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The effect of time on word learning: An examination of decay of the memory trace and vocal rehearsal in children with and without specific language impairment

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ABSTRACT

Purpose: The purpose of this study was to measure the effect of time to response in a fast-mapping word learning task for children with specific language impairment (SLI) and children with typically developing language skills (TD). Manipulating time to response allows us to examine decay of the memory trace, the use of vocal rehearsal, and their effects on word learning.

Method: Participants included 40 school-age children: half with SLI and half with TD. The children were asked to expressively and receptively fast-map 24 novel labels for 24 novel animated dinosaurs. They were asked to demonstrate learning either immediately after presentation of the novel word or after a 10-second delay. Data were collected on the use of vocal rehearsal and for recognition and production accuracy.

Results: Although the SLI group was less accurate overall, there was no evidence of decay of the memory trace. Both groups used vocal rehearsal at comparable rates, which did not vary when learning was tested immediately or after a delay. Use of vocal rehearsal resulted in better accuracy on the recognition task, but only for the TD group.

Conclusions: A delay in time to response without interference was not an undue burden for either group. Despite the fact that children with SLI used a vocal rehearsal strategy as often as unimpaired peers, they did not benefit from the strategy in the same way as their peers. Possible explanations for these findings and clinical implications will be discussed.

Learning outcomes: Readers will learn about how time to response affects word learning in children with specific language impairment and unimpaired peers. They will see how this issue fits into a framework of phonological working memory. They will also become acquainted with the effect of vocal rehearsal on word learning.

1. Introduction

Children with specific language impairment (SLI) have difficulty with word learning (e.g., Alt & Plante, 2006; Ellis-Weismer & Hesketh, 1996; Gray, 2003, 2004; Oetting, Rice, & Swank, 1995; Rice, Oetting, Marquis, Bode, & Pae, 1994). Despite the ease with which typically developing children acquire words, word learning is a complicated task involving the convergence of phonological, lexical, semantic and cognitive abilities. Effectively treating the word learning difficulties of

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children with SLI necessitates pinpointing the source of the problem. Given previous research identifying the ability of phonological short-term memory to predict children's current vocabulary knowledge and their future vocabulary growth (e.g., Gathercole & Baddeley, 1989; Gathercole, Willis, Emslie, & Baddeley, 1992; Gathercole, Hitch, Service, & Martin, 1997; Gathercole, Service, Hitch, Adams, & Martin, 1999), it is reasonable to assume that a breakdown in the phonological memory system may play a role in the lexical learning challenges of children with this disorder. Recent work has demonstrated that, when children with SLI engage in word learning tasks, they present primarily with deficits in initial encoding (Alt, 2011). This paper reports on a companion study which examines decay of the memory trace as another possible reason for the lexical acquisition difficulties characteristic of children with this disorder. Given that decay of the memory trace (or forgetting) during the word learning process can be prevented by rehearsal of the to-be-remembered words (Baddeley & Hitch, 1974; Baddeley, 1986), this investigation also examines the role of vocal rehearsal in word learning for children with SLI.

Successful lexical acquisition involves establishing long-term representations of the phonological sequences associated with the novel words. Research studies have documented that it is easier to establish these representations, and therefore learn new words, if the words are phonologically similar to the word learner's native language (e.g., Frisch, Large, & Pisoni, 2000; Storkel, Armbrüster, & Hogan, 2006; although c.f. Gray & Brinkley, 2011; Storkel & Lee, 2011). One index of phonological similarity that is a clear influence on lexical learning is phonotactic probability (e.g., Storkel & Maekawa, 2005; Storkel & Rogers, 2000; Storkel, 2001, 2003). Phonotactic probability refers to how frequently phonological segments and segment combinations occur in a language (Jusczyk, Luce, & Charles-Luce, 1994). A lexical item's phonotactic probability is determined by the likelihood of occurrence of a given phoneme or given phoneme combination in a given word position. For example, the word initial segment combination/sp/, occurs more frequently in the English language than the word initial segment combination/gl/, and therefore has a higher word initial phonotactic probability in English. With respect to word learning, words of high phonotactic probability are easier for children to recognize and label than words of low phonotactic probability (e.g., Alt, 2011; Storkel & Maekawa, 2005; Storkel & Rogers, 2000; Storkel, 2001, 2003), although see Gray and Brinkley (2011) and Storkel and Lee (2011) for contrasting findings. This is the case for typically developing children and children with SLI, although the magnitude of the phonotactic probability effect appears to be greater for children with SLI (Alt & Plante, 2006; Munson, Kurtz, & Windsor, 2005). This may be because the ability of children to learn the phonological structure of new word forms is supported by their existing lexical knowledge (Gathercole et al., 1997). Because children with SLI frequently present with reduced vocabulary repertoires relative to their typical language peers (Gray, 2006; McGregor, Friedman, Reilly, & Newman, 2002; Watkins & Kelly, 1995), their basis on which to extend their knowledge of sound structures of words to facilitate new word learning is less well-developed than children who have acquired a greater vocabulary repertoire. If low phonotactic probability words are indeed more challenging to learn for typical learners, these words would present a particular challenge for children with SLI who have limited vocabularies.

Importantly, the ability to learn the sound patterns of new words is constrained by the child's capacity to maintain the word's form in temporary phonological memory. Numerous investigations have documented the relationship between phonological memory and lexical acquisition (e.g., Gathercole & Baddeley, 1989; Gathercole et al., 1992, 1997; Gathercole, Service, et al., 1999; Michas & Henry, 1994). Children's performance on phonological short-term memory tasks, such as digit span and nonword repetition tests, has been found to be predictive of their future vocabulary size (Baddeley, Papagno, & Vallar, 1988; Gathercole & Baddeley, 1989). Important to this investigation, children with SLI typically perform worse than their peers on phonological short-term memory tasks (e.g., Bishop, North, & Donlan, 1996; Dollaghan & Campbell, 1998; Edwards & Lahey, 1998; Gathercole & Baddeley, 1990; Gray, 2003; Montgomery, 1995). Studies specifically investigating the word learning process in children with SLI have also documented a positive relationship between phonological short-term memory, as indexed by performance on nonword repetition tasks, and lexical acquisition (e.g., Alt & Plante, 2006; Gray, 2004). Consequently, a number of researchers have proposed that phonological memory deficits underlie the word learning difficulties of children with SLI (e.g., Dollaghan, 1987; Gathercole & Baddeley, 1990; Montgomery, 1995).

Studies identifying the relationship between phonological short-term memory and word learning in children have generally stemmed from Baddeley's (1986) working memory model. One component of this theoretical framework is the phonological loop, a verbal short-term memory subsystem responsible for storing the novel phonological form in the phonological store and rehearsing the phonological information through an articulatory control process. While phonological representations held in the short-term store are subject to decay in approximately two seconds (Baddeley, Thompson, & Buchanan, 1975), the duration of storage can be prolonged by the rehearsal mechanism. Therefore, it is possible that the lexical acquisition difficulties characteristic of children with SLI could be partially due to issues with rapid decay (or forgetting) of the phonological representations.

The rapid decay of the phonological memory trace from the short-term store could result from two possible sources: susceptibility to interference or increased rate of fading over time. A number of researchers purport that forgetting information in the phonological store is due to interference, which refers to when other input impedes the retention of information (e.g., Berman, Jonides, Lewis, 2009; Farrell & Lewandowsky, 2002; Lewandowsky & Farrell, 2008). Indeed prior investigations of children with SLI have documented increased susceptibility to interference in different types of tasks (e.g., Ellis-Weismer, Evans, & Hesketh, 1999; Marton, Schwarts, Farkas, & Katsnelson, 2006; Tomblin, Mainela-Arnold, & Zhang, 2007). In addition to interference, forgetting could also occur because of the passage of time alone (Baddeley & Hitch, 1974; Page & Norris, 1998). Previous research has documented that children with SLI present with a limited capacity system, including for phonological short-term memory (e.g., Alt, 2011; Ellis-Weismer et al., 1999). Although this limited capacity is often viewed from a quantity- or capacity-based perspective, it may also be temporally de-limited as well (Leonard et al.,