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Declarative and procedural memory in Danish speaking children with specific language impairment

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ABSTRACT

It has been proposed that the language problems in specific language impairment (SLI) arise from basal ganglia abnormalities that lead to impairments with procedural and working memory but not declarative memory. In SLI, this profile of memory functioning has been hypothesized to underlie grammatical impairment but leave lexical knowledge relatively unaffected. The current study examined memory and language functioning in 13 Danish-speaking children with SLI and 20 typically developing (TD) children. Participants were administered tasks assessing declarative, procedural and verbal working memory as well as knowledge of past tense and vocabulary. The SLI group performed significantly poorer than the TD group on the measure of verbal working memory. Non-significant differences between groups were observed on the measure of declarative memory, after controlling for verbal working memory. The groups were found to perform at comparable levels on the procedural memory task. On the language measures, the SLI group performed significantly poorer than the TD group on the past tense and vocabulary tasks. However, the magnitude of the difference was larger on the task assessing past tense. These results indicate grammatical knowledge is relatively more affected than lexical knowledge in Danish speaking children with SLI. However, the results were not consistent with the proposal linking impaired grammar to impairments with procedural memory. At the same time, the study does not rule out that other aspects of procedural learning and memory contribute to the language problems in SLI.

Learning outcomes: The reader will be introduced to (1) different memory systems, in particular the declarative, procedural and working memory systems and (2) also research examining the relationship between these different memory systems and language in children with SLI.

1. Introduction

Specific language impairment (SLI) describes a developmental impairment affecting language that is not accounted by intellectual impairments, sensory or medical problems (American Psychiatric Association, 2000; World Health Organization, 2004). Despite the apparent dissociation between language and general development, it has consistently been shown that children with SLI often present with a range of co-occurring cognitive and motor problems (for reviews see Hill, 2001; Leonard, 1998; World Health Organization, 2004). This has led to a number of proposals that one or more of the non-linguistic deficits may underlie the language problems (e.g., Leonard, 1998; Montgomery, Magimairaj, & Finney, 2010; Tallal,

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2004) although, not all models of the impairment consider a causal relationship between non-linguistic and language faculties (e.g., van Der Lely, 2005). Ullman and Pierpont (2005) proposed that the language problems in SLI can be understood in terms of an impaired procedural memory system whose functions are compensated by an intact declarative memory system. The current study investigated procedural and declarative memory in Danish speaking children with SLI.

1.1. The declarative & procedural model of language

Ullman and colleagues (Ullman, 2001a, 2001b, 2004; Ullman et al., 1997) argued that the declarative and procedural memory systems generally support different components of language. Both declarative and procedural memory systems are capable of storing information from minutes to years, but differ with respect to function and supporting neurological structures (e.g., Squire & Zola, 1996). The declarative memory system is principally involved in learning, storing and retrieving general knowledge about the world as well as personal experiences (Eichenbaum, 2000; Squire, Knowlton, & Musen, 1993). A key process undertaken by this memory system is to bind arbitrarily related information; processes that are primarily supported by the medial temporal lobe, in particular the hippocampus (Eichenbaum, 2004; Mayes, Montaldi, & Migo, 2007). Learning via this memory system can be achieved following a single exposure to the target stimuli. However, with repeated exposures the strength of stored representation increases. Ullman argued that the declarative memory system encodes, stores and retrieves aspects of language that are not rule based (Ullman, 2001a, 2001b, 2004). This includes lexical knowledge as well as irregular nouns and verbs where there is an arbitrary relationship between form and meaning.

The procedural memory system is involved in the acquisition, storage and use of information that is sequentially or probabilistically structured (Knowlton, Mangels, & Squire, 1996; Packard & Knowlton, 2002). Initially, procedural memory was considered to primarily support motor routines and habits, however subsequent research has shown an involvement in higher order operations such as probabilistic classification and sequence learning (Knowlton et al., 1996; Seger, 2006). Unlike the declarative memory system, learning via procedural memory requires repeated exposures. The procedural memory system is principally supported by a network that includes the prefrontal cortex, basal ganglia and cerebellum (Packard & Knowlton, 2002). Ullman (2001a, 2001b, 2004) proposed that this system underlies the acquisition and use of grammar such as the regular past tense and regular noun inflections across different language domains including syntax, morphology and phonology. The role of procedural memory in grammar is argued on the grounds that this memory system is better suited to learning and storing of information that may be either deterministic or probabilistic in structure. That is, even though there are differences between information that is deterministically and probabilistically structured both are supported by the procedural memory system.

1.2. Declarative & procedural memory in SLI

Ullman and Pierpont (2005) hypothesized that children with SLI have some form of dysfunction affecting the basal ganglia leading to an impairment of the procedural memory system. At the same time, the model also holds that the medial temporal lobes are largely unaffected thereby sparing the learning and memory functions of the declarative memory system. It is further hypothesized that in SLI, language learning and processing proceeds via the declarative memory system that compensates for the impaired procedural memory system. As a result, lexical items, irregular nouns and verbs as well as all inflectional morphology must be acquired and processed item-by-item via the declarative memory system. While the declarative memory system may be able to learn and process all aspects of grammar, any language related functions that are supported by the basal ganglia are also hypothesized to be impaired. Ullman and Pierpont suggest that lexical retrieval is supported by the basal ganglia and therefore children with SLI should have difficulties recalling regular and irregular forms such as the past tense. Finally, Ullman and Pierpont also suggest that that those aspects of language, which rely largely on the declarative memory system, should be intact in SLI. Specifically, it is hypothesized that children with SLI should be able to complete lexical recognition tasks, because these processes are minimally supported by the basal ganglia.

The difficulty children with SLI have with grammar has been well established. Considerable evidence has accumulated showing that children with SLI have difficulties with syntax and grammatical morphology in both expressive and receptive domains (for review see Leonard, 1998). Of particular relevance to Ullman and Pierpont's claims are findings relating to past tense. Children with SLI have been shown to perform significantly more poorly than typically developing (TD) children on tasks assessing the production of the regular and irregular past tense forms (Marchman, Wulfeck, & Ellis Weismer, 1999; Rice, Wexler, & Cleave, 1995). Interestingly, longitudinal research has shown that the developmental trajectories of regular and irregular past tense use of children with SLI are comparable to TD children. Thus a key difference between past tense use in SLI and TD groups relate to the onset of mastery (Rice, Wexler, & Hershberger, 1998).

The difficulties children with SLI have with grammar are consistent with Ullman and Pierpont's (2005) hypothesis. However, the status of the procedural and declarative memory systems in SLI remains the subject of ongoing research. First, central to Ullman and Pierpont hypothesis is that children with SLI should perform significantly more poorly than typically developing (TD) children on tests of procedural memory. To date, the results of several studies support this position. Both Tomblin, Mainela-Arnold, and Zhang (2007) and Lum, Gelgec, and Conti-Ramsden (2010) examined procedural memory using Serial Reaction Time (SRT) Tasks (e.g., Nissen & Bullemer, 1987). In these tasks participants are repeatedly shown a visual stimulus that appears in different spatial locations on a computer screen. Participants' task is to press a button on a