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The involvement of long-term serial-order memory in reading development: A longitudinal study



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ABSTRACT

Recent findings suggest that Hebb repetition learning—a paradigmatic example of long-term serial-order learning—is impaired in adults with dyslexia. The current study further investigated the link between serial-order learning and reading using a longitudinal developmental design. With this aim, verbal and visual Hebb repetition learning performance and reading skills were assessed in 96 Dutch-speaking children who we followed from first through second grade of primary school. We observed a positive association between order learning capacities and reading ability as well as weaker Hebb learning performance in early readers with poor reading skills even at the onset of reading instruction. Hebb learning further predicted individual differences in later (nonword) reading skills. Finally, Hebb learning was shown to explain a significant part of the variance in reading performance above and beyond phonological awareness. These findings highlight the role of serial-order memory in reading ability.

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Introduction

Whereas most children achieve fluent reading skills with relative ease, for others learning to read involves significant difficulties. Approximately 5 to 10% of the population develops dyslexia, characterized by unexpected and persistent difficulties with reading in the context of normal intelligence, adequate sensory functions, and typical educational opportunities (e.g., Lyon, Shaywitz, & Shaywitz, 2003). What determines this important variability in the acquisition of reading skills? What underlies the difficulties of poor readers? A long tradition of research on literacy acquisition has suggested factors such as phonological skills (e.g., see Melby-Lervag, Lyster, & Hulme, 2012, for a review), letter knowledge (e.g., Bond & Dykstra, 1997; Muter & Diethelm, 2001), and short-term memory capacity (e.g., Gathercole & Baddeley, 1993; Rohl & Pratt, 1995) as important predictors for individual differences in reading ability. In parallel, research on reading disability has focused mostly on phonological problems (impaired phonological representations: e.g., Snowling, 2000; problematic phonological access and retrieval: e.g., Boets et al., 2013; Ramus & Szenkovits, 2008) as well as other impairments in (cognitive) functions such as vision (e.g., Bosse, Tainturier, & Valdois, 2007; Chase & Stein, 2003), attention (e.g., Hari & Renvall, 2001), perceptual anchoring (Ahissar, 2007), and memory (e.g., Hachmann et al., 2014; Martinez Perez, Majerus, Mahot, & Poncelet, 2012; Smith-Spark & Fisk, 2007; Szmalec, Loncke, Page, & Duyck, 2011; see Ramus & Ahissar, 2012, for a nuanced overview).

The current study was specifically concerned with the contribution of *serial-order* memory (i.e., memory for the order in which items are presented within a sequence) to early reading. Building on the assumption that learning to read words may be conceived as the acquisition of ordered sequences of graphemes and their corresponding phonemes (Page & Norris, 2009), and following the study by Szmalec et al. (2011) demonstrating deficient serial-order learning capacities in adults with dyslexia, we hypothesized that serial-order learning may play an important role in normal and pathological reading development.

Linking serial-order memory and language

How does memory for serial order relate to language learning and literacy? From an evolutionary perspective, it has been assumed that short-term memory for verbal information developed primarily to support language learning. Baddeley, Gathercole, and Papagno (1998) argued that verbal working memory represents “the processes and mechanisms by which the sound patterns of the words of the (native) language are learned by the child” (p. 159). Indeed, natural language can be regarded as a well-structured environmental input with an inherently sequential nature. A limited number of phonemes and letters form different words, depending on the order of their arrangement, and these words in turn are sequentially arranged to form sentences. It is becoming increasingly clear that both (a) the ability to *temporarily* represent the order of discrete elements occurring in a sequence (i.e., *short-term order memory*) and (b) the ability to consolidate this sequential information in *long-term memory* (referred to as *serial-order learning* or sequential learning) are implicated in several aspects of human language such as lexical acquisition and reading ability.

Lexical acquisition

Evidence for a tight link between short-term memory for order and lexical development comes, inter alia, from the reports of robust correlations (mostly in the range of .40–.50) between performance on verbal immediate serial recall tasks and both nonword repetition (e.g., Gathercole et al., 1999; Gupta, 2003) and vocabulary scores (in either a first or second language; e.g., Gathercole & Baddeley, 1989; Service, 1992). Furthermore, several recent studies by Majerus and colleagues have highlighted the importance of the serial-order component of short-term memory (STM), as opposed to memory for item identity, in relation to early oral language learning (e.g., Leclercq & Majerus, 2010; Majerus & Boukebza, 2013; Majerus, Poncelet, Greffe, & Van der Linden, 2006) and literacy acquisition (Martinez Perez, Majerus, & Poncelet, 2012). Finally, recent research has demonstrated that the order component of STM seems to be affected in both children and adults with dyslexia

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