INTRODUCTION

Research is indicating a role of visual attention in dyslexia. Studies have shown that individuals with dyslexia have difficulties maintaining attentional focus (Facoetti et al., 2000a), orienting attention (Buchholz and Aimola Davies, 2005; Facoetti et al., 2003; Roach and Hogben, 2004) and shifting attention (Buchholz and McKone, 2004; Iles et al., 2000), in addition to executive function deficiencies related to distractor inhibition and event sequencing (Bednarek et al., 2004; Brosnan et al., 2002).

However, because most previous studies have examined single attentional functions in dyslexia, it remains unclear whether individuals with dyslexia have a general attentional difficulty, or a more specific deficit.

The separate attentional effects of alerting, orienting and executive control (as proposed by Posner & Peterson, 1990) may be assessed using a single test (Attentional Network Test, ANT) which combines spatial cueing with a flanker task (Fan, McCandliss, Sommer, Raz & Posner, 2002).

Alerting is defined as preparing and maintaining a state of readiness to detect a stimulus, orienting selects particular sensory information by shifting and reducing the attentional focus and executive control is the process of deciding about the relevance of presented stimuli to the task requirements.

Studies examining attentional function in dyslexia have generally relied on comparisons between a small group of individuals with dyslexia and a control group. These comparisons do not always consider the nature and distribution of individual differences within the groups. As such, the scores of a small number of individuals who perform poorly can contribute unduly to overall mean differences between the groups (McArthur and Hogben, 2001; Roach et al., 2004).

Aim

In this study, the individual performances of five cases of adult dyslexia (ADys) on a spatial cueing task were compared to a control group. The aim was to investigate the efficiency of the attentional effects of alerting, orienting and executive control in these individuals.

Method

Control group: 11 paid adult volunteers.

ADys: 5 cases who had received a diagnosis of dyslexia as children and currently met the criteria of dyslexia as determined on the Dyslexic Adult Screening Test (DAST: Fawcett & Nicolson, 1998).

Experimental Measures

The Attentional Network Test (ANT; Fan et al., 2002) combines spatial cueing with a flanker task to examine the separate attentional effects of alerting, orienting and executive control (see Figure 1). The task is to press one of two buttons on a keyboard to indicate the direction of a centrally–positioned arrow, presented either directly above or below a fixation cross. This arrow may be accompanied by flanker arrows pointing either in the same direction or in the opposite direction.

Attentional performance is measured by how response times are influenced by alerting cues, spatial cues and flankers.

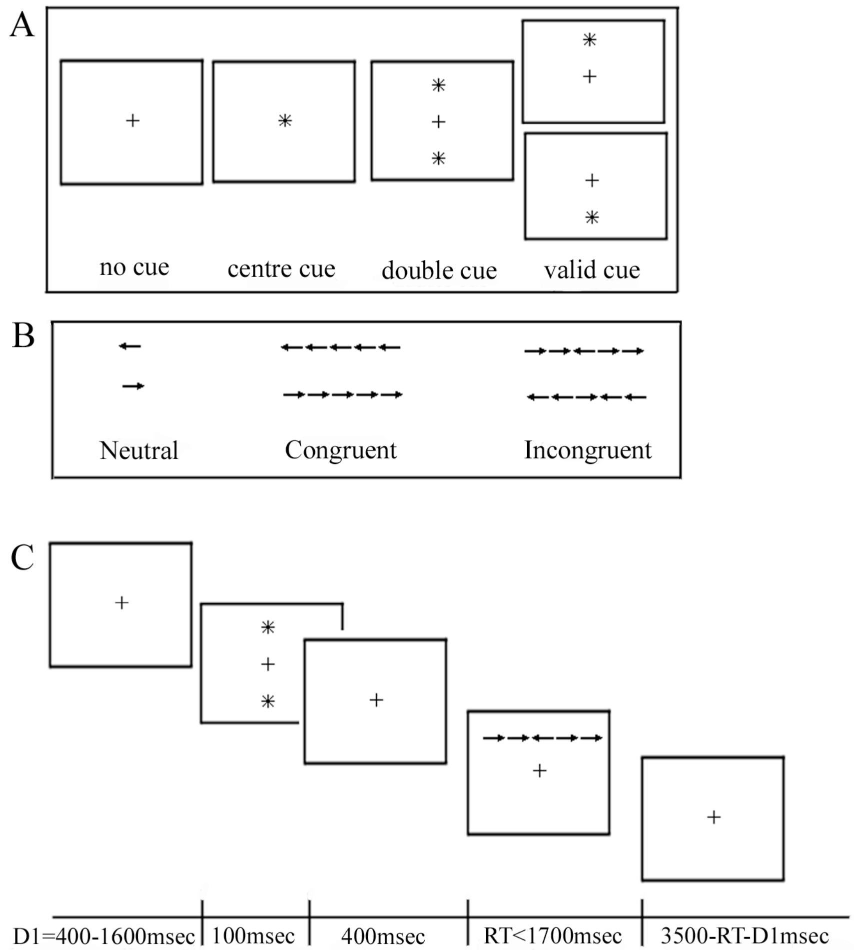

Figure 1. *Experimental procedure: Cueing conditions (A), flanker conditions (B). Example trial with a double-cue and an incongruent flanker(C).*

Results

Trials with RTs less than 300 msec or more than 2.5 standard deviations from the individual's mean were excluded for the analysis of accuracy. Incorrect trials were further excluded for RT analysis. This resulted in less than 1% of data being removed for any individual. In this study we have employed a modified t–test (Crawford and Garthwaite, 2002) when comparing ADys cases and control group means to reduce the likelihood of Type I and Type II error.

Preliminary Analysis

Condition: neutral–flanker and no–cue condition

Factors: arrow direction (right and left) and target location (above centre and below centre).

No significant main effects or interactions were found for the control group or any ADys case ($ps > 0.05$), indicating no differences in general perceptual abilities (e.g., distinguishing right from left). In subsequent analyses, data were pooled across arrow direction and target location.

Accuracy Score Analysis (see Figure 2)

Main effect

Flanker

- A significant effect for the control group ($F(2,20) = 4.84$, $p < 0.02$).
- This indicated a decreased accuracy between the congruent (99%) and incongruent (97%) conditions ($p < 0.05$).
- Also significant for each ADys case ($ps < 0.05$).
- For all ADys cases (except GM) there was a decreased accuracy in the incongruent–flanker condition in relation to the neutral–flanker and congruent–flanker conditions. For case GM, accuracy was reduced for both congruent–flanker (98%) and incongruent–flanker (98%) conditions relative to the neutral–flanker (100%) condition.

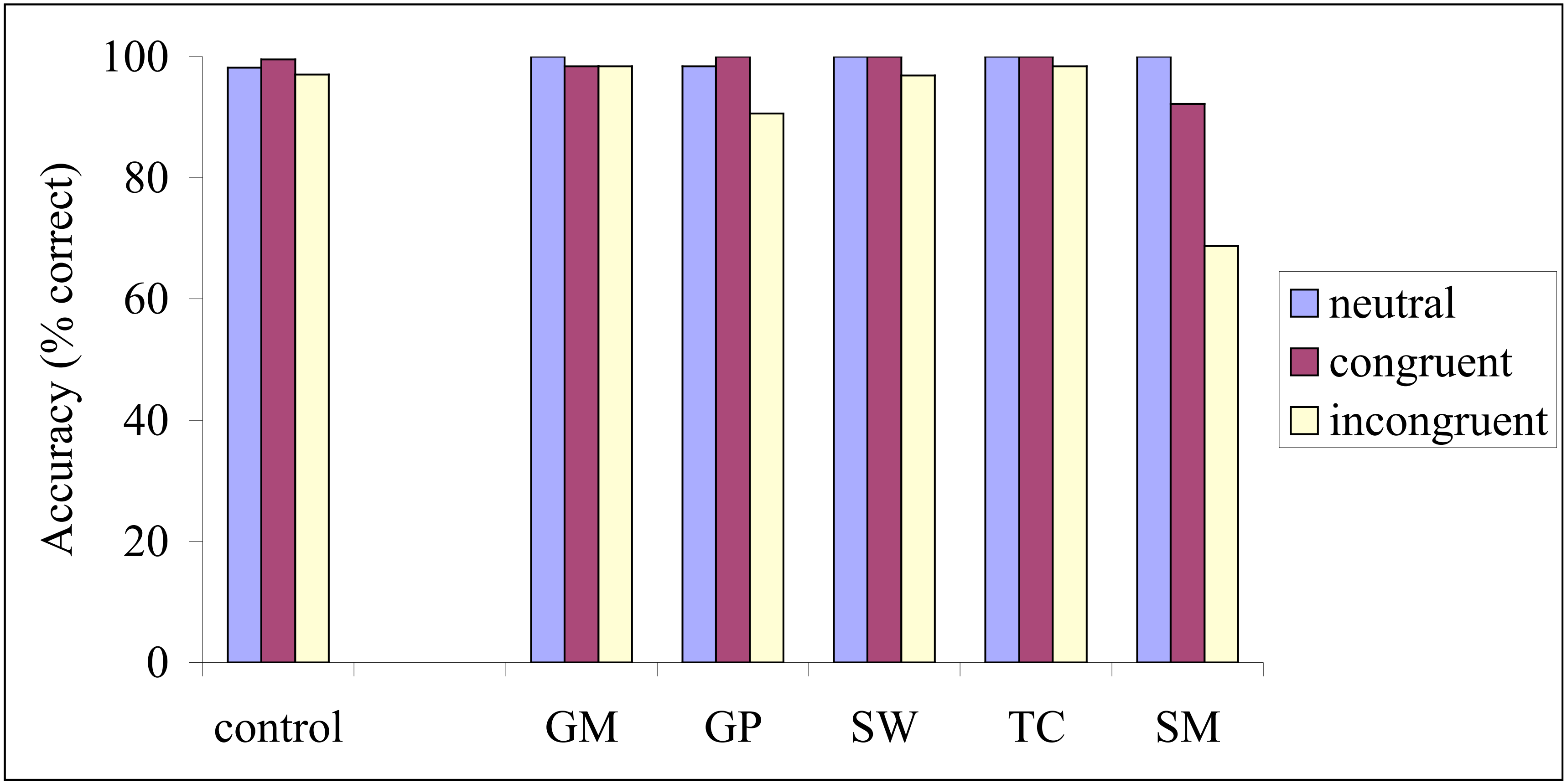

Figure 2. *Mean response accuracy for the control group and each ADys case for the three flanker conditions*.

Response Time Analysis (see Figure 3)

Main effects:

Flanker

- A significant effect for the control group ($F(2,20) = 136.35$, $p < 0.001$)
- Also significant for each ADys case ($ps < 0.001$).
- The fastest RTs occurred in the neutral–flanker condition and the slowest RTs were in the incongruent–flanker condition.

Cue type

- A significant effect for the control group ($F(2,20) = 37.3$, $p < 0.001$). The fastest RT occurred in the spatial–cue condition followed by double–cue, centre–cue and no–cue condition.
- Also significant for each ADys case ($ps < 0.05$). The fastest RT was detected in the double–cue condition.

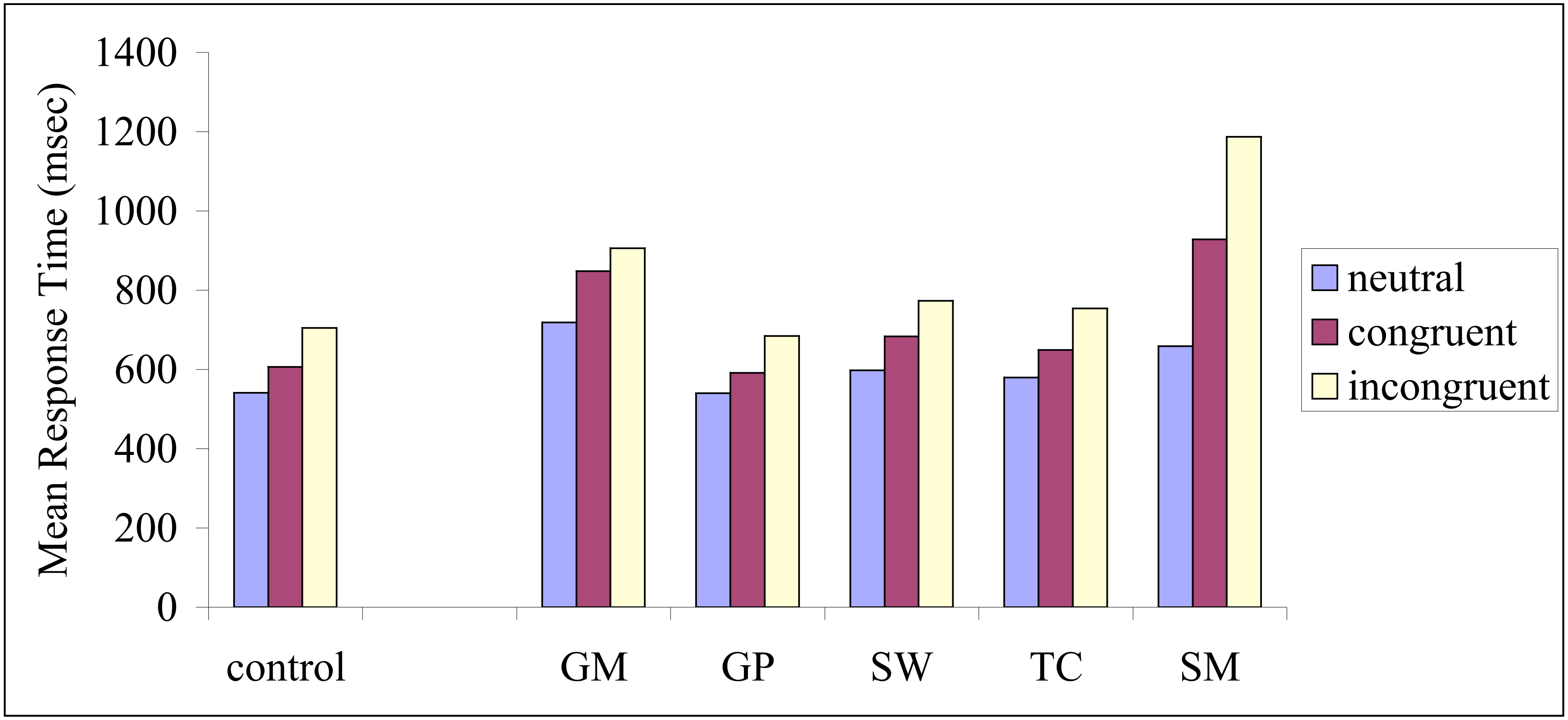

Figure 3. *Mean response time results for the control group and each ADys case for the three flanker conditions.*

Assessing Attentional Networks – Control Group (see Figure 4)

- Mean alerting effect: 33 msec (sd = 11 msec), calculated by subtracting the mean RT of the double–cue condition from the mean RT of the no–cue condition.
- Mean orienting effect: 34 msec (sd =12 msec), calculated by subtracting the mean RT of the spatial–cue condition from the mean RT of the centre–cue condition.
- Mean executive control effect: 99 msec (sd = 36 msec), calculated by subtracting the mean RT of the congruent–flanker condition, summed across cue types, from the mean RT of the incongruent–flanker condition.

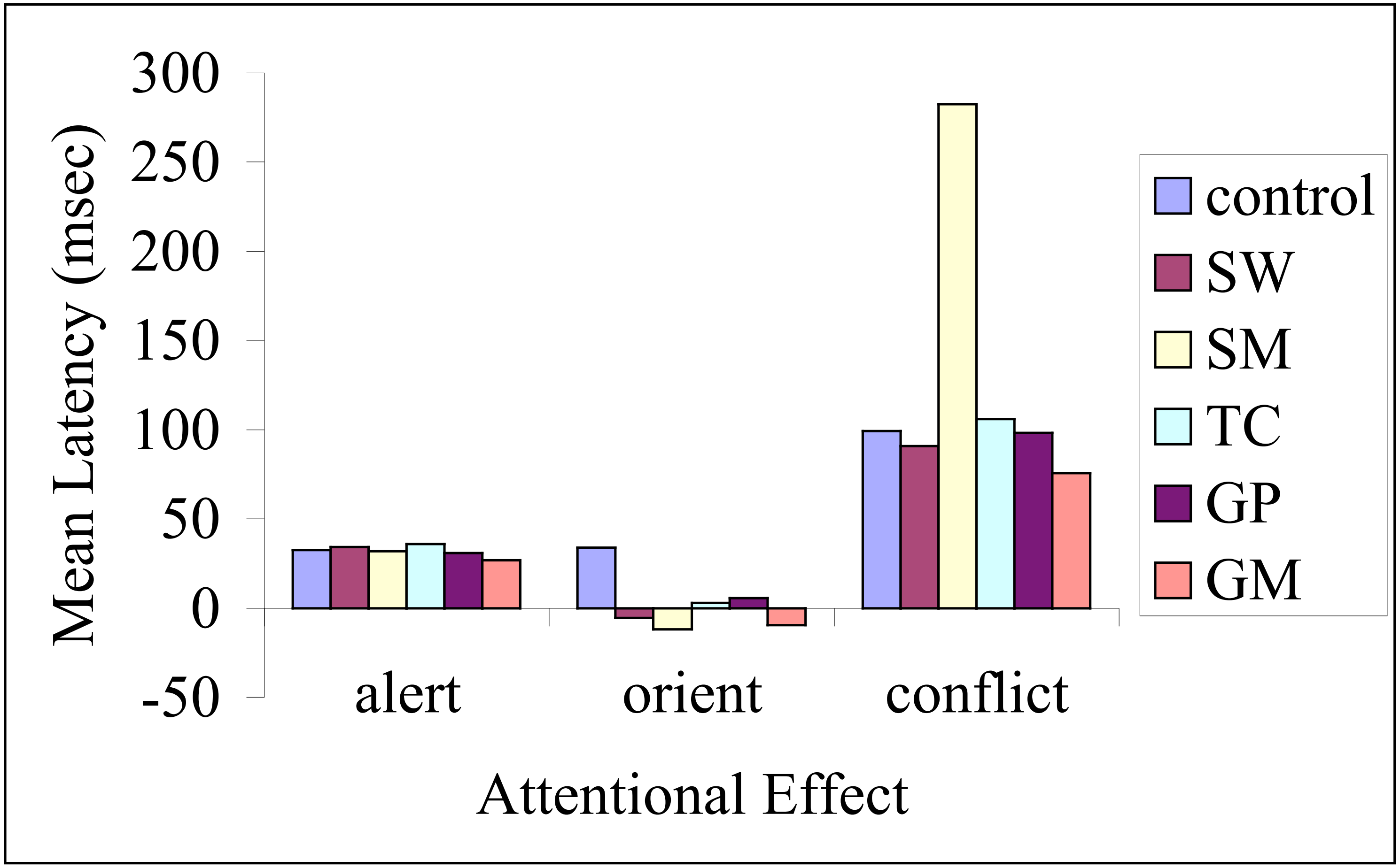

Figure 4. *Mean latency for each attentional effect for the control group and five ADys cases.*

Assessing Attentional Networks – ADys cases (see Figure 4)

<u>Comparisons with the control group</u>

- Mean alerting effect: not significantly different ($ps > 0.05$).
- Mean orienting effect: significantly different ($ps < 0.05$).
- Mean executive control effect: Only one ADys case (SM) required significantly longer RTs to resolve conflict compared to the control group ($p < 0.001$).

<u>Follow-up t-tests for each ADys case</u>

- RTs to centre-cue targets were no different to RTs to spatial–cue targets for all cases ($ps > 0.05$).
- RTs to spatial–cue targets were significantly longer than RTs to double–cue targets for all cases ($ps < 0.05$).

Discussion

The ADys cases in this study showed that while the alerting effects of attention appeared intact, and only two cases, GP and SM, showed a significant deficit in executive control, there were specific orienting difficulties evident for all. In addition, the overall response times of all ADys cases were generally slower than the control group.

The findings are consistent with previous dyslexia research (Facoetti et al., 2000a; Iles et al., 2000; Roach and Hogben, 2004), and suggest an impairment of visual attention in these individuals which is specific to the orienting of attention.

Two accounts

1) A Sluggish Attentional System account (Hari & Renvall, 2001)

According to the SAS theory, the impaired processing of rapid stimulus sequences shown by individuals with dyslexia, arises due to sluggish attentional capture (i.e. a deficit in stimulus engagement and disengagement) and prolonged attentional dwell time.

Thus, if the SOA provided in this study is not long enough to allow attention to be engaged, then no observable difference between response times for the central–cue condition and the valid–cue condition would be expected. Hence, no effect of orienting.

However, it is difficult to explain the double–cue advantage (for target detection) based on this theory.

2) An Attentional Focus Account (e.g., Facoetti et al., 2000b)

According to the AFA account, the individuals with dyslexia distribute their attention over a larger focus area than the control group, resulting in generally slower RTs in individuals with dyslexia.

An inverse relationship between focus size and processing efficiency has been demonstrated in individuals without dyslexia (Castiello and Umilta, 1990; Turatto et al., 2000). As focus size gets smaller, attentional resources become more concentrated within its border and processing speed becomes faster.

Reducing attentional focus size allows distracting information to be minimized during reading, and therefore local word information (letters) can be processed quickly and accurately. If the size to which the attentional focus can be reduced is both limited and dependent on location in space, then the slowed processing of visual information and the greater confusion across words often reported in individuals with dyslexia (Geiger and Lettvin, 1999) is clearly explained.

Studies examining spatial cueing in dyslexia (Bednarek *et al*., 2004; Facoetti *et al*., 2000b; Roach & Hogben, 2004), indicate that the cue size necessary to reduce the size of attentional focus varies across the visual field. That is, the size that the attentional focus can be reduced to, and maintained at, appears limited by spatial location.

For example, Roach and Hogben (2004) reported similar findings to this study in that there was a decreased effect of orienting for their individuals with dyslexia with a cue size less than 0.5°of visual angle (VA) at locations close to fixation (4°).

Bednarek and colleagues (2004) examined attentional effects using the ANT, however they used a cue size greater than 0.5° and found that attentional focus was reduced. This was indicated by the finding of no significant difference in orienting performance between their group of dyslexia children and a control group.

Facoetti and colleagues (2000b) reported that although children with dyslexia showed the usual RT advantage for a small cue size (2.5° faster than 7.5°) at a short SOA, this advantage was lost at a longer SOA. This suggests that the children with dyslexia were capable of focusing on both cue sizes presented peripherally (10°), but had a difficulty in maintaining the smaller focus.

Finally, in the present experiment, the double cue to single cue advantage suggests that two points of reference were able to provide a means for reducing the attentional focus more than the single point of reference.

We are currently carrying out a systematic investigation of the effects of cue size, cue position and SOA on orienting ability in dyslexia.

Conclusion

In this study, impairment of the orienting component of attention was demonstrated by all ADys cases, but the attentional alerting and conflict components were generally intact. These findings suggest a specific attentional processing deficit that is best interpreted in the framework of a distributed attention model of dyslexia (e.g., AFA), that is, the tendency to engage in distributed rather than focused analysis of stimuli.

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