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Working memory deficits in children with reading difficulties: Memory span and dual task coordination

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ABSTRACT

The current study investigated the cause of the reported problems in working memory in children with reading difficulties. Verbal and visuospatial simple and complex span tasks, and digit span and reaction times tasks performed singly and in combination, were administered to 46 children with single word reading difficulties and 45 typically developing children matched for age and nonverbal ability. Children with reading difficulties had pervasive deficits in the simple and complex span tasks and had poorer abilities to coordinate two cognitive demanding tasks. These findings indicate that working memory problems in children with reading difficulties may reflect a core deficit in the central executive.

Introduction

Problems in reading single words accurately and fluently that persist throughout the school years and impair children's academic achievements are extremely common, affecting up to 6% of the school population (e.g., Yule, Rutter, Berger, & Thompson, 1974). The consensus is that deficits in processing the phonological structure of language are strongly associated with reading difficulties, although whether these processing deficits represent a core impairment (Vellutino, Fletcher, Snowling, & Scan-

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lon, 2004) or are themselves a consequence of disruptions of more basic abilities such as analyzing fine-grained temporal structure (Goswami, 2011) is still to be resolved. In the current study, we build on evidence that children with reading difficulties experience difficulties in working memory (e.g., Swanson & Ashbaker, 2000) by investigating whether these problems represent a core deficit in working memory and, if so, what the nature of this deficit might be.

Working memory provides temporary maintenance of information necessary to support complex cognitive processing. Baddeley and Hitch (1974) advanced an influential multicomponent model of working memory consisting of two stores specialized for verbal and visuospatial material: the phonological loop and the visuospatial sketchpad. A third component is the central executive, an attentional control system with limited capacity responsible for the regulation of cognitive processes (Baddeley, 1996). More recently, Baddeley (2000) argued for a fourth component, the episodic buffer, capable of integrating information within and beyond working memory in multidimensional forms. Storage capacity is typically measured by simple span tasks that require only the passive retention of information, whereas working memory is typically measured by complex span tasks that involve simultaneous storage and processing of information. Latent factor studies of children (Alloway, Gathercole, & Pickering, 2006) and adults (Kane et al., 2004) have supported the original three-factor version of the model consisting of a domain-general factor that corresponds to the central executive plus distinct phonological and visuospatial stores. Complex span tasks that impose significant demands on storage and processing rely both on the central executive to support processing and on the relevant domain-specific store for temporary storage. Examples of such tasks include listening span, in which participants make semantic decisions about a series of spoken sentences and then recall the final words of each sentence (Daneman & Carpenter, 1980), and operation span, in which a series of mathematical calculations are made (e.g., 2 + 6/2) and then successive target items accompanying the calculations are recalled (Turner & Engle, 1989). Thus, for example, both the central executive and the phonological store will contribute to a verbal complex span task such as listening span.

Close links are well established between children's performance in working memory, as indexed by complex span tasks, and their reading disabilities, as indexed by performance on standardized tests of word decoding or comprehension 1 standard deviation or more below the levels expected on the basis of chronological age alone despite average performance on measures of intelligence (e.g., de Jong, 1998; Swanson, Zheng, & Jerman, 2009). This link is also identified when reading disabilities are indexed by significant discrepancies between IQ and word reading that are typically required for a diagnosis of dyslexia (e.g., Alloway, 2007; Jeffries & Everatt, 2004; Pickering, 2006b). For the current purposes, the term *reading difficulties* is used to include both overlapping methods of selecting children who are poor readers, although where differences associated with IQ appear to influence memory performance they are noted. Many studies have demonstrated that children with reading difficulties perform poorly both on tasks that involve phonological storage (e.g., Ackerman & Dykman, 1993; Mann, Liberman, & Shankweiler, 1980; Roodenrys & Stokes, 2001) and on measures of verbal complex span (e.g., de Jong, 1998; Pickering, 2006b; Swanson, 1999; Swanson & Ashbaker, 2000). A key question is why these problems arise.

One possibility is that these impairments result from a core deficit in the phonological loop component of working memory, which underlies the deficits both in verbal storage and in more complex activities combining storage with processing. In line with this view, some authors have suggested that verbal working memory does not account for children's reading abilities beyond verbal short-term memory (Hutton & Towse, 2001). On balance, however, the weight of evidence points to an additional impairment in the executive control of working memory. For example, de Jong (1998) compared performance of a group of reading-disabled children and typical readers on measures for verbal working memory, verbal short-term memory, and processing speed. The verbal working memory deficits of the group with reading disabilities could not be explained by these children's verbal storage problems alone, a conclusion also reached by Swanson and Ashbaker (2000). In their study, the performance of poor readers in verbal complex span tasks shared specific links with word recognition and comprehension performance that were independent of the contribution of verbal short-term memory. On this basis, it was proposed that impaired reading abilities of these children reflected deficits in the central executive independent of their problems in verbal short-term memory. Other relevant evidence is provided by a longitudinal study of children identified as having very poor verbal short-term memory