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No differential attentional blink in dyslexia after controlling for baseline sensitivity

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ABSTRACT

Previous research has associated a prolonged attentional blink (AB) with adult dyslexia [Hari, R., Valta, M., & Uutela, K. (1999). Prolonged attentional dwell time in dyslexic adults. *Neuroscience Letters, 271*, 202–204]. The AB represents a limitation in temporal information processing, estimated as the time interval between two targets necessary for accurate recall (e.g., [Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18*, 849–860]). Utilizing single- and dual-target procedures, this investigation extended upon previous research. When controlling for baseline sensitivity as estimated in the dual-target condition, there was no significant difference between dyslexic and control performance. Finding no evidence of a single-target task difference or prolonged AB effect in dyslexia, it is suggested that baseline sensitivity differences relate to difficulties with task demands in dyslexic readers.

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1. Introduction

As many as 10% of the population are unable to read as well as might be expected for their level of intelligence and education, a pattern of behaviour which is labelled specific reading impairment or dyslexia (Snowling, 2000). A widely accepted explanation of a proximal mechanism which underpins reading problems is phonological awareness. In dyslexia it is considered that poor phonological awareness leads to difficulties when speech sounds or phonemes need to be mapped to orthographic representations (e.g., Heath, Hogben, & Clark, 1999; Schulte-Koerne, Deimel, Bartling, & Remschmidt, 1999; Snowling, 2000; Wagner & Torgesen, 1987). Despite evidence suggesting a causal relationship between phonological awareness and dyslexia (Bradley & Bryant, 1983), it is unclear what might underlie these problems. A particular balance (or imbalance) of cognitive abilities, a product of genetic makeup, may be a distal underpinning which leads to proximal and observable behaviours such as poor phonological awareness which in turn leads to reading problems. An alternative account suggests that difficulties with temporal processing may be proximally related to reading problems (Hari, Valta, & Uutela, 1999; Merzenich et al., 1996; Tallal, 1980, 1984; Tallal, Miller, Jenkins, & Merzenich, 1997). This research examined the suggestion that sluggish attentional shifting as determined in the *attentional blink* (AB) is associated with dyslexia.

The AB is measured in a rapid serial visual presentation (RSVP). This involves the sequential presentation of stimuli, commonly letters or numbers, in the same spatial location. Items are commonly presented every 100 ms. Temporal processing can be examined by asking observers to report the presence or identity of target stimuli within the RSVP and the interference associated with temporal proximity can be investigated by varying the number of items presented between two targets. A curious phenomenon has been noted when observers are required to attend to two targets presented within a time interval of 500 ms. Within this time interval, accuracy of reporting the second target (T2) may be severely reduced relative to when the first target (T1) is either not present or is ignored. This effect has been labelled the AB, analogous to an eye-blink in that new information can not be processed when the eye is closed (Raymond, Shapiro, & Arnell, 1992). More recently, evidence suggests that it may be better considered as a *blink* in conscious perception as electrophysiological enquiries indicate that T2 is recognised but fails to be processed at a level required for conscious report (McArthur, Budd, & Michie, 1999; Vogel, Luck, & Shapiro, 1998). A commonly accepted explanation of the AB relates to capacity limitations: until a limited pool of resources have processed T1 they are not available to process T2 (e.g., Chun & Potter, 1995). In order to report on the appearance of T1, target information must be processed to a level at which a robust representation is created in short-term memory and is available for recall. This is referred to as T1 consolidation. On average T1 consolidation requires approximately 500 ms and during this period processing of T2 is degraded. In dyslexia, it has been suggested that the AB effect may be prolonged to a duration of 700 ms (Hari et al., 1999).

Hari et al. (1999) compared dyslexic and normal readers' performance in an AB task initially employed by Raymond et al.

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(1992). Participants were required to identify a white letter (T1) and detect a letter X (T2) within an RSVP of black letters. Hari et al.'s findings suggested that dyslexics demonstrate a larger AB than control readers: detection of T2 was poorer (deeper AB) and performance took longer to recover (longer AB duration). Based upon this evidence, a sluggish attentional shifting account of dyslexia was suggested. However, there are three potential confounds which should be addressed in order to support this temporal processing conclusion: the absence of a single-target condition, control for criterion effects using signal detection procedures to calculate target sensitivity, and the use of letter stimuli.

1.1. Single-target condition

Hari et al. (1999) asked observers to complete only a dual-target task. Under these circumstances it is unknown whether the deficit is restricted to the dual-target task or it is simply related to the RSVP procedure. Visser et al. found no difference in single-target performance in their AB investigation into children with dyslexia (Visser, Boden, & Giaschi, 2004); however, the point has not been clarified with respect to letter stimuli and adult dyslexia, Visser et al. utilising shape stimuli and random dot masks. The inclusion of a single-target task, in which T1 is not presented or participants are instructed to ignore it, is critical in order to rule out the possibility of group differences in backward masking of T2 within the RSVP. Backward masking, the disruption of the visual image by subsequent items, is inherent within the RSVP paradigm and stronger backward masking effects have been associated with dyslexia (Di Lollo, Hanson, & McIntyre, 1983). Thus, until a backward masking explanation of the differences between groups is ruled out, temporal processing conclusions should be withheld.

As repeated exposure to RSVP tasks has been found to reduce the magnitude of the AB effect (Maki & Padmanabhan, 1994), the single-target task employed in the current investigation involved the detection of multiple targets (letters B, F, & Y) which were different from that utilised in the dual-target task (the letter X). In doing so, it was hoped that any acquired distinctiveness of the target, similar to that noted by Maki and Padmanabhan, would be minimised. Pilot testing indicated that there was no difference in sensitivity between the multiple and single target variations.

1.2. Target sensitivity

One of the methodological elements required in a detection task is trials for which the target is absent. The rate at which the target is incorrectly reported as present in the target absent trials gives an estimate of false alarm rate which can then be combined with the raw detection rate in order to determine target sensitivity (Macmillan & Creelman, 2005; Stanislaw & Todorov, 1999). Although Hari et al. (1999) did present one third of their trials with T2 absent, they reported only raw detection rates rather than a sensitivity measure. This could be misleading if the criterion for target detection varied between groups. The present study employed T2-present and absent trials, and used the hit and false alarm rates to estimate the participants' sensitivity to T2.

1.3. Letter stimuli

The procedure implemented by Hari et al. (1999) relied upon letter stimuli. In the context of rapid naming, it has been demonstrated that people with dyslexia take longer to name letter stimuli (Denckla & Rudel, 1976; Waber, Wolff, Forbes, & Weiler, 2000). Similarly, Rutkowski, Crewther, and Crewther (2003) noted that longer exposure durations were needed for a group of dyslexic observers to successfully complete a change detection task consisting of letters. Within the context of RSVP procedures, an association between dyslexia and slower letter processing has not been made. If it is the case that letter processing can be related to the AB effect, letter processing may account for AB difference between dyslexic and control readers. In this case, a stimulus specific deficit should be concluded rather than an attentional shift account.

Whilst it might be beneficial to work with entirely different stimuli, shapes for example (as in Visser et al., 2004), it is worth attaining empirical evidence that letters are problematic within the AB context before this step is made. In order to examine whether letter stimuli are problematic in the AB paradigm, a test of rapid letter naming was included in this investigation. If, as demonstrated in previous research (e.g., Denckla & Rudel, 1976; Waber et al., 2000), dyslexia is associated with slower letter naming and this can be linked to the AB effect, this would provide evidence that the use of letter stimuli constitutes a significant confound.

The current investigation aimed to validate Hari et al.'s (1999) finding that dyslexia is associated with a prolonged AB by examining the evidence related to a single-target task, target sensitivity, and letter stimuli. In order to achieve this, adults with and without dyslexia were compared in a dual-target task involving the identification of a white letter and detection of a black letter X.

2. Method

2.1. Participants

Dyslexic and control participants were recruited through a contact list maintained by The Dyslexia Project at The University of Western Australia. They were originally recruited through newspaper and radio advertisements enquiring for participation in dyslexia research. Reading ability separation was based upon a measure of phonemic decoding from the Test of Word Reading Efficiency (Torgesen, Wagner, & Rashotte, 1999). This is a speeded measure assessing the rapid reading of non-words in a 45 second period. Percentile ranks were taken from the manual, with performance for those aged above 24 years being based on the 24-year-old standardisations. Dyslexia was defined as a phonemic decoding score below the 10th percentile (Z-score < -1.29) in conjunction with a reported history of reading difficulties and at least average general ability. The control group was defined as a phonemic decoding score within the average range or better, greater than the 25th percentile (Z-score > $-.67$), no history of reading difficulties, and at least average general ability. The phonemic decoding criteria refer to the Poor or below and Average or above TOWRE descriptions from the manual (Torgesen et al., 1999) for the dyslexic and control criterion, respectively.

There were 14 individuals (10 females) in the dyslexic group, with a mean age of 40.83 ($SD = 10.17$, minimum = 20, maximum = 65). The 15 individuals (11 females) in the control group had a mean age of 40.42 ($SD = 8.40$, minimum = 23, maximum = 56). Phonemic decoding percentile ranks were converted to Z-scores and the mean for the dyslexic group was -1.38 ($SD = 0.07$) and for the Control group, 0.29 ($SD = 0.67$). Control phonemic decoding was significantly higher than that of the dyslexic group; $t(27) = 9.27$, $p < 0.01$, $d = 3.44$; where d refers to Cohen's d estimate of effect size representing the difference between two means expressed in standard deviation units (<.2 is small, $\sim$.5 is medium, and >.8 is large; Cohen, 1988).

General ability was assessed using the non-verbal matrices of the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990). There was no significant difference between groups: Dyslexic ($M = 102.9$, $SE = 1.96$), Control ($M = 108.7$, $SE = 2.13$), $t(27) = 2.00$, $p > .05$. All participants were free of neurological conditions which may have affected the interpretation of the results.

2.2. Materials

The stimuli were displayed on an LCD monitor running at 60 Hz (16.6 ms/frame). The RSVP program was written in Matlab 6.5 (MathWorks., 2003) utilizing the Psychtoolbox (Brainard, 1997; Pelli, 1997).

2.3. Procedure

2.3.1. Rapid naming

The rapid letter naming subtest from the comprehensive test of phonological processing was used (Wagner, Torgesen, & Rashotte, 1999). The cumulative time taken to name the two single-page series was recorded. Rapid naming was always completed first.

2.3.2. Rapid serial visual presentations

The RSVP included uppercase letter stimuli in Arial font, subtending approximately 1° of visual angle in height and 0.95° width at a viewing distance of 50 cm. The background was a light green colour (luminance of 20.4 cd/m^2 measured using a Pritchard PR 650 colorimeter). A regular trial consisted of a fixation cross presented for 500 ms, followed by 7–18 distracter letters, a first target, 0–11 distracters, a second target (B, F, Y, or X), and 1–12 distracter letters. There were always 13 items following T1, and T2 was always followed by at least one distracter. Each item was presented for 100 ms and there were between 21 and 32 items in each trial. Therefore, T2 could be presented from 100 to 1200 ms following the onset of T1 which is the inter-target interval (ITI). T1 was always a white letter (luminance of 36.6 cd/m^2), randomly selected from the distracters. T2 and the distracters were presented in black (luminance of <0.1 cd/m^2). The distracter letters were randomly selected from the alphabet excluding I, O, Q, due to their poor masking properties; B, F, Y, and X as they acted as targets; and T1 which was selected on each trial.

2.3.3. Single-target condition

Participants were asked to indicate the presence of a single target (one of B, F, or Y) with a yes/no response on the keyboard (the '1' or '0' keys). They were told that a white letter would be present and they should ignore this and only look for the specified black target letter. Feedback was given for five practice trials, or until the task was understood.

The letter X (T2 in the dual-target condition) was not the target in the single-target condition, so that performance in the dual-target condition would be unbiased by previous experience specific to X. B, F, and Y were chosen based on criteria outlined by Gibson (1967): these letters were similar to the X with respect to the number of overlapping features with the distracter letters. Pilot research indicated no significant difference in sensitivity between these letters. The pilot testing included 30 university students, 24 females, with an average age of 23.6 years (SD = 4.2). All were naïve RSVP observers. Half completed a BFY single-target task and half completed an X detection single-target task. An independent samples t-test indicated that there was no difference in overall target sensitivity between the BFY, M = 0.93 SD = 0.04, and letter X conditions, M = 0.91 SD = 0.05; $t(28) = 1.51$, $p > 0.05$, d = 0.55.

There were 120 trials in the single-target condition with 40 target absent trials randomly distributed across the condition. Target identity was varied every 40 trials which corresponded to trial blocks. This was included so that practice effects would be minimised. The single-target condition was always completed before the dual-target condition.

2.3.4. Dual-target condition

Participants were instructed to identify a white letter and then detect the presence of an X. It was also stated that the X, if present, would appear after the white letter, which would always occur, and that identification of the white letter should be the primary task. Responses were entered by the participants using a standard keyboard when prompted at the end of each trial: for T1, the corresponding letter was used on the keyboard, and T2 responses were the same as in the single-target condition. Feedback was given for five practice trials, or until the task was understood.

There were 180 trials in the dual-target condition, presented in six equal blocks. For 120 of these trials T2 was the letter X. The remaining trials acted as letter X absent trials with only T1 being presented: for these, T2 was replaced by a letter randomly selected from the distracter list. The ratio of target to catch trials is a replication of Hari et al. (1999).

3. Results

3.1. Single-target condition – Detect the presence of B, F, or Y

Non-parametric sensitivity (A′) calculations (see Stanislaw & Todorov, 1999) were performed for overall single target accuracy. An A′ sensitivity calculation was selected as it provides an adjustment for floor and ceiling levels of accuracy: Two individuals in the control group and none in the dyslexic group reported at an accuracy of 100% in the single-target task. No participants reported at an accuracy of 0%. Overall raw proportion correct, false alarm rates, and sensitivity estimates are reported for both the dyslexic and control groups in Table 1. Whilst the dyslexic group demonstrated lower raw proportion correct, higher false alarm rates, and lower stimulus sensitivity, independent sample t-tests indicated that there was no statistical difference between the groups for any of these measures (see Table 1).

3.2. Dual-target condition – Identify the white letter and detect the presence of X

In the dual-target condition, evidence of a difference in T1 performance would suggest some initial difficulties with the dual-target task. The mean proportion correct for each group is presented in Table 1. Dyslexic accuracy for T1 was lower than that of the control group, and, although medium in magnitude, an independent sample t-test indicated that there was no difference between the groups.

Five individuals in the dyslexic group and 10 individuals in the control group reported T2 with 100% accuracy at an ITI of 1200 ms. T2 sensitivity was calculated for those trials in which T1 was correctly identified and is displayed for each group as a function of ITI in Panel A of Fig. 1. Overall there is clear evidence of an AB effect with lower sensitivity at short ITIs and higher sensitivity with increasing ITIs. Sensitivity at short ITIs is similar for the two groups, but at longer ITIs lower sensitivity is evident in the dyslexic group. These patterns were analysed using a 2 (Group) by 12 (ITI) analysis of variance. The inferential statistics are presented in Table 2. Overall, sensitivity was lower in the dyslexic group and a significant AB was present.

The overall lower sensitivity in the dyslexic group may be indicative of a lower ceiling on performance. Thus it is important to control for this observation when making comparisons. In order to calculate baseline sensitivity or AB recovery level, mean performance at the longest ITIs (1000, 1100, and 1200 ms) was calculated on an individual basis (see Raymond, Shapiro, & Arnell, 1995), and group means are displayed in Table 2. The 95% confidence intervals surrounding this mean are displayed for each group in Panel A of Fig. 1: dyslexic accuracy is depicted by broken lines and control accuracy is depicted by a solid line. An independent sample t-test indicated that this baseline sensitivity was lower in the dyslexic group (see Table 1).

In order to examine the influence of this baseline sensitivity, T2 sensitivity was subtracted from baseline sensitivity for ITIs of 100 to 900 ms. These difference sensitivities are displayed in Panel B of Fig. 1 for each group. A 2 (Group) by 9 (ITI) repeated measures ANOVA indicated a significant effect of ITI but no difference between the groups and no interaction (see Table 2). The nine ITIs included in the analysis did not include 1000, 1100, and 1200 as these provided the baseline estimate. Simple within-subject contrasts indicated that AB sensitivity was lower than baseline sensitivity for

Table 1
Overall descriptives and inferential statistics for the dyslexic and control groups in the single-target task: raw proportion correct, false alarm rates, and sensitivity (A'); and dual-target task: T1 proportion correct, T2 raw proportion correct, T2 false alarm rates, T2 sensitivity (A'), and baseline sensitivity (mean sensitivity at ITIs 1000, 1100, & 1200)

Measure	Dyslexic	Control	t-value	Cohen's d
Single-target task				
Proportion correct	0.90(0.07)	0.92(0.06)	1.16	0.43
False alarms	0.24(0.18)	0.19(0.09)	1.09	0.41
Sensitivity (A')	0.89(0.06)	0.92(0.04)	1.53	0.57
Dual-target task				
T1	0.66(0.15)	0.73(0.14)	1.43	0.53
T2 proportion correct	0.48(0.26)	0.60(0.16)	1.51	0.56
T2 FA	0.17(0.15)	0.13(0.13)	0.66	0.25
T2 (A')	0.72(0.11)	0.80(0.06)	2.55*	0.95
Baseline sensitivity	0.83(0.14)	0.92(0.04)	2.41*,a	0.92

T2 calculations are based upon those trials for which T1 was correctly identified. Cohen's d estimates of effect size are also included (<.2 is small, ∼.5 is medium, and >.8 is large; Cohen, 1988).
[a] Equal variance not assumed.
* $p < .05$.

ITIs of 100–700, $p < .006$ (corrected for multiple comparisons, see Rom, 1990). Therefore, against the dual-target baseline, the AB in the dyslexic group was no different in depth or duration to the AB in the control group.

3.3. Attentional blink magnitude and rapid letter naming

Rapid letter naming was examined in order to determine whether initial AB differences might be stimulus specific; that is, related to slower letter processing in dyslexia. Consistent with previous research, rapid letter naming was significantly slower in the dyslexic group ($M = 31.33$ s, $SD = 4.51$; control $M = 24.40$, $SD = 4.32$), $t(27) = 4.22$, $p < .001$, $d = 1.57$. In order to examine letter naming with AB performance, the AB was summarised to obtain a single parameter to characterise performance (see Raymond et al., 1995). Two AB magnitudes were calculated: the T2 average sensitivity across all 12 ITIs, labelled AB magnitude; and the average difference between the baseline sensitivity and T2 performance at each 9 ITIs, labelled the difference magnitude.

Pearson correlations were performed between rapid naming of letters and single-target RSVP performance, T1 accuracy, AB magnitude, baseline sensitivity, and the difference magnitude. The correlations are displayed in Table 3 for each group as well as overall.

Aside from the relationship between rapid naming and single-target performance and AB magnitude in the control group, all correlations were negative suggesting lower performance in RSVP tasks to be associated with slower letter naming times. Only the overall relationships between letter naming and the regular AB magnitude and baseline sensitivity were statistically significant. These can be largely attributed to the scores within the dyslexic group as the dyslexic within-group correlations are similar to the overall relationship, albeit not statistically significant due to the small sample size. It should be noted that after baseline accuracy was corrected for, rapid naming was not related to the AB effect.

4. Discussion

In comparing dyslexic and control readers' target sensitivity in single- and dual-target RSVP tasks as well as rapid letter naming, there are four points of note. (1) Groups were not differentiated in a single-target task. (2) Groups were differentiated in a dual-target task, dyslexia being apparently associated with a larger AB effect; however, (3) baseline sensitivity was lower in the dyslexic group and when baseline accuracy was corrected for, there was no differential AB associated with dyslexia. (4) Finally, rapid letter naming was related to AB magnitude before but not after baseline sensitivity was considered. These findings will be discussed under three headings: single-target task, dual-target task (points 2 and 3), and letter naming.

Table 2
Inferential statistics for two, 2 (group: dyslexic, control) by 12 (Inter-target Interval, ITI: 100–1200 ms) repeated measure ANOVAs

Effect	T2 sensitivity			Difference sensitivity	
	df	*F*	Partial-η^2	*F*	Partial-η^2
Group	1,27	6.51*	0.194	2.34	0.08
ITI	11,297	22.05**	0.45	22.05**	0.45
Group × ITI	11,297	0.60	0.022	0.60	0.022

The two ANOVAs refer to those conducted for T2 Sensitivity and Difference Sensitivity estimates. Each of these summaries reflects T2 performance for those trials in which T1 was correctly reported. Partial-η^2 is reported as a measure of effect size reflecting the amount of variance accounted for by the specific effect (<.09 is small, <.25 is medium, and >.25 is large; Cohen, 1988).
* $p < .05$.
** $p < .01$.

4.1. Single-target task

Whilst sensitivity to detecting the presence of three different targets in a single-target task was lower in dyslexia, there was no statistical difference between the groups. This supports the notion that a difference noted in a dual-target task between dyslexic and control readers is likely to reflect more than a simple difficulty with RSVP performance or backward masking. This should be considered in light of the high overall accuracy of report in the single-target condition. Although only two individuals in the control group reported at 100% accuracy, potentially a ceiling has been reached in the single-target task. If this is the case the limited difference between the groups may be an under estimation of the true effects. Therefore, single-target performance would be better examined utilising a more difficult task to determine whether the groups show similar performance when the sensitivity range is not attenuated.

4.2. Dual-target task

In the dual-target task, dyslexia was associated with poorer overall sensitivity to T2. However, when baseline accuracy, estimated as the average sensitivity at the three longest ITIs, was corrected for, there was no difference in the AB effect between groups. This is at odds with the existing adult research (Hari et al., 1999); however, in a careful case study-like investigation of five dyslexic individuals Buchholz and Davies (2007) noted that not all individuals displayed significant AB effects. This is consistent with the

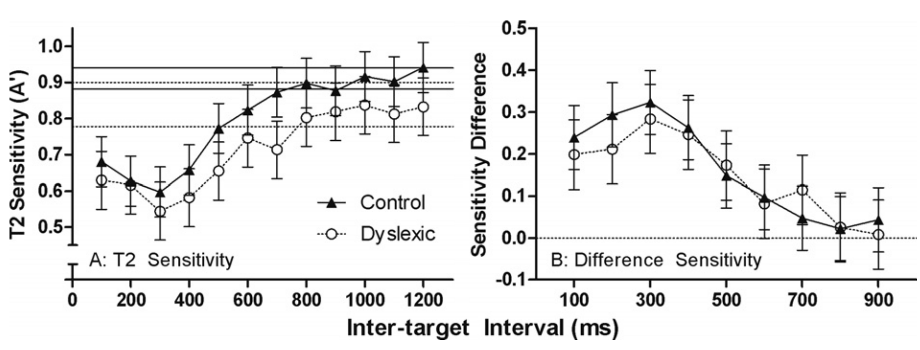

Fig. 1. Dyslexic and Control group A′ sensitivity (Panel A) and difference sensitivity (Panel B) as a function of the inter-target interval between the white letter and black letter target in milliseconds. T2 performance is based upon those trials for which T1 was correctly identified. In Panel A, the horizontal lines represent the upper and lower 95% confidence intervals of a dual-target baseline sensitivity (Mean sensitivity at ITIs of 1000, 1100, and 1200 ms): the dotted lines reflect the dyslexic group sensitivity and the solid lines reflect the control group sensitivity. Panel B difference sensitivity reflects the difference between T2 sensitivity and baseline sensitivity. Error bars represent the within subject 95% confidence intervals (Loftus & Masson, 1994).

Table 3
Pearson product moment correlation coefficients for the relationship between rapid letter naming and single-target RSVP sensitivity, Overall T1 dual-target accuracy, T2 AB magnitude, T2 baseline sensitivity (mean sensitivity at ITIs 1000, 1100, and 1200), and T2 difference magnitude (mean of the differences between T2 sensitivity at each ITI and baseline sensitivity)

Letter naming	Single-target	Overall T1 accuracy	AB magnitude	Baseline sensitivity	Difference magnitude
Dyslexic	−.07	−.09	−.51	−.52	−.20
Control	.27	−.20	.25	−.13	−.32
Overall	−.28	−.09	−.44*	−.54**	−.24

Summaries are reported for the dyslexic ($n = 14$), and control ($n = 15$) groups as well as overall.
* $p < .05$.
** $p < .01$.

large degree of variation apparent in the current investigation. Therefore as Buchholz and Davies concluded, an enhanced AB does not appear to be a core deficit of dyslexia. In fact, at the group level in the current research there is no difference in AB. The particular factor differentiating the groups appears to be a difference in baseline sensitivity. Before this is considered, further comparison to the previous research is useful.

Hari et al. (1999) defined dyslexia based upon a history of reading disorders and as a group, the dyslexic readers were significantly slower in reading and word recognition than the control group. Therefore, it is difficult to categorise the type of dyslexia characterising Hari et al.'s sample and is not clear that the reading difficulties were not due to lower general abilities. The current investigation defined dyslexia based upon a history of reading difficulties, non-word reading below the 10th percentile, and normal general functioning. Our dyslexic group can be described as phonological dyslexics, the diagnosis based upon poor phonemic decoding, this not being related to lower general ability. Thus, potentially the discrepancies noted between the investigations may be related to sampling differences as well as differences in general functioning in the dyslexic group.

The current results are also at odds with that of Visser et al. (2004). Their examination was based upon children with dyslexia and indicated overall lower reporting accuracy and a prolonged AB effect in the dyslexic group relative to age-matched controls. Similarly to the current investigation, before difference sensitivity was considered, the highest level of T2 accuracy in the dyslexic group was considerably lower than that of controls at 1400 ms. Therefore, the conclusion of a prolonged AB in dyslexia was made. As in the current investigation, Visser et al. also found no group difference in a single-target task. A possible explanation for this is that the cognitive load of a dual-target task is an issue for the dyslexic readers. Therefore, the expectation that baseline sensitivity in the dyslexic group will reach the levels of the control group is not necessarily sound and a prolonged AB *per se* not the only conclusion. This rationale provides justification for examining performance against the dual-target baseline as was done with respect to sensitivity differences.

In a dual-target task, two task goals must be maintained in order to attend to the targets and, if attended, both targets must be maintained in memory for recall. Therefore, one or both of these factors may be problematic for the dyslexic readers. In order to control for task and memory demands, baseline sensitivity must be estimated within a dual-target task in which inter-target interference is minimised. This could be done using a *long enough* ITI. However, determining just how long an ITI must be is problematic. A solution to this would be to separate the targets by a fixed interval, say, 1000 ms, and ensure that the T1 task was trivial. This could be achieved by doubling the exposure duration for example. The end result would be a task with exactly the same task demands yet inter-target interference would be minimised.

Analysing Visser et al.'s (2004) data relative to a dual-target baseline would provide results similar to the current findings. Therefore, rather than a prolonged AB in dyslexia, difficulties with the cognitive demands of the dual-target task, reflected in lower baseline sensitivity, could be concluded. This would suggest a more executive deficit, essentially task goal and/or response coordination, consistent with previous research (e.g., Ransby & Swanson, 2003; Swanson & Carole, 2001).

4.3. Letter naming

The rapid naming of letters was negatively associated with AB magnitude. From this it can be suggested that slower letter naming in the dyslexic group may be related to their overall lower T2 sensitivity in the AB. Therefore, removal of this difference, which abolished the between-group difference, is consistent with as lower letter naming explanation. Existing research, confirmed in the present study, indicates that individuals with dyslexia take longer to name letters (e.g., Denckla & Rudel, 1976; Waber et al., 2000), therefore it would be reasonable to suggest that slower letter processing is associated with dyslexia. Letter naming was not significantly related to single-target performance or T1 accuracy in the current research. Thus it appears that the deficit may be most apparent when two or more items must be processed in rapid succession. As stated in the introduction, it was not clear that slower letter processing was definitely a critical factor in this research: the association between letter naming and AB magnitude does not necessarily suggest that it is. The commonality between rapid naming and the AB in the current situation may be the coordination of two or more tasks in rapid succession. A relationship between letter naming and the AB is consistent with theoretical accounts of the AB.

The AB has been explained with respect to limitations in cognitive resources required for target processing. A two-stage model suggests that initial perceptual encoding of all RSVP stimuli may be conducted in a parallel fashion; however, a second stage of target consolidation required for conscious report is considered to be a serial process, dependent upon a limited set of resources (Chun & Potter, 1995). If these resources are engaged in T1-processing, they are unavailable to process T2. As the time between the two targets increases, these resources complete T1 processing and become available and the accuracy of T2 report increases (Chun & Potter, 1995). Therefore, if letters required longer processing time for dyslexic readers they should demonstrate an AB effect of greater magnitude than controls, but this effect is then stimulus specific rather than related to the AB. Conversely, if individuals with dyslexia approached the AB task with fewer cognitive resources, a similar result may be evident. The term *cognitive resources* is used to refer to an individually differing mental capacity for the maintenance of task goals and response coordination. Individuals with greater resources would be expected to have better RSVP performance due to better coordination of task goals; that is, ignoring distracters and attending to targets, for example. Therefore, both stimulus specific and task demand explanations of the current results are feasible. The stimulus specific account does not, however, offer an adequate explanation of differences between dyslexic and control readers noted when the targets were shape stimuli (Visser et al., 2004) or numbers (Buchholz & Davies, 2007). Therefore, in conjunction with previous research and consistent with Buchholz and Davies, difficulties with task demands provides the best explanation of the current AB results in dyslexia.

5. Summary and conclusion

Comparison of the AB effect between dyslexic and control readers suggested that once differences in dual-target baseline sensitivity were removed from overall performance, there was no difference in the AB effect between groups. The most compelling explanation of the results suggests that the coordination of task demands is the difficulty for dyslexic readers and not the AB effect *per se*. Future research must be careful to adequately define and equate for baseline sensitivity using a dual-target task before AB differences can be concluded.

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