent fixating the left side of the string. This indicates that left-sided eye movements are independent from awareness of the contralesional orthographic material. Coherently, using a covert attention task Làdavas, Zeloni, Zaccara, and Gangemi (1997) found that neglect patients with fronto-parietal lesions could not inhibit left-sided saccades that were performed toward the unattended and otherwise ignored stimuli. Contrary to these findings, Behrmann, Black, McKeeff, and Barton (2002) found a direct correspondence between the oculomotor performance of patients with neglect dyslexia and their reading behavior. In this paradigm, patients were asked to read sets of 15 words arranged in 5 columns that covered the whole screen. The authors found that, similar to unimpaired control subjects, USN patients without ND showed no difference in number of fixations and fixation duration in the left compared to the right visual field. Vice versa, patients with ND showed an abnormal eye movement pattern with very few brief fixations towards the left columns. Furthermore, they made more and longer fixations to the ipsilesional side compared with both the USN patients and the control group. The authors concluded that ND may be due to failure to register and perceive controlesional information.

Eye movement analysis in neglect patients highlighted important aspects of this syndrome that contribute towards explaining some of its specificities (e.g., object-based neglect, Walker & Findlay, 1996). A more systematic analysis of eye movements in patients with ND compared with the eye movement exploratory pattern in patients with USN without ND and controls might highlight important aspects of the reading impairment.

The first aim of this study was to investigate whether ND is associated with an abnormal eye movement exploratory pattern different from the oculomotor behavior shown by USN patients without ND, as suggested by Behrmann et al. (2002) results (Experiment 1). To evaluate the role of the oculomotor component independent of reading and to examine the relationship between USN and ND without using orthographic material, we investigated the eye movement pattern during a saccadic non-reading task (Experiment 2). Indeed, the ability to program and execute a saccade of the correct amplitude in simple non-verbal tasks is a prerequisite for appropriate saccade execution during reading (e.g. De Luca, Di Pace, Judica, Spinelli, & Zoccolotti, 1999; Pavlidis, 1981). Finally, in Experiment 3 we aimed to clarify whether the co-occurrence of USN and the impossibility of producing exploratory eye movements during reading might be sufficient to induce the types of errors seen in neglect dyslexia.

For this purpose, we tried to simulate "ND-like" reading behavior in USN patients without ND and controls by preventing eye movements while they read at threshold.