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Brief article

On the importance of considering individual profiles when investigating the role of auditory sequential deficits in developmental dyslexia

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ABSTRACT

The goal of this study was to gain a better understanding of the relationship between non-verbal auditory disorders and developmental dyslexia. This question has led to conflicting results in the literature, which we argued might be due to a failure to consider the heterogeneity of dyslexic profiles. This study included three groups of adult participants: unimpaired readers and dyslexic readers with or without a phonological deficit. Auditory temporal processing deficits, as measured by stream segregation thresholds, were present in most dyslexic participants with phonological disorders. In contrast, most dyslexic participants with preserved phonological skills had normal auditory stream segregation thresholds. Overall, the present study leads to a better understanding of the relationship between phonological and sequential auditory processing disorders in developmental dyslexia. In addition, it demonstrates for the first time the importance of considering the heterogeneity of individual cognitive profiles when investigating the role of auditory deficits in developmental dyslexia.

1. Introduction

Developmental dyslexia is a specific deficit in literacy acquisition that occurs despite normal intelligence and learning opportunities and in the absence of sensory or psychiatric disorders (Shaywitz & Shaywitz, 2005). A prominent view is that dyslexia arises from an underlying phonological deficit, a specific linguistic impairment which would result from noisy and poorly encoded phonological representations (see Vellutino, Fletcher, Snowling, & Scanlon, 2004, for a review). The specific nature of this phonological deficit and its etiology are still under debate (e.g., Ramus & Szenkovits, 2008).

Starting with Tallal (1980), it has been postulated that phonological deficits in dyslexia may result from more basic rapid auditory processing disorders. Indeed, deficits in rapid auditory perception have been reported in temporal order judgment tasks involving both verbal (e.g., De Martino, Espesser, Rey, & Habib, 2001) and non-verbal stimuli (Laasonen, Service, & Virsu, 2001). From this general proposal, the two following hypotheses have emerged.

The first hypothesis is that auditory *transient* temporal deficits (i.e., temporal processing *within* stimuli) are implicated in dyslexia, as suggested by difficulties in processing frequency or amplitude modulations within a tone for example (Hari, Saaskilahti, Helenius, & Uutela, 1999; Witton, Stein, Stoodley, Rosner, & Talcott, 2002). Such deficits have been attributed to a magnocellular dysfunction (e.g., Stein & Talcott, 1999).

The second hypothesis is that phonological and temporal auditory disorders in dyslexia are due to a slower shifting of attention in situations requiring to automatically engage and disengage the attentional focus from one stimulus to the next, like in rapid auditory tone sequences or in speech streams (i.e., temporal processing *between* stimuli, Hari & Renvall, 2001). This sluggish attentional shifting (SAS) hypothesis is not fundamentally different from the rapid processing deficit hypothesis observed in temporal order judgment tasks (Tallal, 1980). Yet, processing

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stimulus streams (as opposed to stimulus pairs) may be more closely related to the sequential phonological processes involved in reading acquisition. In other words, SAS would affect attentional processes required for speech streams encoding, yielding phonological deficits and dyslexia (e.g., Lallier, Donnadieu, Berger, & Valdois, 2010).

Although auditory processing deficits are clearly associated with developmental dyslexia, it remains unclear whether they are responsible for phonological impairments and reading difficulties. Studies of normal reading have established a link between rapid auditory temporal processes and phonological abilities (e.g., Boets, Wouters, van Wieringen, De Smedt, & Ghesquiere, 2008; Hulslander et al., 2004; Meng et al., 2005). However, the few studies that have addressed this question in developmental dyslexia have lead to inconsistent conclusions. In particular, there is disagreement regarding the existence of a link between phonological and auditory temporal processing difficulties in dyslexia (e.g., for: Lallier et al., 2009, and against: Ramus et al., 2003) for at least two reasons.

First, a wide range of tasks has been used to assess rapid auditory disorders. Although often considered equivalent, different tasks are likely to tap into fundamentally different processes. For example, magnocellular (e.g., amplitude modulation detection) and sequential (e.g., temporal order judgment) tasks measure different auditory processes which may be differentially implicated in phonological deficits and dyslexia. In this study, we examine the link between rapid auditory processing deficits and phonological disorders in dyslexia using a stream segregation task known to be sensitive to sequential auditory disorders in dyslexic children and adults (Helenius, Salmelin, Service, & Connolly, 1999; Lallier et al., 2009, 2010; Ouimet & Balaban, 2010) and to reflect the engagement of automatic auditory attention (Macken, Tremblay, Houghton, Nicholls, & Jones, 2003). The auditory stream segregation paradigm estimates the highest speed at which participants can automatically shift their auditory attentional focus back and forth between alternating high- and low-pitched tones. The highest shifting speed (stream segregation threshold) corresponds to a stimulus onset asynchrony (SOA) just long enough to enable perception of successive tones as independent entities (perception of one stream of alternating high and low pitch tones). With shorter SOAs, participants cannot shift their attention back and forth between the successive stimuli, leading to the perception of two concurrent high and low pitch streams. Preliminary evidence suggests a relationship between stream segregation and phonological abilities: Children with good reading skills show faster attentional shifting speed than nondyslexic children with lower reading skills (Lallier et al., 2009). behavioural and electrophysiological evidence in dyslexic adults also indicates deficits in stream segregation (Lallier, Tainturier et al., 2010).

A second source of inconsistency regarding the role of auditory disorders in dyslexia, and one which the present study will focus on, relates to the heterogeneity of the dyslexic population. Although phonological deficits are undeniably ubiquitous in studies evaluating dyslexia at the *group* level, there is increasing evidence that a significant fraction of dyslexic children and adults do *not* present phonological deficits, suggesting that their dyslexia may have a different origin (e.g., Bosse, Tainturier, & Valdois, 2007; Peyrin et al., 2012; Vidyasagar & Pammer, 2010). This raises the possibility that studies examining the link between dyslexia and rapid auditory temporal processing may have been clouded by the variability of underlying deficits, in part because of differing selection criteria and/or failure to consider individual performance.

The present study aims at providing evidence for the special relationship between phonological disorders and auditory SAS, as measured by auditory stream segregation thresholds, in developmental dyslexia. For this purpose, we took into account the heterogeneity of the dyslexic population by comparing rapid auditory temporal processing performance in dyslexic participants *with* versus *without* a phonological disorder. Under the general hypothesis of a causal relation between SAS and phonological deficits in dyslexia, we predicted that only the phonological dyslexic group would show impaired stream segregation thresholds. In addition, we expected that phonological processing and stream segregation thresholds would correlate with each other in the whole sample of participants.

2. Materials and method

2.1. Cognitive profiles of participants

Nine skilled readers and 18 dyslexic readers were recruited via the Bangor University's student participant panel and the Bangor Miles Dyslexia Centre. They were native English speakers and reported normal or corrected-to-normal vision, normal hearing, and no history of neurological or psychiatric disorders. The study was approved by the School of Psychology ethics' committee. Participants gave their written consent to participate in the experiment and received course/printer credits or financial compensation.

To be included in the study, participants needed a standardised score of at least 7 on the matrix reasoning and vocabulary subtests of the Wechsler Adult Intelligence Scale (WAISIIIUK; Wechsler, 1999). All dyslexic participants had a formal diagnosis of ongoing dyslexia. In addition, they obtained mildly to severely impaired scores on the 1-min reading and/or the 2-min spelling tasks of the Dyslexia Adult Screening Test (DAST; Fawcett & Nicholson, 1998). Lastly, a picture RAN task (DAST) was also administered as part of the screening battery since it has been shown to be a strong predictor of reading abilities (e.g., Caravolas et al., 2012).

2.1.1. Phonological skills assessment

The first goal of the study was to constitute two groups of dyslexic participants with and without a phonological deficit in order to compare their performance on the stream segregation task. Several tasks were used to assess phonological abilities for spoken stimuli.

2.1.1.1. Phonemic fluency (DAST) – phonological lexical access. Participants had to say as many words as possible starting with the sound [s] in 1 min. The total number of correct non-repeated responses was registered.