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Investigating working memory and sustained attention in dyslexic adults

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ABSTRACT

The aim of this pilot study was to investigate the profile of working memory and sustained attention skills in adults with dyslexia. Measures of verbal and visuo-spatial working memory functioning and sustained attention with stimulus presentation times of 1000–2000 ms were used. The findings indicated that the adults with dyslexia performed similarly to the control group in working memory tests. However, a gender difference was found within the dyslexic group: males performed significantly better than females on both working memory tests. With respect to the sustained attention test, there was a switching cost in moving from one block of trials to another. However, both the dyslexic adults and the controls exhibited similar rates of accuracy and response times. This pattern of findings is interpreted in light of an automaticity deficit previously reported in dyslexia.

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According to the British Dyslexia Association (BDA), dyslexia is a prevalent learning disability characterized by difficulties in reading and spelling, along with deficiencies in phonological awareness, verbal memory, and verbal processing speed. Dyslexia is considered a heterogeneous disorder (Berninger, 2004; Ramus et al., 2003) that has a genetic basis (Fisher & DeFries, 2002), and can be driven by a phonological deficit (Wagner & Torgesen, 1987), as well as a verbal memory deficit (Swanson & Siegel, 2001). As the effects of dyslexia often extend into adulthood and can potentially interfere with one's daily activities such as job duties, this area demands further attention. Although there is an abundance of research on dyslexia in children, there is relatively little literature on adults with dyslexia. Thus, the present study extends existing research to adults and investigates the role of two key cognitive skills associated with reading—working memory and sustained attention.

1. Working memory and dyslexia

Working memory is a higher-level skill that is linked to a range of cognitive activities from reasoning tasks to verbal comprehension (see Cowan and Alloway, 2008, for a review). In typically developing children, scores on working memory tasks predicted reading achievement independently of measures of phonological skills (Swanson & Beebe-Frankenberger, 2004). Working memory skills in kindergarten were an excellent predictor of reading skills six years later (Alloway & Alloway, 2010). Deficits in verbal working memory have been linked to reading difficulties characteristic of dyslexia (Jeffries & Everatt, 2004; Kibby, Marks, Morgan, & Long, 2004; Schuchardt, Maehler, & Hasselhorn, 2008; Smith-Spark, Fisk, Fawcett, & Nicolson, 2003), even in young adults (Palmer, 2000; Smith-Spark & Fisk, 2007).

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Why does verbal working memory play a role in reading disabilities? Based on a meta-review of over 50 studies, Swanson (2012) suggested that verbal memory underpins other processes related to reading, and acts as a compensatory mechanism for other deficiencies. For example, working memory would be involved in keeping multiple pieces of information in mind, such as matching the words on the page with the appropriate sounds, and then combining the words to comprehend what they read. If some information is not automatized, such as the individual unit sounds, working memory could be recruited to break down each word into smaller units before they can read it. As a result, working memory resources could be used both for lower-level processes like reading the individual words, as well as higher level processes, like putting the words together to understand the meaning of a sentence, thereby taxing an already impaired working memory system.

Visual deficits have also been associated with difficulties in processing letters and words (see Ramus et al., 2003, for a review), however, very few studies on reading difficulties have included visuo-spatial memory tests. In the few that have, the dyslexic children demonstrated relative strengths in visuo-spatial short-term memory (Pickering, 2006); though others have demonstrated a weakness in using visuo-spatial memory strategies (Bacon, Parmentier, & Barr, 2012). In the present study, we included both verbal and visuo-spatial memory tests to gain a better understanding of their profile in adult dyslexics.

2. Sustained attention and dyslexia

Sustained attention, the ability to focus attention on a task for a prolonged period (Sarter, Givens, & Bruno, 2001), is another important skill in reading, as the individual has to direct and maintain attention on the material at hand, such as analyzing of strings of letters (see LaBerge & Brown, 1989). When attention is focused on the goal, performance will be fast and accurate. However, if the individual is unable to sustain attention on the task at hand, failures will likely be present (Unsworth, Redick, Lakey, & Young, 2010).

The importance of this skill in reading has been supported by research with dyslexic teenagers without a diagnosis of ADHD. Moores and Andrade (2000) gave their participants a sustained attention task consisting of two types of stimuli. In one version, they had to respond to a set of single digits, with instructions to press the mouse for every digit except the number 3. In another version, the stimuli consisted of novel, unrecognizable patterns. Moores and Andrade found that the dyslexic teenagers produced more errors than the controls for the numbers, but not the novel shapes. The authors' explanation for this pattern was that dyslexic individuals had not automatized the number stimuli, and thus, performed worse compared to the controls. In contrast, the shapes were novel for both the controls and the dyslexics, so the latter group showed no disadvantage. Moores and Andrade concluded that this pattern reflected a stimulus recognition automaticity deficit rather than a sustained attention deficit. This idea is in line with the generalized automaticity deficit proposed to explain speed processing deficiencies in dyslexia (Nicolson & Fawcett, 1990).

The aim of the present study was to extend the existing research in dyslexia in several ways. First, we wanted to understand the working memory profile of adults with dyslexia, compared to a gender-matched control group without reading difficulties. While there is an abundance of research on the cognitive deficits associated with dyslexia in development, the literature is relatively sparse with respect to adults. We included tasks of both verbal and visuo-spatial working memory that required both maintenance and manipulation of information (Alloway & Alloway, 2013; Daneman & Carpenter, 1980).

We were also interested in the role of sustained attention in adult reading difficulties. We included a sustained attention task similar to that used by Moores and Andrade (2000), with two crucial differences. In order to investigate two competing theories—stimulus recognition automaticity deficit versus sustained attention deficit—we extended the presentation time of single digits from the original 250 to 1000 ms and 2000 ms. It is possible that by extending the presentation time, adults with dyslexia would have sufficient time to respond, and thus be able to overcome a possible recognition automaticity deficit. We could also compare any potential improvements in accuracy when adults had even longer exposure to the stimuli (2000 ms). The second alteration to the sustained attention task was that it was three times longer than the task employed by Moores and Andrade (2000). The rationale for extending the time was so we could address the view that may have a difficulty sustaining attention on a task for an extended period (see de Jong, Berendsen, & Cools, 1999).

Finally, there is a substantial amount of research connecting working memory with sustained attention, both functionally (Morey, Cowan, Morey, & Rouder, 2011; Unsworth & Spillers, 2010) and its localization in the brain (see Silver & Feldman, 2005). The present study investigated how these skills might work together to contribute to reading difficulties in dyslexic adults.

In summary, this pilot work addresses the following research questions:

- (1) What is the working memory profile of adults with dyslexia?
- (2) Do adult dyslexics have a sustained attention deficit or a stimulus recognition automaticity deficit?
- (3) What is the relationship between working memory, sustained attention, and reading difficulties in adults?

3. Method

3.1. Participants

There were 40 participants in the present study (16 males and 24 females), ages 17–26 years ($M = 20.4$, $SD = 2.02$). The dyslexic group ($n = 19$) was recruited based on their scores on the *Adult Dyslexia Checklist* (ADC; Smyth & Everatt, 2001),

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