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Serial order short-term memory capacities and specific language impairment: No evidence for a causal association

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ABSTRACT

This study re-explored the nature of verbal short-term memory (STM) deficits in children with specific language impairment (SLI), by distinguishing item and serial order STM processes. Recent studies have shown serial order STM capacity to be a critical determinant of language development, relative to item STM. In Experiment 1, 12 children with SLI, 12 age-matched children and 12 language-matched children were administered serial order recognition and reconstruction tasks. Experiment 2 assessed implicit serial learning abilities via a Hebb learning task. The SLI group showed impaired performance for the serial order reconstruction and recognition tasks, relative to language-matched and/or age-matched control groups. However, normal serial position effects were observed in all SLI children in the serial order reconstruction task, suggesting normal coding of serial position information. Similarly, performance on the Hebb serial learning task was at chronological age appropriate levels. Experiment 3 showed that the group differences observed for the serial order STM tasks in Experiment 1 disappeared when the SLI group was compared to a mental age-matched control group. Experiment 4 showed similar performance levels in the SLI group and the mental age-matched control group for a nonword recognition task assessing item STM capacities. This study shows that children with SLI have no specific impairments for serial order and item STM components but that poorer general cognitive efficiency is related to functional limitations in verbal STM tasks. The data are in line with limited information processing accounts of SLI.

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1. Introduction

Specific language impairment (SLI) has received considerable research interest during the past 20 years, yet the nature of this developmental language disorder is still poorly understood, at both cognitive and neurobiological levels. The aim of the present study is to explore one specific cognitive factor that has been causally linked to SLI, verbal short-term

memory (STM). Although verbal STM, most often estimated by nonword repetition tasks in the SLI literature, seems to be very consistently impaired in children SLI, the reason for this impairment and its possible causal impact on the poor language development of children with SLI still remain an intensive matter of debate.

1.1. Verbal STM impairments as a causal factor of SLI

Verbal STM capacities, or at least the tasks used to measure these capacities, are very consistently impaired in SLI. Many studies, using most often nonword repetition tasks, have documented poor performance in children with SLI for these tasks, and this relative to both age and language-matched control groups (e.g., Archibald and Gathercole, 2006a, 2006b; Gathercole and Baddeley, 1990; Gillam et al., 1998; Majerus et al., 2003; Montgomery, 2004). This deficit seems to be relatively specific since visuo-spatial STM is in general less impaired than verbal STM or not impaired at all relative to age-matched control groups, although there is ongoing debate on this issue (Archibald and Gathercole, 2006a, 2006b; Bavin et al., 2005; Hick et al., 2005). Nonword repetition has also been shown to be a highly reliable diagnostic marker of SLI and is one of the most reliable measures when it comes to relate phenotypical markers of SLI to genetic correlates of SLI (see for example, Bishop, 2006; Conti-Ramsden et al., 2001; Newbury et al., 2005). In the light of these results, it has been argued that the SLI children's poor performance in nonword repetition tasks reflects poor verbal STM storage capacity, which is causally related to the poor lexical learning abilities that characterize many children with SLI (e.g., Gathercole and Baddeley, 1990; see also Newbury et al., 2005). This interpretation is also based on numerous studies showing strong correlations between vocabulary development and verbal STM performance in typically developing children as well as on studies showing that patients with verbal STM deficits have difficulties in acquiring new verbal information (e.g., Baddeley, 1993). This has led to a theoretical proposal suggesting that verbal short-term storage capacity is a critical building block of lexical learning. Following this perspective, the quality of the temporary representations in STM for new verbal information will determine the quality and speed of acquisition of a more stable long-term memory representation for this information (e.g., Baddeley et al., 1998).

However, this interpretation has been challenged given that nonword repetition is a highly multi-determined task measuring not only phonological STM capacity, but also a number of other processes such as phonological segmentation and access to sublexical phonological knowledge in order to ensure correct decoding (at input) and encoding (at output) of the unfamiliar phonological sequence. Hence, poor performance on nonword repetition tasks can also be considered to reflect poorly developed phonological representations and is itself determined by the language system, rather than determining language acquisition (e.g., Metsala, 1999; Chiat, 2001). A current series of theoretical discussion papers on nonword repetition highlight the concern these issues continue to raise (e.g., Gathercole, 2006). The aim of the present study is to further our understanding of the complex relationship between verbal STM and lexical language

impairment in SLI by adopting an increasingly important distinction in the STM literature, the distinction between order and item information.

1.2. STM for order versus item information

Most recent models of STM assume the existence of distinct mechanisms and capacities for the storage of serial order information and item information. Serial order information concerns the sequential order in which the different items of a list are presented. Item information concerns the phonological and semantic properties of the verbal stimuli themselves. A number of models assume that verbal item information is stored directly via activation of corresponding phonological and semantic levels of representations in the language system; in that sense, processing and storage of verbal item information depends very directly upon the quality of underlying phonological and semantic representations (e.g., Burgess and Hitch, 2006; Gupta, 2003; Martin and Saffran, 1992). On the other hand, processing and storage of order information is assumed to depend on a specialized STM system encoding the sequential order of appearance of the different items within a list, which also amounts to encoding the order of activation of corresponding language representations in the language system (e.g., Gupta, 2003).

This distinction is based on a number of empirical studies showing dissociations between STM capacities for the retention of item and order information in neuropsychological and neurodevelopmental populations (e.g., Majerus et al., 2007a), with deficits in item STM being strongly related to the integrity of underlying language representations (Majerus et al., 2007b). A series of experimental studies in adult participants have also shown that linguistic knowledge affects mainly item recall but much less order recall in immediate serial recall tasks (as for example when comparing recall for lists of words of high vs low lexical frequency; Nairne and Kelley, 2004).

Most importantly, some of these models, and most explicitly the model by Gupta (2003), assume that the capacity of serial order STM is crucial for vocabulary learning. Following Gupta (2003), the serial order STM system, interconnected to phonological levels of language representation, permits to refresh and 'replay' an unfamiliar phonological sequence that has been presented and hence increases the chances that the temporary phonological representation that has been created for the new phonological sequence will be eventually transformed into a stable long-term memory representation. This prediction is supported by recent developmental data, showing that tasks maximizing recall of order information (serial order reconstruction for sequences containing highly familiar items and varying only in their order of presentation across the different trials) and STM tasks maximizing recall of item information (delayed recall of single, short verbal items, each item being new at each trial) are independently related to vocabulary knowledge in children aged 4–6 years (Majerus et al., 2006a). Recent studies in monolingual and bilingual adults also showed that serial order STM measures are the most consistent predictors of new word learning as opposed to item STM (Majerus et al., 2006b, 2008).