Working Memory, Short-term Memory, Speech Rate, Word Recognition and Reading Comprehension in Learning Disabled Readers: Does the Executive System Have a Role?[1]

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This study explored the contribution of two working memory systems (the articulatory loop and the central executive) and short-term memory to the word recognition and comprehension deficits of children with learning disabilities (LD). In Experiment 1, performance of LD, chronological age (CA)-matched, and reading level (RL)-matched children was compared on measures of articulation rate, short-term memory (STM), and working memory (WM). Experiment 2 included the same procedures as Experiment 1, except that WM tasks were administered under cued-recall conditions. The results indicated that (a) LD readers' STM and WM performance was inferior to CA-matched and RL matched readers when articulation speed (the articulatory system) was partialed from the analysis and (b) WM predicted word recognition and comprehension performance independent of the contribution of STM and articulatory rate. The results were interpreted as support for the notion that LD readers' poor word recognition and comprehension performance reflected deficits in a central executive system independent of their deficits in the articulatory loop.

The temporary storage of material that has been read is said to depend on working memory (WM, e.g., Baddeley, 1986, 1996; Cantor & Engle, 1993; Just & Carpenter, 1992). Working memory is distinguished from other forms of memory because it reflects both processing and storage (Baddeley, 1986; Just & Carpenter, 1992). More specifi-

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cally, WM differs from a related concept of short-term memory (STM) that is typically used to describe situations in which small amounts of material are held passively (e.g., digit- or word-span tasks) and then reproduced in an untransformed fashion (e.g., reproduce the sequence of items in the order they were presented; Daneman & Carpenter, 1980; Dempster, 1985; Klapp, Marshburn, & Lester, 1983). Everyday examples of WM tasks would thus include holding a person's address in mind while listening to instructions about how to get there, or perhaps listening to the sequence of events in a story while trying to understand what the story means. Everyday examples of STM tasks might include recalling a series of digits in order, such as a telephone number, immediately after their presentation.

Performance differences between learning disabled (LD) and nondisabled readers on measures of reading are often attributed to limitations in WM (e.g., De Jong, 1998; Siegel & Ryan, 1989; Swanson, 1989). However, there is no consensus about the nature of WM or, more specifically, which components of WM that are most affected by deficiencies in reading ability. One model currently used to capture LD readers' WM deficits is the multicomponent model of Baddeley (1986, 1996). Baddeley (1986, 1992) describes WM as a limited capacity central executive system that interacts with a set of two passive store systems used for temporary storage of different classes of information: the speech-based articulatory loop, and the visual sketch pad. The phonological or articulatory loop is responsible for the temporary storage of verbal information; items are held within a phonological store of limited duration, and the items are maintained within the store via the process of articulation. The visual sketch-pad is responsible for the storage of visual–spatial information over brief periods and also plays a key role in the generation and manipulation of mental images. Both storage systems are in direct contact with the central executive system. The central executive system is considered to be primarily responsible for the coordinating activity within the cognitive system, but also devotes some of its limited capacity to increasing the amount of information that can be held in the two subsystems.

The majority of studies that compare LD readers' memory performance with skilled readers utilize STM measures. These measures are assumed to capture a subset of WM performance, the utilization and/or operation of the articulatory loop (see Hulme, 1992; Hulme & MacKenzie, 1992, for a comprehensive review). Some authors have suggested that the articulatory loop may be referred to as short-term memory (e.g., Baddeley, 1986; Bisiacchi, Cipolotti, & Denes, 1989; Brown & Hulme, 1992; Dempster, 1985), because it involves two major components discussed in the short-term memory literature: a speech-based phonological input store and a rehearsal process (see Baddeley, 1986, for review). In contrast to this assumption, however, others argue that STM and WM are distinct operations (e.g., Cantor, Engle, & Hamilton, 1991; Daneman & Carpenter, 1980; Swanson, Ashbaker, & Lee, 1996). Regardless of whether or not STM tasks are synonymous with the articulatory loop and therefore a subset of WM, the research to date indicates that LD readers appear to rehearse less and perform poorly on verbal tasks requiring short-term retention of order information than skilled readers (Ackerman, Dykman, & Gardner, 1990; O'Shaughnessy & Swanson, 1998), suggesting deficient utilization of the articulatory rehearsal process. They are also less able to generate pronunciations for unfamiliar or nonsense words (Gathercole & Baddeley, 1989; Rack, Snowling, & Olson, 1992), suggesting a deficient utilization of the phonological