Attentional deficit in dyslexia: a general or specific impairment?

Dorota B. Bednarek,1,2 C A David Saldana,2 Eliana Quintero-Gallego,3 Isabel Garcia,2 Anna Grabowska1 and Carlos M. Gomez3

1Laboratory of Psychophysiology and Nencki Institute of Experimental Biology, 3 Pasteur St., 02-093 Warsaw, Poland; 2Department of Developmental Educational Psychology, University of Seville, Spain; 3Department of Experimental Psychology, University of Seville, Spain

CA Corresponding Author: balbina@nencki.gov.pl

Received 25 April 2004; accepted 21 May 2004

DOI: 10.1097/01.wnr.0000134843.32260.bf

Dyslexic and control children were tested in a visuomotor attentional task, which provides independent measures of the alerting, orienting and conflict components of the attentional system. Our results show that dyslexics are impaired with respect to controls in the attentional conflict component (resolution of conflict of incongruent peripheral information), while the alerting and orienting components remain preserved. It excludes an overall attentional impairment and points to more specific attentional processing difficulty i.e. distributed attention strategy. Generally, results of dyslexic boys are within the range of the control group, while reaction times of dyslexic girls are significantly slower than that of all other groups.

Key words: Attention; Dyslexia; Executive control; Flanked stimuli; Gender differences; Magnocellular channel

INTRODUCTION

Reading disability (dyslexia) is defined as a specific reading and writing disorder despite normal intelligence and teaching, and in the absence of any sensory deficit [1]. Despite 100 years of research on its characteristics, and accumulation of impressive amount of data, the efforts at uncovering the neurological base of reading disability appear unsatisfactory.

Numerous studies have shown that attention deficits may accompany dyslexia. Dyslexic children are easily distracted and exhibit difficulty in maintaining attention on a single task for a long period of time [2]. Coincidence of attention deficit and hyperactivity disorder (ADHD) and reading disability has been observed [3]. Dyslexics have also been shown to be impaired in visual search [4], in attending to stimuli located centrally, rather than peripherally [5], in suppressing interfering information from the periphery [6], in narrowing the focus of attention [7] and in using peripheral cues to automatically orient attention [8].

In visual perception attention serves to filter the visual information, which leads to selection of objects or object’s features to be processed at a given moment. Posner has proposed the existence of three independent components of visual attention: alerting, orienting, and conflict control [9]. Attention alerting can be defined as preparation to detect a target [10] and can be assessed by using warning signals prior to target’s presentation. Attention orienting facilitates the perception in a specific location in the field [11] and is usually assessed using a cue indicating the locus of target presentation. One of the main properties of conflict control is to suppress irrelevant or conflicting information from other locations [12] and may be measured using flanker stimuli surrounding the target.

It is not clear whether dyslexics suffer from an overall attentional difficulty, or are affected by more specific attention deficits. The goal of this study was to assess alerting, orienting and conflict components of attentional processing using visuomotor attentional task in disabled and normal readers.

MATERIALS AND METHODS

Subjects: Nineteen dyslexic and 22 control children, matched in IQ, were selected from a school children population (control group mean age 9.7 years, s.d. 90 days; dyslexic group mean age 9.7 years, s.d. 98 days). The dyslexic group included 11 boys and 8 girls and the control group 11 boys and 11 girls.

All of the participants were native Spanish speakers and met the following criteria: normal or above normal intelligence, standard educational opportunities, normal or corrected to normal visual acuity, no gross sensory or attention deficits, no gross behavioural problems, no history of neurological disease. The study was carried out in accordance with the guidelines of the Declaration of Helsinki.

IQ was assessed with the Raven Progressive Matrices [13]. The mean (± s.d.) IQ in the control group was 107.99 ± 10.39 and in the dyslexic group 107.17 ± 10.40. To assess the children’s reading and writing skills selected trials from PROLEC [14] and PROESC [15], both standardized tests validated with Spanish school-aged children, were used. The final sample of the dyslexic group included children
showing both writing and reading disability, whereas performance in the control group was adequate to the age of the children. The mean scores in reading were: control group mean errors 1.7±1.3; reading time 64.5±10.8 s; dyslexic group mean errors 5.9±3.5; reading time 115.5±28.2 s. The mean scores in writing were: control group mean errors of arbitrary spelling words 2.9±2.0, and rule-governed spelling words 2.0±1.5; dyslexic group respectively 11.4±2.8, and 8.9±2.3.

Stimuli and procedure: The Attentional Network Test [16] was used to present the stimuli on a TFT 14 inch monitor. The refresh rate of the screen was 66.7 Hz. Luminance and contrast of the monitor were set at their maximum values. The experiment was carried out individually, took on average 20 min (its length was established in a pilot study to match the children’s ability to concentrate). The subjects were first acquainted with the task, performed some practice trials, and then the measurements started.

Children sat at a distance of 43 cm from the monitor. A black fixation cross (0.39° of visual angle) was constantly presented in the centre of a light blue-green background. The target had the shape of a yellow fish 1.6° and appeared 1° above or below the fixation cross. The subjects’ task was to indicate whether the fish’s head was oriented toward the left or right by pressing the keys on a computer mouse with a corresponding finger (index or middle) of the preferred hand (right in all cases). Subjects were asked to maintain the fixation on the cross throughout the task and to respond as quickly and accurately as possible.

There were two main experimental factors: warning and flanker. In the warning, after the first fixation period (400–1600 ms), a warning stimulus (an asterisk subtending 0.66°) was presented for 150 ms, and switched off 450 ms prior to the target presentation. The factor of warning had 4 levels: (A) no warning, (B) central warning (the warning asterisk located in the place of the fixation cross), (C) double cue warning (two asterisks appearing simultaneously above and below the fixation cross, at the usual target locations), (D) orienting cue warning (a single asterisk presented in the location where the target was going to appear).

In the flanker, the target fish was accompanied by two additional fish stimuli to the left and the right of it. The five fish were located along a horizontal line (subtending 11°) and were separated by 0.26° from each other. The factor of flanker had 3 levels: (A) no flanker, (B) congruent flanker (the target oriented congruently with flanking stimuli), (C) incongruent flanker (the opposite orientation of the target and flanking stimuli).

The number of presentations above or below the fixation cross, as well as target orientation to the left or to the right was balanced. The warning and flanker factors were combined with each other, providing 12 types trials (i.e. no warning, no flanker; no warning, congruent flanker; no warning, incongruent flanker, etc.).

The target presentation continued until the subject responded or a maximum of 1700 ms had elapsed. When the response was successful, visual and auditory positive feedback was provided in all measurements to maintain subjects’ interest in the task (the target fish smiles and some bubbles come out of its mouth accompanied by a ‘woohoo’ sound!). Incorrect responses were followed by an auditory negative feedback (pure tone of low frequency). Reaction times defined as the time between the target onset and the subject’s response, as well as response accuracy, was recorded in each trial.

RESULTS

Reaction times and accuracy in dyslexic and control groups: Incorrect responses, as well as anticipatory reaction times (<300 ms) were excluded from the analysis. The mean number of correct responses and mean reaction times were computed for each subject for each of 12 types of trials. Series of statistical analyses were performed separately for response accuracy and reaction times.

First, two two-way ANOVAs were performed for the no flanker, no warning trial (one of the 12 types of trials), with the factor of group (control vs dyslexic) and gender (male vs female). No significant group or sex differences were found in accuracy or reaction times. It shows that the two groups did not differ in terms of their general perceptual abilities, in their capacity to distinguish between their right and left side, or in carrying out this decision.

Response accuracy and reaction times were then analysed separately with two four-way MANOVAs (repeated measures). Group (dyslexic vs control) and gender (male vs female) were the main between subject factors, while flanker (no flanker, congruent, and incongruent) and warning (no warning, central warning, double warning, orienting warning) were the main within subject factors. Analysis of the accuracy data revealed a significant group effect (F(1,37)=7.51; p < 0.009), showing subtle, but systematically lower accuracy in dyslexics compared to controls (98.8% of correct responses in the control group, and 97% in the dyslexic group). The main effect of flanker (F(2,74)=9.36; p < 0.0001) reflected decrease of accuracy in the incongruent flanker condition in relation to the congruent one in both groups. Interaction between group and flanker (F(2,74)=5.53; p < 0.005; Fig. 1a) revealed that dyslexics’ response accuracy was significantly lower than that of controls only in the incongruent flanker condition (LSD test of planned comparison).

Analysis of reaction time data revealed significant effects of flanker (F(2,74)=82.92; p < 0.0001), and warning (F(3,111)=51.48; p < 0.000). No main group effect was obtained. Generally, reaction times in the no flanker condition were the shortest, while the reaction times in the incongruent flanker condition were the longest. Warnings produced significant differences in reaction times: the fastest responses were detected in the orienting condition,
followed by double and central warning, with the slowest in the no warning condition.

The interaction between group and flanker was at the level of trend \((F(2,74) = 2.85; p < 0.06; \text{Fig. 1b})\). Since it was in line with the significant interaction found for the response accuracy, post-hoc comparisons were performed. They showed significant group differences for all flanker conditions, with the most pronounced difference for the incongruent flanker (on average, reaction times in the dyslexic group were 78 ms longer than in the control group).

Interestingly, there was a significant interaction between group and gender \((F(1,37) = 5.97; p < 0.019; \text{Fig. 2})\). The post-hoc analyses revealed that reaction times of dyslexic girls were significantly slower than those of control girls \((p < 0.01)\) and dyslexic boys \((p < 0.02)\). Control and dyslexic boys did not differ from each other (surprisingly, the average reaction times in dyslexic boys were even slightly shorter then in the controls).

**Alerting, orienting and conflict components of attention:** Following the Posner model, the attentional effects of alerting, orienting, and conflict were computed [9]. The alerting effect for each person was computed by subtracting the mean reaction time of the double warning condition (the mean of three trials corresponding to three levels of flanker) from the mean reaction time of the no warning condition (the mean of three trials corresponding to three levels of flanker). The orienting effect was computed similarly, by subtracting the mean reaction time of the orienting condition from the mean reaction time of the central warning condition. The conflict effect was computed by subtracting the mean reaction time of the congruent flanker condition (the mean of four trials corresponding to four levels of warning) from the mean reaction time of the incongruent flanker condition (the mean of four trials). These data were then analysed with three separate two-way ANOVAs, in which group (dyslexic vs control) and gender (male vs female) were the main factors. A significant group effect was obtained, for conflict component showing higher discrepancy between incongruent and congruent condition (due to relative reaction time prolongation in the incongruent condition) in dyslexics than in controls \((F(1,37) = 6.09; p < 0.018)\). Analysis for the alerting effect revealed an interaction between group and gender \((F(1,37) = 4.55; p < 0.039)\). In the control group, the warning prior to the target presentation reduced reaction times to a larger extent in boys, while in the dyslexic group, this happened, surprisingly, in girls. For the orienting component, a significant gender effect was obtained \((F(1,37) = 6.55; p < 0.014)\). Indication of the exact target presentation helped to relatively decrease reaction times in girls more than in boys.

As the general differences in the mean lengths of reaction times in different groups could influence the results of computed effects of different attention components, the additional analyses were carried out on standardised data using the longest mean reaction time for the no warning, incongruent flanker trial as 100% for each subject and computing the respective percentage of this value for the reaction times in other experimental trials. The results obtained on the standardised data were congruent with those already described (this is why we do not repeat them here), except for the alerting effect, in which the group × gender interaction no longer resulted significant, although it remained at the level of trend \((F(1,37) = 3.41; p < 0.072)\).

Finally, correlations between reading and writing scores and reaction times for all experimental conditions, and the three types of attentional effects, were computed. Positive relation between reading time \((r = 0.44)\), the number of errors in reading \((r = 0.34)\), and the number of errors in writing \((r = 0.47\) and \(r = 0.42\), respectively) were found for the conflict effect.

**DISCUSSION**

The present experiment involving children with reading difficulties yielded a few important results. First, no group differences were obtained for the no flanker, no warning trial either in response accuracy or in reaction times. This shows that the two groups did not differ in terms of their general perceptual and attentional abilities, in their capacity to distinguish between their right and left side, or in carrying out this decision. Thus, any differences observed in other trials should be attributed to different interfering or enhancing effects of experimental conditions. Second, the predicted general effects of flanker and warning were obtained for reaction times and partly for the response accuracy data, corroborating previous findings obtained in the same experimental paradigm [16], and are in line with the Posner’s model [9]. Third, our data show a specific disability of dyslexic subjects to narrow the focus of attention and to inhibit the interference of the flanker stimuli. It manifests itself in their worse reaction times and accuracy performance in incongruent flanker condition compared with controls and in their larger effect of conflict, which is the only measure correlating with reading and writing scores. These findings together with the lack of deficits in alerting and orienting effects point to a specific, not global, attentional deficit in dyslexia. Finally, through most analyses the results are systematically different for girls than for boys.

Although, the group differences for the incongruent flanker condition, and the conflict effect provide the evidence for specific attention deficit, the interpretation of these data is not straightforward. These results can be interpreted as an executive control deficit as the inhibition of distracting information is required. Interestingly, other studies also report various deficits in executive functions in dyslexics showing that they perform poorly on tasks...
Neuropsychological Underpinnings of the Deficit in Attentional Processes

D. B. Bednarek ET AL.

Neuroreport

Vol 15 No 11 6 August 2004

1790

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

requiring inhibition of distracting information (e.g. the group-embedded figures test [17], Stroop test [18]). On the other hand, as suggested by Facetti [5], our data as well as frequently reported dyslexics anomalies in peripheral vision can result from the tendency to analyse the visual pattern globally rather than in a focused mode. This distributed attention may be related to deficient magnocellular channel (one of the main systems of parallel transmission of visual information) found to be altered in many dyslexics subjects [19]. The magnocellular channel has a strong projection to the posterior parietal cortex, a structure dealing with many aspects of attention [20]. As stimuli that predominantly capture visual attention, preferentially trigger the magnocellular pathway [21], it is possible that an attentional feedback (attentional light spot which selectively reinforces neuronal responses for the attended location) arises from the posterior parietal cortex thanks to the fast input from the magnocellular channel [22]. Interestingly, some data suggest that this is the magnocellular channel responsible for the identification of flanked stimuli [23]. Summing up, on the base of the behavioural study we are not able to determine the neurophysiological underpinnings of the deficit in the conflict component we have found. The cause may be in the prefrontal cortex (associated with executive functions [24]), posterior parietal cortex (related to attentional processes), or in the magnocellular channel of visual system. The future studies should probably concentrate on the one hand on the specification of attentional problems in dyslexia, as we show that they are not general, and on the other hand, to aim at joining behavioural and structural or functional studies.

Finally, it is worth to underline the confusing effect of gender in different aspects of our data. Generally, the effect of gender is different in controls, where girls have faster reaction times than boys, and in dyslexics, where girls are substantially slower. Curiously, general results of dyslexic boys are located within the range of the control group (they are slower than control girls, but slightly faster than control boys), while reaction times of dyslexic girls are significantly slower than that of all other groups. On the other hand, the best effect of alerting was observed in dyslexic girls, and the biggest effect of orienting was found for girls, including dyslexics. It seems that dyslexic girls, however generally slower than others, are relatively the most able to use additional cues (warning that the target is going to be exposed, and cueing where it is going to be presented) to capture their attentional resources and to facilitate the perception and image analysis.

Conclusions

Although many studies show attention deficits in children with reading disability, our data point to specific difficulties and not an overall attentional impairment. The dyslexics we tested do not present alterations of alerting and orienting component of attention, but are impaired in the executive function (resolution of conflict of incongruent peripheral information), which correlates with their poor results of reading and writing. This result may be interpreted as caused by a distributed attention (the tendency to global rather than focused analysing) or as an executive function deficit. Our data also strongly suggest that the different aspects of attention deficits in dyslexia depend on the sex of the subjects.

References


Acknowledgements: We would like to thank Dr M.I. Posner and Dr J. Fan for the permission to use the Attentional Network Test to data collection.