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Suppressing irrelevant information from working memory: Evidence for domain-specific deficits in poor comprehenders

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ABSTRACT

Previous research has suggested that children with specific reading comprehension deficits (poor comprehenders) show an impaired ability to suppress irrelevant information from working memory, with this deficit detrimentally impacting on their working memory ability, and consequently limiting their reading comprehension performance. However, the extent to which these suppression deficits are specific to the verbal domain has not yet been explored. Experiment 1 examined the memory profiles of poor comprehenders and demonstrated a memory deficit specific to working memory, and the verbal domain within working memory. Experiment 2 compared the same poor comprehenders and controls on both verbal and non-verbal versions of a proactive interference task designed to assess their ability to suppress no-longer-relevant information from working memory. The poor comprehenders showed domain-specific suppression deficits, demonstrating impairments relative to the controls only in the verbal version of the task. Experiment 3 replicated these findings after the response modes of the verbal and non-verbal tasks were equated, confirming the domain specificity of our sample of poor comprehenders' suppression deficits.

Introduction

For the majority of children, word reading and reading comprehension are correlated skills. For some children, however, the two abilities dissociate and specific deficits in reading comprehension or reading accuracy can be observed. Approximately 10% of primary school-aged children show significant and specific impairments in their reading comprehension performance (Nation & Snowling, 1997). When matched with control children on measures of reading accuracy and non-verbal ability, poor comprehenders exhibit reading comprehension performance that is substantially below that of the controls. A question that therefore presents itself is why these children find it so hard to derive coherent meaning from what they have read.

One explanation has been couched in terms of underlying impairments in the working memory processes that are necessary for skilled reading comprehension (Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Yuill, Oakhill, & Parkin, 1989). A more specific version of this hypothesis suggests that working memory impairments in poor comprehenders are a consequence of inefficient regulation of the contents of working memory, resulting from weak cognitive inhibitory skills (Carretti, Cornoldi, De Beni, & Romano, 2005; De Beni & Palladino, 2000; De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Palladino, Cornoldi, De Beni, & Pazzaglia, 2001).

Before discussing the evidence that links working memory performance with reading comprehension ability, it is first necessary to consider what we mean by working memory. Baddeley's multicomponent model (see Baddeley, 2007) posits the existence of two domain-specific slave systems, the phonological loop and the visuospatial sketchpad, subserving short-term storage of verbal and visual information respectively. It also argues for the existence of a domain general central executive which controls the operation of the two slave

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systems, playing an important role in attentional control. Based on a series of empirical findings that the original three component model was unable to accommodate, Baddeley (2000) modified the model to include an episodic buffer; a multi-modal, limited-capacity storage system that serves to integrate information from multiple mnemonic sources in order to create multi-dimensional representations, or 'episodes'.

Although other theoretical conceptualisations of working memory diverge from Baddeley's multicomponent model in many ways (Miyake & Shah, 1999a), the central tenet of working memory seems to be that it is a system involved in the simultaneous storage and processing of information. In line with this, Miyake and Shah (1999b) suggested that the definition of working memory as 'those mechanisms or processes that are involved in the control, regulation, and active maintenance of task-relevant information in the service of complex cognition' is one on which the majority of working memory researchers agree. There exist large individual differences in working memory (Conway, Jarrold, Kane, Miyake, & Towse, 2007), and variation in working memory ability is an important predictor of a diverse range of cognitive, educational, behavioural, and psychological outcomes (e.g., Barrett, Tugade, & Engle, 2004; Conway, Cowan, & Bunting, 2001; Daneman & Carpenter, 1980; Gathercole, Pickering, Knight, & Stegmann, 2004; Moore, Clark, & Kane, 2008; Rasmussen & Bisanz, 2005). Importantly for our discussion of poor comprehenders, working memory is significantly associated with both reading and language comprehension.

Daneman and Merikle (1996) reported a large meta-analysis (77 studies, with a combined total of 6179 participants), showing that performance on a range of verbal working memory measures predicts comprehension ability. By contrast, short-term, storage-only memory capacity was a much weaker predictor of comprehension. Intuitively, one can see why working memory is vital for reading comprehension performance: To build a coherent representation of a text while reading it, it is necessary to hold online in temporary memory a mental model of the situation described by that text, as well as dynamically update it as new information becomes available, particularly if this new information is incompatible with previous information. Similarly, these dynamic and updating processes are necessary for grammatical comprehension, for example, resolving an anaphor from a temporally distinct series of options.

In line with this general relationship between working memory and reading comprehension, children with specific reading comprehension difficulties show impairments on tasks tapping working memory (e.g., Cain, 2006; Nation, Adams, Bowyer-Crane, & Snowling, 1999; Yuill et al., 1989). Turning to the question of what cognitive processes might underpin weak working memory in these children, there are now numerous demonstrations of unimpaired phonological loop function, arguing against an impairment at the level of storage: poor comprehenders show equivalent effects of length, lexicality and phonological confusability in short-term recall to controls, and they have normal levels of phonological short-term memory, as measured by nonword repetition (Cain, 2006; Nation, Clarke, Marshall & Durand, 2004; Oakhill, Yuill, & Parkin, 1988; Stothard & Hulme, 1992). However, there is evidence that poor comprehenders perform less well on tasks that require simultaneous processing and storage of information (Cain, 2006; Carretti, Borella, Cornoldi, & De Beni, 2009; Nation et al., 1999). These findings, in combination with no impairment in storage, point to some form of central executive deficit.

In recent years, evidence has accumulated pointing to weaknesses in cognitive inhibition characterising individuals with reading comprehension difficulties. For example, adults with poor reading comprehension are worse than skilled comprehenders at suppressing irrelevant information, such as the contextually inappropriate meanings of ambiguous words or homophones (Gernsbacher & Faust, 1991; Gernsbacher, Varner, & Faust, 1990). Adults with poor comprehension also make more intrusion errors in recall tasks, producing irrelevant or no-longer-relevant words instead of the targets (De Beni et al., 1998; Palladino et al., 2001). These weaknesses are posited to result in inefficient regulation of the contents of working memory, and thereby to detrimentally impact on poor comprehenders' working memory performance. These difficulties with the suppression of irrelevant information add weight to the idea that deficits in cognitive inhibition are associated with reading comprehension problems in adults.

Similar results have been found in children with poor reading comprehension. De Beni and Palladino (2000) compared the suppression efficiency of children who performed poorly on an inferential comprehension measure with that of children who performed well on this measure, but who had the same levels of non-verbal intelligence. Poor comprehenders made more intrusion errors on a memory task. They also produced more irrelevant information when asked to remember the central elements of a passage they had read. Work by Carretti et al. (2005) and Cain (2006) has supported the idea that individuals with poor reading comprehension have problems with working memory, and that these working memory deficits are associated with difficulties in suppressing irrelevant information. Both studies revealed inhibition deficits in memory in poor comprehenders. Information that was initially relevant but then became irrelevant was particularly difficult for poor comprehenders to suppress. Taken together, these findings suggest poor comprehenders have underlying inefficient cognitive inhibition. Plausibly, these weaknesses in inhibition lead to difficulties with regulating the contents of working memory, and consequent difficulties with reading comprehension.

Previous research into poor comprehenders' suppression weaknesses has assumed that these reflect a domain general, central executive problem with regulating the contents of working memory (e.g. De Beni & Palladino, 2000). If poor comprehenders do have a domain-general problem with regulating the contents of working memory, this should detrimentally impact on their performance on both verbal and visuospatial working memory tasks. At odds with this prediction is Nation et al.'s (1999) finding that poor comprehenders showed deficits in listening span but not in visuospatial span. However, these must be treated with a certain degree of caution, as the verbal and visuospatial working memory tasks used in their experiment