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The time course of attentional focusing in dyslexic and normally reading children

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Abstract

A cue size procedure was used to evaluate the time course of visuo-spatial attention in dyslexic and normally reading children. When a stimulus target is presented inside a large cue vs a small cue the identification time is slower. In the present study two cue-target delays (100 and 500 ms) were used. Results showed a slower time course of attentional focusing in dyslexics vs normal readers. Indeed, dyslexics exhibited no cue size effect at a shorter cue-target delay (100 ms), while it was present at a longer cue-target delay (500 ms). In contrast, a cue size effect was found at both cue-target delays in normally reading children. These results further support the hypothesis of sluggish automatic focusing of visual attention in dyslexics. This impairment could be a consequence of a general magnocellular deficit demonstrated previously in dyslexics.

1. Introduction

Developmental dyslexia is a specific reading disorder in spite of normal intelligence and teaching, and regardless of any manifest sensory deficit. Recently, the hypothesis of a "temporal processing deficit" has become of central interest in the study of the etiology of dyslexia (for a review see Farmer & Klein, 1995). Accordingly, it has been suggested that the major problem in dyslexia would be a general impairment in the processing of rapid streams of multi-modal information (e.g., Hari, Renvall, & Tanskanen, 2001). The magnocellular (M) system is thought to be the neural basis underlying such deficit (for a review see Stein & Walsh, 1997). The information processed by the M system ends in the parietal posterior cortex (PPC), which is an important supra-modal selective spatial attention area (for a recent review see Vidyasagar, 1999). An impairment of this area would be responsible for a reduced ability to focus attention in the stimulated modality. There is evidence of an impaired focusing of attention (Facoetti, Paganoni, & Lorusso, 2000a) as well as of impaired automatic orienting (Facoetti, Paganoni, Turatto, Marzola, & Mascetti, 2000b) in dyslexic children and of a prolonged dwell time in dyslexic adults (Hari, Valta, & Uutela, 1999).

The present study was aimed at further investigating a possible sluggish attentional focusing in dyslexia. To this end, a cue size procedure was used (e.g., Castiello & Umiltà, 1990). Typically, participants are required to detect a central target presented inside a large or small cue. Smaller cues have been found to produce faster reaction times (RTs) than larger ones. Because attentional resources would be more concentrated in a narrow area than in a wide one, the smaller the focus, the higher the processing speed within its borders (e.g., Eriksen & St. James, 1986). The RT difference between the large and the small cues is defined as "*cue size effect*." In this case, focusing can be defined as the process by means of which the width of the attentional focus is adapted to the size of a given object. Recent studies provide electrophysiological evidence that attentional focusing modulates neural activity in early visual cortical areas (Luo, Greenwood, & Parasuraman, 2001).

The time course of attentional focusing seems to consist of two stages: an earlier stage, during which the

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focus is automatically triggered by the abrupt onset of the new object (i.e., automatic mechanism), and a later stage, during which the size of the focus is maintained in a controlled manner (i.e., voluntary mechanism) (Benso, Turatto, Mascetti, & Umiltà, 1998; Turatto et al., 2000).

2. Methods

2.1. Participants

Participants were 10 dyslexic children (mean and *SD*; age 12.5 ± 2.2 years, 3 females and 7 males) and 13 normally reading children (mean and *SD*; age 12.4 ± 2.2 years, 4 females and 9 males). Selection criteria were the following: (1) a full scale IQ higher than 85; (2) normal or corrected-to-normal vision and hearing; (3) absence of attention deficit disorder with hyperactivity; (4) no known gross behavioral or emotional problems; (5) normal teaching opportunities; and (6) right manual preference. Dyslexic children were considered as such if their performances in oral reading of a text (Cornoldi & Colpo, 1981), words, and nonwords (Sartori, Job, & Tressoldi, 1995) were 2 *SD*s below the mean on age-standardized Italian tests. The variables considered were speed and accuracy. There was no difference in IQ between the two groups (mean and *SD*; dyslexics' IQ was 97 ± 12 and normal readers' IQ was 105 ± 11).

2.2. Procedure and stimuli

Tests were carried out in a dimly lit room with an ambient luminance of 1.5 cd/m^2. Participants sat in front of a monitor (15 in. and with a luminance of 0.5 cd/m^2), with their heads positioned on a headrest. The eyes-screen distance was 40 cm. Fig. 1 shows the experimental setup. A small white dot (0.5° of visual angle) projected in the center of the screen served as fixation point. Two white circles of 2.5° (small cue) and 7.5° (large cue) were used as cues. The target was either a left-pointing arrow or a right-pointing arrow (1.5°), presented after a variable stimulus onset asynchrony (SOA 100- and 500-ms, randomly displayed) at the center of the cue. Stimulus luminance was set at 24 cd/m^2. Each trial began at the onset of the fixation point (accompanied by a 1000-Hz warning tone), which lasted for 250 ms and was followed by a 50-ms blank screen. After that, the cue appeared. After the SOA, the target was shown for 200 ms (see Fig. 1). Eye movements were monitored by means of a micro-camera system. Any eye movement 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: 60 trials with the large cue (30 trials for each SOA) and 60 trials with the small cue (30 trials for each SOA). Before the experiment began, participants made some practice trials until they felt confident with the task.

3. Results

Fig. 2 shows participants' RTs for target detection as a function of group, cue size, and SOA. Since error rates were very low (less than 6%), errors were not analyzed. Mean correct RTs were entered into a three-way analysis of variance (ANOVA) in which the within factors were cue size (large and small) and SOA (100 and 500 ms), whereas the between factor was group (normal readers and dyslexics). The main cue size effect was significant $F(1,21) = 15.18$, $P < .001$; the cue size effect

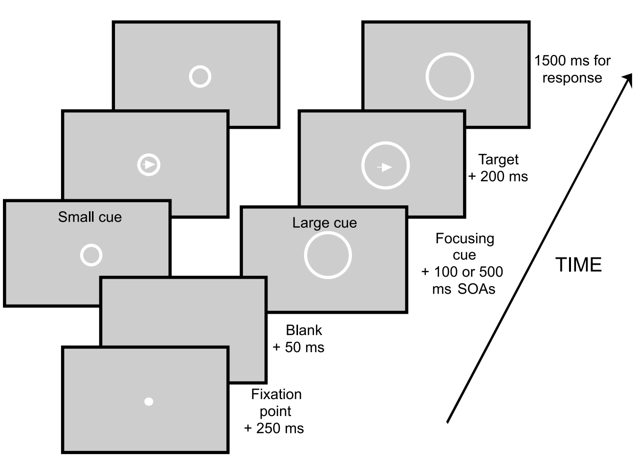

Fig. 1. Schematic representation of the display used in the experiment.

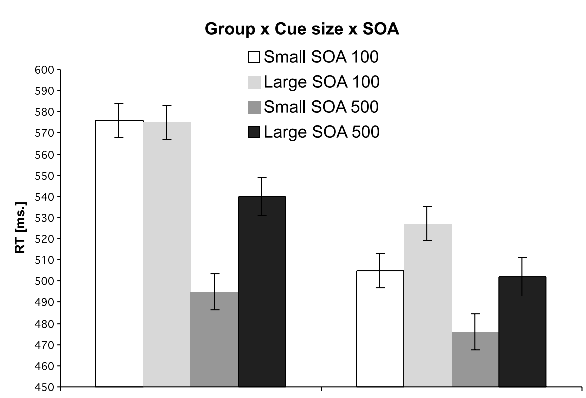

Fig. 2. Mean reaction times as a function of cue size (large and small), SOA (100 and 500 ms), and group (dyslexics and normal readers). Data show a slower time course of attentional focusing in dyslexics.

was 23 ms. The main SOA effect was significant $F(1,21) = 53.32$, $P < .0001$; the SOA or warning effect was 40 ms. Also, the SOA × group interaction was significant $F(1,21) = 7.4$, $P < .02$, which indicated that the two groups showed different warning time courses. Indeed, dyslexics' RTs were slower than normal readers' RTs, especially at the earlier cue-target delay (group difference at 100 ms SOA = 57 ms; group difference at 500 ms SOA = 27 ms; $P < .02$, suggesting a visual attentional capture deficit).

Further, the cue size × SOA × group interaction was significant $F(1,21) = 5.9$, $P < .05$, indicating a different time course of attentional focusing in the two groups. Planned comparisons showed that in normal readers the cue size effect was present at both the 100-ms SOA (22 ms, $P < .05$) and the 500-ms SOA (26 ms, $P < .02$), and the difference in cue size effect between the two SOAs was not significant (4 ms, $P > .05$). By contrast, dyslexics exhibited an abnormal time course of attentional focusing. In fact, a cue size effect was absent at the 100-ms SOA (1 ms, $P > .05$), but clearly present at the 500-ms SOA (45 ms, $P < .001$). On the basis of the present results it may be suggested that dyslexics display a sluggish and abnormal time course of attentional focusing.

4. Discussion

The RT pattern that emerged from this study can be interpreted in the light of the findings showing a temporal processing deficit in dyslexics (e.g., Farmer & Klein, 1995).

The M deficit hypothesis suggests that the disorder is a neurodevelopmental impairment of the M system. The M system seems crucial for efficient automatic capturing of visuo-spatial attention (Steinman, Steinman, & Lehmkuhle, 1997). Accordingly, Hari et al. (1999) showed that the dwell time of visual attention is longer in dyslexics than in normal readers. The spatial and temporal deficits found in dyslexic subjects seem to alter the automatic capture of visual attention.

In a previous study it was shown that dyslexics have a specific disability in orienting of attention triggered by peripheral cues at short SOAs (i.e., automatic mechanism) (Facoetti et al., 2000b). Furthermore, abrupt stimuli captured attention in both visual hemifields less effectively in dyslexics than in normal readers (Hari et al., 2001). These results suggest sluggish automatic orienting of visuo-spatial attention in dyslexia (see, Sluggish Attentional Shifting theory of dyslexia by Hari & Renvall, 2001).

However, Facoetti et al. (2000b), with an experimental paradigm based on simple RTs in a detection task, have shown that there is also a deficit in sustained focusing of visuo-spatial attention. The different temporal trends found in the two studies might simply be explained in terms of task difficulty, different perceptual load, and optimal allocation of processing resources (e.g., Eriksen and St. James, 1986).

As suggested by LaBerge and Brown (1989), the ability to suppress information flanking the attended area through attentional focusing would be crucial especially when unfamiliar words have to be identified. Also, the studies conducted by Geiger and Lettvin (1999) support the notion of a difficulty in suppressing information from the peripheral visual field (i.e., lateral masking).

A right parietal cortex dysfunction has been suggested as the neurological basis underlying the spatial and temporal attentional deficits in dyslexia (Facoetti & Molteni, 2001; Facoetti & Turatto, 2000; Facoetti, Turatto, Lorusso, & Mascetti, 2001; Hari & Koivikko, 1999; Hari et al., 2001).

To conclude, the present study provides converging indications that dyslexia is associated with sluggish spatial attention focusing. Moreover, sluggish attentional capture and focusing could be the cause of a multi-modal temporal processing deficit in dyslexia (Hari & Renvall, 2001).

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