Asymmetrical visual fields distribution of attention in dyslexic children: a neuropsychological study

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Abstract

Visual spatial attention was evaluated in dyslexic and normally reading children by using a flanker task. When an irrelevant distractor is presented adjacent to a target stimulus, interference is observed when the two stimuli are associated with conflicting responses. In the present study the distractor flanked the target either to the right or to the left. Results showed an asymmetric flanker effect in dyslexics, whereas it was symmetrical in normal readers. Dyslexics exhibited a reduced flanker effect in the left visual field, concomitant with a strong flanker effect in the right visual field. These results give further support to the hypothesized left-side minineglect in dyslexics. Data also provide evidence for a reduced ability in suppressing distracting information in the right visual field. Such visual field asymmetry is thought to play a crucial role in reading disorders. Right over-distractibility and left inattention suggest an impairment of the right parietal functions as supported by the magnocellular theory of dyslexia.

Keywords: Dyslexia; Spatial attention; Flanker effect; Visual field; Asymmetry; Right parietal lobe

Developmental dyslexia is defined as a specific reading disorder despite normal intelligence and teaching, regardless of any manifest sensory deficit. Recently, the hypothesis of an 'auditory temporal processing deficit' has become of central interest in the study of dyslexia etiology [4]. However, a temporal processing deficit appears to affect information processing in different sensory modalities [15]. Accordingly, it has been suggested that the major problem of dyslexic children would be a general impairment in the processing of rapid streams of information, regardless of the stimulated modalities. The magnocellular-transient (M) system, which would also include the auditory system, is thought to be the neural basis underlying such deficit [10]. The information processed by the M system ends in the parietal posterior cortex (PPC), which is an important supramodal selective spatial attention area [17]. An impairment of this area would lead to a reduced ability to focus attention in the stimulated modality. As far as the visual domain is concerned, there is evidence of both an impaired focusing of attention in dyslexic children [3] and a prolonged dwell time in dyslexic adults [8]. In addition, much converging evidence indicated an asymmetric distribution of attention between the two visual fields in dyslexics. Hari and Koivikko [7] suggested that, as compared to the right visual field (RVF), dyslexics suffer from 'mini-neglect' in the left visual field (LVF). Fowler et al. [5], and Eden et al. [1] showed that in visual search tasks dyslexic children omitted a greater number of targets when presented in the LVF than in the RVF. This left-side deficit appears to be linked to a right-side enhancement in the processing of visual information, as demonstrated by an increased ability of dyslexics in letter recognition in the RVF [6].

Therefore, the present study was aimed at further exploring a possible attentional visual field asymmetry in dyslexia. To this purpose, we used the response competition procedure [2]. Typically participants are required to react to a central target flanked by either a response-compatible or response-incompatible distractor. What has been observed is that compatible distractors produce faster reaction times (RTs) than the incompatible ones. The RT difference between the compatible and the incompatible condition is defined as 'flanker effect'. Participants consisted of 14 dyslexic children (mean and SD, age 12.1 $\pm$ 2.3 years, ten males, four females) and 11 normally reading children.
(mean and SD, age 11.4 ± 2.7 years, eight males, three females). All children were selected by: (1) a full scale IQ > 85, (2) normal or corrected-to-normal vision and hearing, (3) normal visual field, (4) absence of attention deficit disorder with hyperactivity (ADHD), (5) no known gross behavioral or emotional problems, (6) absence of drug therapy, (7) normal teaching opportunities, and (8) right manual preference. The children were classified as dyslexic as their performances in oral reading of text, words and non-words were 2 SD below the norm on age-standardized Italian tests. Variables considered are speed and accuracy. The dyslexic group had significantly lower reading test scores in comparison to control children (reading accuracy, one-sided t-test, \( P < 0.0001 \), and reading speed, \( P < 0.0001 \)). The two groups did not differ with regard to IQs (mean IQ of dyslexics was 99 ± 14, mean IQ of normal readers was 104 ± 12).

Tests were carried out in a dimly lit room with a ambient luminance of 1.5 cd/m². Participants sat in the front of a monitor (15 inches and with a luminance of 0.5 cd/m²) with their head positioned on a headrest so that the eyes-screen distance was 40 cm. Fig. 1 shows the experimental set-up. A small white dot (0.5° of visual angle) presented in the center of the screen served as fixation point. The target stimulus was either a left-pointing arrow or right-pointing arrow (2°) presented at the center of the screen. A smaller arrow (1°) flanking the target either to the right to the left side was used as flanker. Target-flanker distance covered 4° of visual angle. In the compatible condition both the target and the flanker pointed to the same direction, whereas in the incompatible condition the target and the flanker pointed to opposite directions. Stimuli luminance was set at 24 cd/m². Each trial began with the onset of the fixation point (accompanied by a 1000-Hz warning tone) which lasted for 201 ms, followed by a 50-ms blank screen. After that the target and the flanker appeared for 201 ms (see Fig. 1). Eye movements were monitored by means of a system composed of infrared-ray spectacles. Any eye movements larger than 1° was detected by the system and the correspondent trial was discarded and replaced. Participants were instructed to press a key on the keyboard as quickly as possible at the onset of the target (the ‘Y’ key for the left-pointing arrow, and the ‘B’ key for the right-pointing arrow). RTs were recorded by the computer with millisecond accuracy, and the maximum time allowed for response was 1500 ms. The experimental session consisted of 240 trials divided into two blocks of 120 trials distributed as follows: compatible and incompatible conditions consisted of 60 trials each. In each condition there were 30 trials in which the target and the flanker pointed to the left (15 trials with the flanker in the LVF and 15 trials with the flanker in the RVF), and 30 trials in which the target and the flanker pointed to the right (15 trials with the flanker in the LVF and 15 trials with the flanker in the RVF). Before the experiment began participants made some practice trials until they felt confident with the task.

Fig. 2 shows participants’ RTs for target detection as a function of flanker compatibility and location (LVF and RVF). Mean correct RTs were entered into a three-way analysis of variance in which the within-subjects factors were type of flanker (compatible and incompatible) and location (LVF and RVF), whereas the between-subjects factor was group (normal readers and dyslexics). The main flanker-type effect was significant \( F(1,23) = 66.26; P < 0.0001 \), the flanker effect was 82 ms. Also, the type of flanker X location X group interaction was significant \( F(1,23) = 6.23, P < 0.02 \), indicating that the two groups processed the flanker in the two visual fields differentially. Planned comparisons showed that in normal readers the flanker effect was present in both the LVF \( (M = 70 \text{ ms}, P < 0.02) \) and the RVF \( (M = 73 \text{ ms}, P < 0.02) \), but the difference between the two visual fields was not significant \( (3\text{ ms}, P > 0.05) \). By contrast, dyslexics exhibited an asymmetrical flanker effect, with the flanker effect virtually absent in the LVF \( (M = 36 \text{ ms}, P > 0.05) \), but deeply present in the RVF \( (M = 144 \text{ ms}, P < 0.0001) \). On the basis of the present results it may be hypothesized that dyslexics display a reduced processing of the flanker in

![Fig. 1. Schematic representation of the display used in the experiment.](image1)

![Fig. 2. Mean reaction times as a function of compatible and incompatible flanker condition, visual field and group. Data show an asymmetrical effect of the flanker in dyslexics but not in normal readers.](image2)
the LVF, concomitant with an exaggerated flanker processing in the RVF. In line with this interpretation we found that in compatible trials dyslexics showed an increased flanker effect in the RVF vs. the LVF ($P < 0.03$). Likewise, in incompatible trials a decreased flanker effect was observed in the LVF vs. the RVF ($P < 0.02$).

The RT pattern emerged from this study can be interpreted in light of recent findings showing an asymmetrical distribution of spatial attention in dyslexics. Such an asymmetry is reflected by a left-side minineglect as suggested by Hari and Koivikko [7] and by Stein and Fowler [16], and by an increased ability in letter recognition in the RVF [6]. Thus, the left deficit exhibited by dyslexic children can potentially indicate an increased inhibition for information presented in the LVF, as shown by a reduced flanker effect. By contrast, the profound flanker effect in the right side might be due to an impairment in the ability to suppress distracting information in the RVF.

How can these deficits be related to the reading problem manifested by dyslexic children? Basically, the idea is that during reading visual information presented in the RVF is not filtered out efficiently in order to obtain an efficient letter and/or word processing. As suggested by LaBerge and Brown [9], the ability to suppress information flanking the attended area would crucial especially when unfamiliar words have to be identified. It can be suggested that this suppressive mechanism could be particularly defective in the RVF in dyslexics, which would be distracted by letters or words to the right from fixation. What is more difficult to explain is how the left inattention deficit might affect the reading process in dyslexic children. It can be speculated that this deficit might play a role during regressive saccades, which are rapid backward eye movements involved in reading [11].

A right parietal cortex dysfunction is thought to be the neurological basis underlying dyslexics’ attentional deficits [7,15]. This interpretation is supported by the fact that a visual spatial deficit similar to that emerged in the present study and in those from Hari and Koivikko [7] has also been reported by Ro et al. [12] in subjects suffering from a temporoparietal junction lesion. These patients, like dyslexics in our study, did not show the interference flanker effect in the contralateral visual field (left side), but displayed a larger interference effect in the ipsilateral visual field (right side). This suggests not only that there was no interference when incongruent distractors were presented to the contralesional field but also that there was a ‘hyperorienting’ response towards the ipsilesional field [13]. In addition, a Smania et al. [14] study revealed that left-hemineglect and extinction patients with a right parietal cortex damage showed a paradoxical RT decrement in the RVF as target eccentricity increased.

To conclude, the present study as well as other recent works provide converging indications that dyslexia is associated with an asymmetrical distribution of spatial attention in the visual field. However, on the basis of our findings, we suggest that the major problem of dyslexic children might be an inability to suppress distracting information in the RVF.