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Update article

Acquired spatial dyslexia

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ABSTRACT

Acquired spatial dyslexia is a reading disorder frequently occurring after left or right posterior brain lesions. This article describes several types of spatial dyslexia with an attentional approach. After right posterior lesions, patients show left neglect dyslexia with errors on the left side of text, words, and non-words. The deficit is frequently associated with left unilateral spatial neglect. Severe left neglect dyslexia can be detected with unlimited exposure duration of words or non-words. Minor neglect dyslexia is detected with brief presentation of bilateral words, one in the left and one in the right visual field (phenomenon of contralesional extinction). Neglect dyslexia can be explained as a difficulty in orienting attention to the left side of verbal stimuli. With left posterior lesions, spatial dyslexia is also frequent but multiform. Right neglect dyslexia is frequent, but right unilateral spatial neglect is rare. Attentional dyslexia represents difficulty in selecting a stimulus, letter or word among other similar stimuli; it is a deficit of attentional selection, and the left hemisphere plays a crucial role in selection. Two other types of spatial dyslexia can be found after left posterior lesions: paradoxical ipsilesional extinction and stimulus-centred neglect dyslexia. Disconnections between left or right parietal attentional areas and the left temporal visual word form area could explain these deficits. Overall, a model of attention dissociating modulation, selection control, and selection positioning can help in understanding these reading disorders.

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1. Introduction

Reading disorders are frequent with lesions of the posterior part of the brain. Alexia without agraphia and letter-by-letter dyslexia affects linguistic processes, whereas spatial dyslexia (SD) affects spatial processes involved in reading. The evaluation of SD is mainly based on 3 methods. The first one is text reading, whereby the patient is asked to read aloud a simple text. This method has the advantage of using a natural situation, even though we do not really pronounce the words aloud when reading a text. The method gives indications on reading errors that the patient makes in everyday life. The second method involves single words or non-words (i.e., letter strings not constituting a real word) in a reading-aloud task, lexical decision or letter search. In the reading-aloud task, emphasis is on the type of errors, their location (left, right; beginning, end) or their nature (omissions, substitutions, etc.). The third method is the tachistoscopic presentation of words (i.e. a rapid visual presentation, usually 100 ms or 200 ms) so that saccades cannot occur. The patient fixates on an item in the centre of the screen without moving the eyes, and words can be presented in the left visual field (LVF) or right visual field (RVF). This method provides precise information on the patient's deficit. It is more sensitive than the previous methods and is particularly useful when the deficit is minor.

This paper presents left neglect dyslexia (ND) after right posterior lesions, then various SDs occurring after left posterior lesions. Finally, although letter-by-letter dyslexia is beyond the scope of this article, it presents some spatial strategies found in this syndrome.

2. Neglect dyslexia after right posterior lesions

The most well-known example of SD is ND [1] occurring in the context of unilateral spatial neglect (USN). USN represents a difficulty in orienting the gaze and attention toward the contralesional part of space and is found after a unilateral temporo-parietal lesion, usually in the right hemisphere. Because orientation is so important in reading, patients with USN after right posterior lesions not unsurprisingly make left-sided errors when reading text and words [2].

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2.1. Text reading

Left USN patients frequently omit words located in the left part of a text and have difficulties returning to the beginning of the next line, so an increasing number of left-sided words are omitted as the reader continues to read the text. Omission of words is a characteristic of ND in the context of left USN [3], but patients can also erroneously read some words included in the text, particularly long words [4].

2.2. Single word reading

Left USN patients may also err when reading single words presented in isolation or listed on a sheet of paper. Errors are mostly located on the left side of words; this is called unilateral paralexia [5] or neglect errors. Errors are visual and are not influenced by phonology (i.e., do not respect the grapheme/phoneme organization of words) [6]. The most common error type is letter substitutions (e.g., table is read as "fable"), followed by letter omissions ("able"), and letter inversions; letter additions are rare. Weinzierl et al. [7] compared reading errors in USN patients and normal controls, with the presentation time of words reduced in normal controls to elicit reading errors. The authors found a linear left-right gradient of errors in USN patients, whatever the error type, whereas errors in controls were more equally distributed on the different letter locations in the word. They also found that omission errors were pathognomonic of ND. For Daini et al. [8], omissions might be related to an exploratory deficit, and substitutions to a deficit of perceptual integration. Omissions at the level of the word [8] or the text [9] are specifically reduced by optokinetic stimulation, which improves oculomotor behaviour. However, Primativo et al. [10] showed that neglect errors in reading are identical when words are tachistoscopically presented, preventing saccades, or in an unlimited presentation duration, allowing saccades. This result discounts an abnormal oculomotor explanation of ND and favours an attentional explanation.

2.3. Superiority of words over non-words

Neglect errors are more frequent with non-words than words in a reading-aloud task [11,12] as in tasks that do not require reading the letter string aloud, like bisecting a line located underneath the letter string [13] or comparing letter strings located one above the other [14]. In reading, two thirds of patients show a larger number of neglect errors with non-words than words [15].

This superiority of words over non-words in ND can be explained by the top-down facilitation of lexical knowledge on the processing of letters "degraded" by neglect. The reduced perception of letters on the neglected side may be sufficient to identify a familiar word but not an unfamiliar letter string, like a non-word. The identification of letters in a non-word would require more spatial attention than letters in a word [16]. An alternative explanation is the sophisticated guessing strategy, whereby patients with ND explicitly guess the letters located in the contralesional side of the letter string, with more chance to be correct when the letter string is actually a familiar word. In contrast to the guessing explanation, word superiority is not found when the degradation of contralesional letters by neglect is too strong [15] or when spaces between letters disrupt the integration of the letters into a lexical representation [17,18]. In these cases, neglect errors in words increase, although guessing should be similar.

Finally, the superiority of words in ND has been described with compound words such as cookbook [19,20] and with irreversible binomial forms such as "dead or alive" [21]. The nature of the non-words, specifically the phonological plausibility or the lexical resemblance of the letter string (pseudowords such as "blimarel" vs illegal non-words such as "lbmiaerl"), has been diversely evaluated and more studies are needed.

2.4. Script direction

Another question remaining largely unresolved is the effect of script direction on ND, because few studies have been conducted in languages involving reading from right to left. One study of Hebrew showed that with a right hemisphere lesion, the left side of words was neglected [22]. Another study of Japanese showed that 5 of 9 patients with ND neglected the left side of words written from right to left or from left to right (in kana or in kanji), but 2 made more errors when reading words from left to right [23].

2.5. Representation level of the deficit

ND is more severe when words are tachistoscopically presented in the LVF than RVF [19], so the deficit is located at the level of a retino-centred representation. However, neglect errors can also occur on the left side of words located in the RVF [2,17], so the deficit can occur at the level of a stimulus-centred representation.

Reading left-to-right scripts requires first the adjustment of an attentional window of processing on the global limits of the text and second its adjustment on individual words (focus), beginning by the leftmost word of the line and followed by a rightward scan. Similarly, at the word level, the attentional window is adjusted to the whole letter string, then focused on individual letters, beginning by the leftmost one and followed by a rightward scan, even though the process is much faster with words than non-words [24]. Operations of attentional orienting and focusing at the level of the text or the word may be closely related [24], and patients may have deficits at both levels. In texts, the deficit would occur in the LVF; in words, the deficit could occur in both the LVF and RVF. Note that global attention can also play a role in reading [17].

2.6. Neglect dyslexia and unilateral spatial neglect

In 70% of cases, left ND is associated with left USN [25]. Although ND is frequently found with oculomotor difficulties [26], ND has not been correlated with specific test results of USN. In USN patients, rightward deviation in line bisection increases with line length [27]. Veronelli et al. [28] asked patients to bisect lines or words of different length (4 cm–12 cm) and found an effect of length on rightward deviation in words as in lines. However, some patients showed dissociations between words and lines, which suggests that close but different mechanisms may underlie ND and USN. Moreover, most patients are tested with words measuring < 4 cm [29], although rightward bias is rarely found with lines < 4 cm.

In agreement with the hypothesis of different mechanisms in ND and USN, patients with ND do not systematically show USN. I suggest 3 possibilities. First, reading tests are more sensitive to attentional orienting deficits than usual USN, because reading is more attention-demanding than bisecting lines, canceling objects, or copying; the attentional orienting deficit might be less severe in ND without USN. Second, ND without USN may be caused by a lesion on the tracks relating right-hemisphere regions playing a role in attentional orienting and regions necessary to identify visual words (i.e., the visual word form area [VWFA] located in the posterior part of the left fusiform region) [30]. ND usually occurs after temporo-parietal lesions or in lesions in the posterior part of basal ganglia and insula [19,25], so determining whether the lesion affects callosal fibres is of interest. Third, the lesion may spare the middle superior longitudinal fasciculus shown to play a role in line bisection bias and spatial orienting [31].

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