PERGAMON

Neuropsychologia 39 (2001) 352–357

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

The gradient of visual attention in developmental dyslexia

Andrea Facoetti [a,b,*], Massimo Molteni [c]

[a] Dipartimento di Psicologia Generale, Università degli Studi di Padova, Padova, Italy
[b] Unità di Neuropsichiatria Infantile, Azienda Ospedaliera di Bergamo, Bergamo, Italy
[c] Unità di Neuropsicologia, Istituto Scientifico 'E. Medea' di Bosisio P., Lecco, Italy

Received 8 February 2000; received in revised form 27 September 2000; accepted 16 October 2000

Abstract

This study investigated the gradient of visual attention in 21 children, 11 children with specific reading disorder (SRD) or dyslexia and 10 children with normal reading skills. We recorded reaction times (RTs) at the onset of a small point along the horizontal axis in the two visual fields. In 70% of the cases the target appeared inside a circle acting as focusing cue and in 30% of the cases it appeared outside, allowing us to study the distribution of attentional resources outside the selected area. Normally reading children showed a normal symmetric distribution of attention. Indeed, RTs were directly proportional to the eccentricity of the target, and no visual field effect was observable. In contrast, children with SRD showed an anomalous and asymmetric distribution. The effect of the target eccentricity influenced RTs only when the stimulus was projected in the left visual field, whereas no effect was observable when the stimulus was projected in the right visual field. Findings allowed us to discuss the relation between this anomalous spatial distribution of visual attentional resources and dyslexia. To interpret the visual perceptual difficulties of children with SRD the hypothesis was made of a selective disorder of spatial attention (left inattention and right over-distractibility) related to a right parietal cortex dysfunction.

Keywords: Dyslexia; Specific reading disorder; Spatial attention; Attentional gradient; Right parietal cortex; Reaction time

1. Introduction

Although several studies have provided evidence for a phonological deficit in developmental dyslexia (e.g. [3]), many dyslexic children also show visual perceptual deficits (characteristic missequencing, omission and mislocating errors) when they attempt to read. These deficits may be attributed to defective visual information processing. Recent studies have revealed a deficit of the magnocellular (M) or transient visual system — responsible for processing information about the position of visual stimuli (e.g. [2,26]) — in some children with specific reading disorder (SRD) or dyslexia (for a review, cf. [38]). However, the specific mechanism through which the M-pathway deficit might cause dyslexia has not been described in full detail yet. The information processed by the M system ends in the parietal posterior cortex (PPC), which is an important supramodal selective spatial attention area [40].

The complex process of reading presupposes as an intrinsic mechanism the capacity to select a particular area of the visual field so as to process relevant information and filter irrelevant and distracting information [25]. This mechanism, also known as spatial attention, is generally defined as the operation that facilitates processing in a particular area of the visual field. Theoretically, spatial attention acts as filter to enhance the information from a target object (facilitation) or suppress the information from the distractor objects (inhibition), or operations that do both (for a review, cf. [8]).

Empirical evidence showed the difficulty of subjects with dyslexia to perform serial visual search tasks [5,23,41,44]. Furthermore, Casco et al. [6] found reading skills to be related to selective visual attention. Previous research indicated that poor readers have considerable difficulty attending to local details when such details are embedded in a more global structure [43].

* Corresponding author. Present address: Unità di Psicologia Cognitiva-Neuropsicologia, Istituto Scientifico 'Eugenio Medea', Via Don Luigi Monza 20, 23842 Bosisio Parini (LC), Italy. Tel.: +39-31-877581; fax: +39-31-877499.

E-mail address: afacoetti@bp.lnf.it (A. Facoetti).

0028-3932/01/$ - see front matter
PII: S0028-3932(00)00138-X

Brannan and Williams [4] showed that poor readers were unable to orient their attention using a peripheral cue. Rayner et al. [30] reported the case of a subject with developmental dyslexia who performed better than controls in reporting letters shown in parafoveal vision. The authors attributed that performance to a deficit of selective spatial attention present in dyslexics so that letters from words viewed parafoveally would interfere with the processing of concurrently fixated words. Also, Geiger and coworkers [20,21] reported that dyslexics showed a disability to suppress information from the periphery of the visual field, which would cause a deficit in foveal reading. Subjects with learning disabilities (LD) made more errors than controls on a selective attention task when distractor letters were adjacent to the target letter, thus suggesting that LD children are less able to narrow the focus of attention [32]. Facoetti et al. [15] proved that children with dyslexia have difficulty in sustaining attentional focusing which is necessary for effective processing of visual information. Lastly, in a recent study Facoetti et al. [13] suggested that the M pathway deficit might influence reading, thus hampering inhibition of lateral information. The authors used two experiments to show that children with dyslexia exploit a diffuse-distributed attention mode. More specifically, results of the first experiment proved that reaction times (RTs) of children with dyslexia vs. normally reading children are not influenced by eccentricity of the target. These data suggest that visual perceptual disorders, often associated with dyslexia, might be determined by a deficit of spatial attention, that is, a deficit of the mechanisms inhibiting laterally distracting information.

Nevertheless, much converging evidence indicated an asymmetric distribution of attention between the two visual fields in dyslexics. Hari and Koivikko [22] suggested that, as compared to the right visual field (RVF), dyslexics suffer from 'mini-neglect' in the left visual field (LVF). 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 [20,21]. Indeed, dyslexics exhibited a reduced interference effect in the LVF (left inattention), concomitant with a strong interference effect in the RVF (right over-distractibility) [16].

Therefore, the present study was aimed at further exploring a possible attentional visual field asymmetry in dyslexia. The objective was to determine whether the visual spatial attention deficit might be specific to a visual field or involve both visual fields. Indeed, the visual field factor and thus hemisphere factor had not been studied previously [13]. To this end, we investigated the gradient of visual attention in a group of normally reading children and in a group of children with SRD or dyslexia. The attentional gradient is defined as the increase in RTs with increasing eccentricity of the target from the attentional focus (e.g. [25,36]). The gradient that generates the shape of the RTs V curve is assumed to be represented in the location expectation domain [25], whose function may be instantiated by cells of the posterior parietal cortex that are responsive to the visuotopic location of objects (e.g. [28,29]). RTs recording at the onset of a white dot projected at different eccentricities from the fixation point allowed us to study the distribution of attentional resources inside the visual field. A focusing cue indicated the most probable location where the target would appear. As shown by many studies, the spatial cue-size allows one to regulate the dimension of the attentional focus (e.g. [7,12,14,39]). Another area of investigation was, therefore, the processing of visual information outside the attentional focus. Indeed, in some trials (30%) the target appeared outside the focusing cue at 6 or 9° from the fixation point along the horizontal axis.

2. Method

2.1. Subjects

We tested 21 children (16 males and 5 females). Inclusion criteria were: (1) full scale IQ > 85 as measured by the Wechsler Intelligence Scale for Children-Revised [42]; (2) no known gross behavioral or emotional problems; (3) normal or corrected-to-normal vision and hearing; (4) absence of drug therapy; (5) normal visual field; and (6) absence of attention deficit disorder with hyperactivity (ADHD) [1]. Eleven children (9 males and 2 females), mean age 12.1 years, were classified as dyslexic as their performance in oral reading of text, words and non-words was 2 S.D. below the norm on age-standardized Italian tests. The remaining ten children (7 males and 3 females), mean age 11.4 years, were normal readers. Children of the two groups were matched for age and IQ. Table 1 shows descriptive data of the two groups.

Table 1
Details (means and S.D.) of age, full IQ and reading abilities (*z* scores) of the two groups participating in the study

	Normal readers	Dyslexics	*P*
Age (years)	11.4 (2.1)	12.1 (1.7)	>0.05
Full IQ (WISC-R)	108 (8.5)	102 (12.2)	>0.05
Text errors	0.3 (0.5)	−3.1 (1.5)	<0.05
Text time	0.4 (0.3)	−3.6 (1.8)	<0.05
Words errors	0.6 (0.5)	−2.8 (2.1)	<0.05
Words time	0.1 (0.7)	−3.4 (1.9)	<0.05
Non-words errors	−0.2 (0.4)	−2.6 (2.1)	<0.05
Non-words time	0.4 (0.7)	−3.2 (1.8)	<0.05