Left minineglect or inverse pseudoneglect in children with dyslexia?

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This study compared the visuospatial asymmetries in children with dyslexia and healthy children by using the manual line bisection task, and investigated the processing of spatial context with a 'local' cueing paradigm consisting of geometric symbols placed on the extremities of the lines. The performance between healthy children (leftward bias) and children with dyslexia (rightward bias) was significantly different. Furthermore, the bisection mark was shifted in the direction of the unilaterally cued extremities in all children. As children with dyslexia showed a rightward bias in their spatial representation, which did not interfere with local context processing, we proposed the term 'inverse pseudoneglect' to depict their behaviour in line bisection. *NeuroReport* **00:000–000 © 2010 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Developmental dyslexia is classically described as a neurological condition afflicting the school-age population. This mild hereditary neurological disorder manifests as a persistent difficulty in learning to read. This disorder is associated with sensory difficulties, balance, and motor control problems [1,2], otherwise normal intellectual functioning (for review see ref. [3]). There is much evidence that indicates general attentional deficits in dyslexia. Children with dyslexia exhibit asymmetrical distribution of spatial attention (left inattention vs. right over-distractibility) (e.g. [4]) suggesting a left 'minineglect' [5].

As the orientation of attention affects space representation [6], we studied space representation in patients with dyslexia. We used the manual line bisection task that requires participants to indicate the centre of a line with a pen. This test is widely used to quantify the rightward representational bias in neglect [7] and the mild leftward representation bias in healthy individuals [8,9]. On account of the similarity of the distribution of spatial attention between neglect and dyslexia, we predicted that children with dyslexia may exhibit a moderate rightward bias as shown earlier in a perceptual task [5] or by moving a cursor with a method of manipulation of wheels [10] or more recently in bisection [11]. We also investigated the processing of spatial context with a cueing paradigm. If children with dyslexia showed a healthy preservation of spatial context processing, we expected a bidirectional effect of cueing: a leftward (or rightward) displacement of the bisection mark for left-cued (or right-cued) lines (e.g. [6]). In contrast, if children with dyslexia exhibited a neglect-like spatial context processing, we expected a unilateral effect of cueing, that is, only a leftward displacement of the bisection mark with left-cued lines as it was shown earlier in neglect patients (e.g. [12,13]).

Materials and methods

Children

Two groups of 10 right-handed children, with normal or corrected-to-normal vision, participated in this study. They gave their informed consent before their inclusion in the study, which was carried out in agreement with legal requirements and international norms (Declaration of Helsinki, 1964), and was approved by the regional ethics committee of Burgundy (C.E.R.). The group of healthy children (12.90 ± 1.52 years) was age matched with the group of children with dyslexia (12.20 ± 1.62 years) (t-test, $P > 0.33$).

In France, the diagnosis of dyslexia is given by a speech therapist. The inclusion criteria were at least 24 months of school retardation for literacy impairment with a normal IQ (Intelligence Quotient)-documented diagnosis and past speech therapy. In this experiment, all the children were given one test of language abilities to assess impairments in word reading (leximetric global validated test 'de l'Alouette'). This test made it possible to determine speed and accuracy indexes based on a test that accounted the time to read 265 words and the number of errors [14]. The group with dyslexia had significant lower reading text scores in comparison with the control children ($P < 0.001$).

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Experimental procedure

The bisection consists of setting a mark with the right hand across the centre of a line. It needs a few repetitions of the presentation, which may avoid any time-on-task effect related to declining alertness [15]. Twenty-four lines were presented in front of the body midline of children at a viewing distance of approximately 45 cm. The lines (200 mm long and 1 mm wide) were printed individually and centred on a white A4 landscape card. Each stimulus sheet was presented one at a time on an empty table. Subsets of six lines had either a cue at the left end, at the right end, at both ends ('two cues' condition) or no cue ('no cue' condition). The cues were two kinds of plain black geometric symbols (circle and square), which were separated from the end of the line by a 6 mm space. Each symbol was 7.5 mm long and 7.5 mm large. All the conditions were ordered pseudorandomly. During the visual exploration, the hands were positioned so as not to hide any part of the line.

Data analysis

Bisection deviations were established using the usual method, which involved measuring the distance (to the nearest 0.5 mm) from the objective centre. Deviations drawn to the right of the objective centre were given a positive value and those to the left were given a negative value.

We analyzed the observed bias using a two-way analysis of variance with condition (no cue, two-cues, left cue and right cue) as a within-child factor, and group (healthy children and children with dyslexia) as a between-children factor. The specific effect of group for no cue condition and the effect of cue compared with no cue condition in each group were analyzed by contrast analyses. A correlation analysis (Spearman's ρ) was carried out between parameters of the Alouette test and the bisection bias for each condition in all the children. All statistical analyses were carried out using the Statistica software package (release 7.1, Tulsa, Oklahoma, USA). An α level of 0.05 was used to determine the statistical significance. In the results section, the mean and standard deviation are presented in parentheses.

Results

Before setting the bisection mark, the children were requested to name the geometrical cues placed on the extremities of the lines. All the children performed the task correctly; no omission was observed. When bilateral cues were presented, all the children began spontaneously with the left cue.

A two-way analysis of variance showed a significant main effect of group [$F(1,18) = 7.50$; $P < 0.02$] and a significant main effect of cueing [$F(3,54) = 23.45$; $P < 0.01$]. The group of children with dyslexia showed a rightward bias compared with healthy children. Nevertheless, both groups exhibited the same modulation of space representation by cueing (Fig. 1).

In the 'no cue' condition, healthy children showed a mild leftward bias of the bisection mark (-1.34 ± 1.62 mm), which was significantly different from zero ($P < 0.03$). Children with dyslexia showed a mild rightward bias of the bisection mark (2.05 ± 3.11 mm), which was insignificantly different from zero ($P = 0.06$). The performance between the two groups was different ($P < 0.01$) and was oriented in opposite directions.

With left-cued lines

There was a significant difference between 'no cue' and 'left cue' conditions in both groups (Ps < 0.01). With respect to the 'no cue' condition, the bisection mark was displaced -2.09 ± 2.14 mm leftward in healthy children and displaced -1.91 ± 1.97 mm leftward in children with dyslexia.

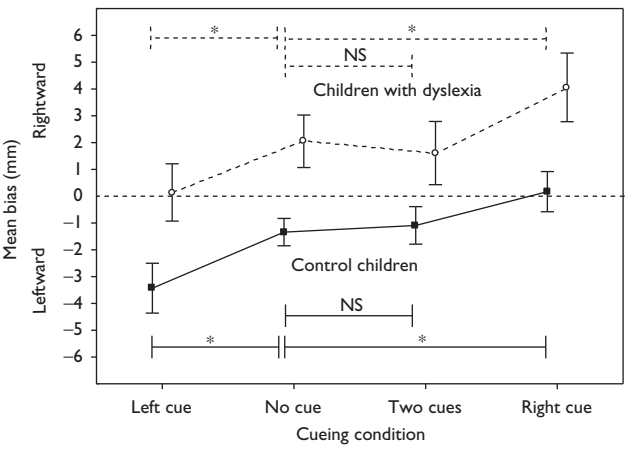
With right-cued lines

There was a significant difference between 'no cue' and 'right cue' conditions in both groups (Ps < 0.03). With respect to the 'no cue' condition, the bisection mark was displaced 1.52 ± 2.14 mm rightward in healthy children and displaced 2.01 ± 1.80 mm rightward in children with dyslexia.

In the 'two cues' condition

Healthy children (-1.09 mm $\pm$ 2.22) and children with dyslexia (1.61 mm $\pm$ 3.74) nearly showed a perfect

Fig. 1



Manual estimation of the centre of the line for the four conditions of bisection (left cue, no cue, two cues and right cue conditions) in healthy children and children with dyslexia. White circles represent performance of children with dyslexia (mean ± standard error). Black squares represent performance of healthy children. The horizontal dotted line indicates the objective centre of the line. Leftward biases are indicated with a negative value and rightward biases with a positive value. The comparisons between no cue condition and other conditions are shown in the figure. *, significant; NS, not significant.

performance. There was no difference between 'no cue' and 'two cues' conditions in both groups ($P > 0.4$).

Furthermore, when the performances of all the children were considered for a correlation analysis, there were significant correlations between reading text scores (accuracy and speed scores) and bisection biases (no cue, left cue, right cue and two cues conditions). The values for Spearman's ρ ranged from -0.47 to -0.61 ($P < 0.05$). Only the correlation between the left cue condition and the reading speed score was not significant ($P > 0.05$). Nevertheless, no correlation was shown when we considered only the group of children with dyslexia.

Discussion

This study showed (i) an overall rightward bias in the bisection mark for children with dyslexia compared with healthy children and (ii) a preservation of the capacity for processing spatial contexts in children with dyslexia. The following discussion will attempt to provide explanations for our main results.

Minineglect versus pseudoneglect

Right hemisphere dominance for visuospatial functions in healthy individuals [16] produces a slight leftward bias of attention responsible for a leftward bias in line bisection [6]. This bias is termed 'pseudoneglect' [9] in comparison with the large rightward bias observed in neglect (e.g. [7]). This hemispheric dominance appears early in childhood [17,18]. The healthy children of this study exhibited this leftward bias suggesting right hemisphere dominance in this age group. The rightward bias in children with dyslexia suggests reduced right hemisphere functioning. The amplitude of the rightward bias is quite similar to the bias observed very recently in the study by Waldie and Hausmann [11] and to the perceptual bias in the study by Sireteanu *et al.* [5]. This result emphasizes the representational bias in children with dyslexia, which reinforces the comparison between dyslexia and a mild version of the left neglect after a right hemisphere lesion. Despite the overall rightward bias, children with dyslexia showed a preservation of the spatial context processing. Therefore, it is worth wondering whether the designation 'minineglect' is appropriate to depict the response of children with dyslexia in line bisection.

Dissociation between the rightward bias and the preservation of the spatial context processing in dyslexia

In healthy individuals, the bisection mark is shifted towards the unilateral cue regardless of the cued end [19], and there are similar performances in no cue and bilateral cue conditions [6]. Here, the response of children with dyslexia to cueing is similar to the response of healthy children and differs from the classical response of neglect patients in two points. First, only left-sided cue produces a shift of the bisection bias in neglect patients [12,13]. Second, neglect patients showed that bilateral cues were as effective in reducing the rightward error as the left cue alone [12].

Furthermore, the pathological representational bias is associated with the asymmetrical effect of cueing. In the field of neurology, the large rightward bias of neglect patients is modulated by left-sided cues [12]. In the field of psychiatry, the leftward bias of patients with schizophrenia is modulated by right-sided cues [20]. On the contrary, the right bias in children with dyslexia does not seem to be strong enough to restrict the effect of the left cue, which is as much powerful as the right cue.

Therefore, we propose the term 'inverse pseudoneglect' that would be more acceptable in so far as it expresses not only the mild amplitude of the rightward bias but also the healthy spatial context processing as in pseudoneglect.

Putative neurological substrate

The right inferior parietal cortex is consistently implicated in line bisection (e.g. [21]) and is also frequently damaged in neglect patients [22]. Therefore, it would be logical to assume a minor right parietal lobe dysfunction in dyslexia. Alternatively, a disconnection hypothesis on the posterior corpus callosum could be proposed [23]. The rightward bias in children with dyslexia could be compared with the bias with the right hand in left-handed children because of their putative commissural immaturity [17] and, to a lesser degree, in patients with partial callosal disconnection [24].

In conclusion, children with dyslexia showed an 'inverse pseudoneglect' that is to say a rightward bias in line bisection with a preserved capacity for context processing. The link between space representation and spatial attention needs to be further investigated to better understand spatial cognition in children with dyslexia. Further studies with greater sample size using other sensitive tools that are more appropriate to measure spatial orientation are necessary to confirm and complete our preliminary results.

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