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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.

Keywords

Specific Language Impairment (SLI); word learning; vocal rehearsal; strategy use; decay of memory trace; fast mapping

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, &

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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 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, Hitch, Service, & Martin, 1997; Gathercole, Service, Hitch, Adams, & Martin, 1999; Gathercole, Willis, Emslie, & Baddeley, 1992), 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, 1986; Baddeley & Hitch, 1974), 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, Armbruster, & 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, 2001; 2003; Storkel & Maekawa, 2005; Storkel & Rogers, 2000). 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, 2001; 2003; 2004; Storkel & Maekawa, 2005; Storkel & Rogers, 2000), 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, Hitch, Service, & Martin, 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., 1997; Gathercole et al.,

1999; Gathercole et al., 1992; 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, Schwartz, 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, Evans, & Hesketh, 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., 2007). In other words, their limited capacity may not be just for the amount of information to be recalled or the space available for the to-be-remembered information, but also for how long they can retain that information in the phonological store. Therefore, their poor word learning may be the result of an abnormally rapid rate of decay of the temporarily-stored phonological representations. Although no studies have been designed to examine decay effects in this population, the possibility of temporally-based decay has been mentioned by a number of researchers investigating children with SLI (e.g., Conti-Ramsden, Botting, & Faragher, 2001; Leonard, 1998; Leonard, Eyer, Bedore, & Grela 1997).

As per the working memory model (Baddeley, 1986), if children with SLI exhibit rapid decay of the phonological memory trace from the short-term store relative to their typically developing peers, it could also be due to insufficient or ineffective rehearsal of the verbal information. This is because decay is prevented by refreshing the information in the phonological store via rehearsal mechanisms. Rehearsal is the strategy of repeating or

practicing an item in order to remember it. In lexical acquisition, rehearsal may facilitate the formation of new phonological representations by allowing the word learner repeated and prolonged access to the phonological form. The memory representations associated with new words may fade away more quickly for children with SLI relative to their peers, not because of interference or a restriction in temporal storage capacity, but because they either fail to rehearse, inefficiently rehearse, or do not derive as much benefit from rehearsing the phonological information.

The rehearsal mechanism identified within the phonological loop is thought to be a covert subvocal process that occurs automatically upon exposure to novel verbal input (see Baddeley, 1986; 2000; 2001). Because a direct measurement of subvocal rehearsal is not feasible, its presence is typically inferred through behavioral differences on tasks that allow for and tasks that inhibit the use of rehearsal (e.g. Baddeley, Lewis & Vallar, 1984) or is gauged by directly asking participants about their strategy use (e.g. Henry, Turner, Smith, & Leather, 2000). In addition, some researchers have attempted to measure subvocal rehearsal through the use of EMGs to monitor muscle movement (e.g. Garrity, 1975). Although there are many advantages to these measurement techniques, rehearsal is typically defined as either present or absent. If we expect differences in gradations of strategy use between groups, or disparate effects resulting from rehearsal, current assessment techniques for inferring subvocal rehearsal will be unable to determine these fine distinctions. In order to make these comparisons, the current investigation assessed the use of vocal rehearsal, a strategy that is directly observable and more amenable to measurement in children with documented language difficulties who might be unable to accurately report their strategy use.

Rehearsal may not be as automatic as once believed as research has identified a developmental component to both the rehearsal approach used and its efficiency. Henry and Millar's (1993) review of the use of developmental rehearsal strategies on recall tasks found that rehearsal was not commonly used in children under ten years of age, but was occasionally used by younger children. When rehearsal was used, it was unambiguously helpful (Henry & Millar, 1993). In a subsequent investigation, Henry et al. (2000) updated this work to demonstrate that even 4-year-old children occasionally used some type of verbalization strategy with no instruction when engaged in a serial recall task. However, there were different types of strategies used among older children. Some children simply rehearsed an item's name as it was presented, while others used a more comprehensive strategy including the rehearsal of serial position. Those children who used the more elaborate rehearsal strategy, relative to those who rehearsed the items' names only, exhibited better performance on the task. The results of these studies, when combined, suggest that at least for young children, the use of rehearsal may not be as automatic as previously believed. In addition, it appears that even among typically-developing children, there is a range of efficient and effective strategy use.

Although strategies such as vocal rehearsal are typically employed to improve performance, they are not always successful in this regard. In fact, in many instances, children apply strategies that are inefficient and ineffective (Kuhn, 2002; Siegler 1996). This is commonly referred to as a utilization deficiency, defined as a deficiency resulting from when a child uses an appropriate strategy but receives little or no benefit from it (Miller & Seier, 1994; see also Bjorklund & Coyle, 1995 and Bjorklund, Miller, Coyle, & Slawinski, 1997). Research has documented that, for typically-developing children, a utilization deficiency is most likely to occur when a child begins to use a novel strategy (e.g., Bjorklund & Coyle, 1995; Bjorklund et al., 1997; Miller, 1990; Miller & Seir, 1994). In addition, a meta-analysis of memory strategy use found that younger children are more likely than older children to present with a utilization deficiency (Bjorkland et al., 1997). Although this analysis was

restricted to memory tasks, there is reason to believe that the same may hold true for tasks assessing word learning as well. One plausible reason for the novelty and age effect is that executing a strategy, especially a new one, requires a great deal of cognitive effort, leaving fewer cognitive resources remaining to perform well on the task (Bjorkland et al., 1997; Miller & Seier, 1994). Because younger children tend to exhibit reduced cognitive capacity relative to older children (Andrews & Halford, 1998; Halford, 1993; Siegler, 1983), they may be more at risk of applying strategies that do not enhance performance.

Although research suggests that school-age children use vocal rehearsal (e.g., Flavell, Beach, & Chinsky, 1966; Henry & Millar, 1993; Henry et al., 2000; Keeney, Cannizzo, & Flavell, 1967; Kennedy & Miller, 1976), no studies to date have examined the spontaneous use of vocal rehearsal in children with SLI specifically. What is clear is that children with SLI struggle on word learning tasks (e.g., Alt, Plante, & Creusere, 2004; Nash & Donaldson, 2005; Oetting, Rice, & Swank, 1995). It is important to determine whether or not differences between children with SLI and their typical language peers are apparent in either vocal rehearsal use and/or its derived benefit in order to ascertain vocal rehearsal's relative contribution to word learning in this population. It is possible that children with SLI do not naturally employ vocal rehearsal during word learning, and therefore are at a disadvantage relative to typically developing children because, in contrast to their peers, they do not reap the benefit derived from rehearsing the to-be-remembered words. This lack of rehearsal use on the part of children with SLI may occur because activating a rehearsal mechanism involves metalinguistic ability, recognition of task difficulty without explicit feedback, and credence of its potential benefit in the absence of direct instruction to use it.

In contrast, when engaged in a word learning task, it is feasible that children with SLI will use rehearsal as often as their typical language peers and derive equivalent benefit from its use. This possibility is supported by Henry and Millar (1993), who found that when children use rehearsal it is beneficial to their performance. Further support for the benefit of vocal rehearsal for children with SLI comes from an investigation by Gill and colleagues who found that their ability to follow directions improved when they were trained to vocally rehearse the directions (Gill, Klecan-Aker, Roberts, & Fredenburg, 2003). If this is the case, poor performance of children with SLI on word learning tasks could not be attributable to a deficient rehearsal mechanism. Finally, it is possible that both children with SLI and their typical language peers use vocal rehearsal, but children with SLI do not derive as much benefit from its use. This benefit disparity may be because children with SLI have difficulty repeating nonwords, and tasks which assess word learning typically employ nonwords. Therefore, vocally rehearsing sound sequences which are difficult for children with SLI to repeat aloud after their presentation may result in a utilization deficiency. In other words, the cognitive cost of using a vocal rehearsal strategy for children with SLI may outweigh its benefit.

The benefit of vocal rehearsal for all children, however, may depend on the phonotactic makeup of the words to be learned. Recent research comparing the effects of vocal and subvocal rehearsal on word learning in adults found that vocal rehearsal was more beneficial for learning phonologically familiar words while subvocal rehearsal was more beneficial for retrieving phonologically unfamiliar words (Kaushanskaya & Yoo, 2011). Although the general benefit of rehearsal to word learning cannot be established due to the lack of a control condition, it appears that phonotactics may play a role in the benefit gleaned from the rehearsal process. Prior research has found that children, including children with SLI, are better able to recall nonwords when their phonotactic probability is high (e.g. Alt, 2011; Gathercole, Frankish, Pickering, & Peaker, 1999; Gathercole & Pickering, 1999; Storkel, 2001; 2003; Storkel & Maekawa, 2005). In addition, research investigations have documented that words and nonwords of high phonotactic probability are named faster and

more accurately than those of low phonotactic probability (Gathercole, Frankish, Pickering, & Peaker, 1998; Vitevitch, Luce, Charles-Luce, & Kemmerer, 1997). This may be partially because individuals are not accustomed to the motor planning and execution associated with producing the infrequent phonotactic sequences. Consequently the vocal production of phonotactically infrequent words likely requires more effort relative to words of higher phonotactic probability, leaving fewer resources remaining to devote to learning the new words. It is important to note that the high phonotactic probability advantage is not unambiguous. Low phonotactic probability appears to be advantageous in triggering new learning for adults (Storkel, Arbruster, & Hogan, 2006). New research is also showing low phonotactic probability advantages for preschool children (Gray & Brinkley, 2011; Storkel & Lee, 2011). In both of these studies, the advantages for the low phonotactic probability words appear when children have had multiple exposures to the novel words.

1.1 The Current Study

In sum, word learning is a challenge for children with SLI and may in part be due to failure to prevent decay of the memory trace associated with novel words. If novel words are subject to decay, this decay can be a result of interference, the passage of time, a malfunctioning rehearsal system, or some combination of these factors. However, it is first necessary to determine whether or not there are differences between children with and without SLI in decay of the memory trace during the word learning process prior to identifying the reasoning behind the decay itself. The current study was designed to determine if children with SLI are more vulnerable to decay of the memory trace compared to typically developing (TD) peers during a fast-mapping word learning task. Given that this is the first experiment to date to assess this phenomenon in children with SLI during the word learning process, it was important to determine what these children naturally do when confronted with a word learning task. Therefore, the second aim of this study was to examine if children with and without SLI naturally employ vocal rehearsal during word learning and if so, whether or not there were differences in the effectiveness of this strategy on their word learning outcomes.

If decay differences are apparent between children with SLI and their TD peers, it is most likely to occur when SLI children's lexical learning abilities are taxed. Therefore, word learning was assessed by comparing lexical acquisition with and without an imposed time delay and by comparing performance on words which differ as a function of phonotactic probability. We predicted that word learning in the face of increased length of delay and low phonotactic probability words would be more difficult for all children relative to a short delay and high phonotactic probability words, and that this difficulty would be more pronounced for the children with SLI.

We also examined differences in the use and effectiveness of vocal rehearsal for both typically developing children and children with SLI. We predicted that some children would spontaneously use vocal rehearsal to maintain the phonological representations of novel words in their working memory systems, although we anticipated that fewer children in the SLI group relative to the TD group would recruit and use this strategy. We also predicted that the use of vocal rehearsal would increase under conditions which increased task difficulty (long delay/low phonotactic probability). In addition, we predicted that the magnitude of the benefit of vocal rehearsal would be greater for the TD group relative to the SLI group, reflective of a utilization deficiency in the SLI group.

2. Methods

2.1 Participants

Participants included 40 7–8-year old children, half with SLI and half TD. Children were recruited from local schools and afterschool programs. The participants in the SLI group were individually matched to children in the TD group by chronological age (± 6 months) and sex. They were matched for maternal level of education as a group. Maternal level of education in years was determined through parental report. We used t-tests to ensure that the groups did not differ significantly on this measure. (See Table 1.) For all participants, language or cognitive matches were not used because this would create additional methodological confounds which could negatively impact the interpretation of the study results (Plante, Swisher, Kiernan, & Restrepo, 1993). We did not match the groups for language ability because of the resulting confound, an extraneous age effect. This is because matching for language would necessarily require having younger TD control participants. To attribute findings to language level, then we must assume that there is no developmental difference in the way the younger, typically developing children and the older SLI children approach word learning. Given that both word learning and vocal rehearsal both evidence age effects (Henry et al., 2000; Henry & Millar, 1993; Halberda, 2003; Samuelson et al., 2008), this would be a difficult case to make. Furthermore, cognitive-matches were not used because this would restrict both our SLI and TD population and decrease the generalizability of the study's findings. Specifically, this type of matching would necessarily result in matching higher functioning children with SLI to lower functioning TD children, decreasing the external validity of the study results to TD and SLI children in general, the populations of interest. Participants were excluded from the study if parent or teacher questionnaires revealed a history of neurological impairment. In addition, participants were excluded if they had a diagnosis of attention deficit hyperactivity disorder, autism spectrum disorder, or other handicapping sensory, motor, or behavior condition. All participants spoke English as their primary and dominant language, exhibited normal hearing sensitivity verified by a hearing screening at 25 db HL at 500 Hz and 20 db HL at 1000, 2000, and 4000 Hz, and presented with nonverbal intelligence within normal limits as defined by 75 (70 ± 1 SEM) or above on the Kaufman Assessment Battery for Children, Second Edition (KABC-II; Kaufman & Kaufman, 2004). This criterion was used because the *Diagnostic and Statistical Manual of Mental Disorders Fourth Edition* (American Psychiatric Association, 1994) sets the IQ portion of the criteria for mental retardation at $<70 \pm 1$ SEM for the test employed. A number of researchers have historically used a higher-cutoff score for nonverbal IQ (e.g., Polite & Leonard, 2007; Rice, Redmond, & Hoffman, 2006; Mainela-Arnold & Evans, 2005). In this investigation, the 75 cut-off score was used because of accumulating research documenting the lack of evidence for treating children with developmental language impairment whose performance IQs are below 85 but not in the intellectually disabled range as different from those who obtain performance IQ scores at or above 85. For example, these two groups of children do not appear to differ in their language profiles (Tomblin & Zhang, 1999) or in their response to language intervention (Cole, Dale, & Mills, 1990; Fey, Long, & Cleave, 1994). In addition, Tomblin (2008) recently documented in a longitudinal study that there is little difference in the long-term adolescent outcomes for these two groups of children. Consequently he states, "there is very little evidence that would suggest that the inclusion of performance IQ criteria into a clinical diagnosis of developmental impairment is warranted" (p. 112). For additional information on the lack of utility from this distinction based on theoretical and clinical grounds see Plante, 1998, Tager-Flusberg and Cooper, 1999, and Lahey, 1990.

Participants in the SLI group exhibited test scores consistent with language impairment on the core language components of the *Clinical Evaluation of Language Fundamentals-Fourth Edition* (CELF-IV) while those in the TD group presented with test scores consistent

with typically developing language. The diagnostic accuracy of this test of child language includes 100% sensitivity and 82% specificity at a standard score cut-off of 85 (Semel, Wiig, & Secord, 2003). One child in the SLI group had a score slightly higher than this cut-off (88). This child was still included in the SLI group based on the fact that this child was currently receiving services for impaired language skills, and was judged to be impaired by a second licensed, certified speech language pathologist. All children in the TD group had standard scores higher than 85 on the CELF-IV. Additional descriptive tests of word reading, speech, and receptive vocabulary were also administered. Performance on descriptive measures had no bearing on group inclusion, with the exception of the Goldman-Fristoe Test of Articulation 2 (Goldman & Fristoe, 2000). Although no specific cut-off was determined a-priori, a child who showed evidence of a significant speech sound disorder on this measure would have been disqualified. No children were disqualified based on their performance on this measure. Descriptive summary data for the participants are reported in Table 1.

2.2 Design

This study was designed to measure the influence of a time delay on children's performance on recognition and production of newly fast-mapped lexical labels. We were also interested in the use and effectiveness of vocal rehearsal for each group. The study included a mispronunciation detection task (recognition task) and a production task. There were 24 novel 4-syllable words that varied by phonotactic probability (high v. low). These novel words were varied in terms of the time to response (short delay (immediately after presentation) or long delay (> 10 sec.)).

2.3 Experimental Task

The experimental task required children to view novel animated dinosaurs that were paired with novel lexical labels and fast-map those labels. Before children began the experimental task, they had to pass a training portion which explained the task and gave children feedback on their performance. All children passed the training. The training included stimuli with real lexical labels (e.g. dog, t-rex), but acclimated the children to the experimental task. During the training the children demonstrated that they understood what was expected of them during the recognition and production portions of the task.

During the task, children sat in front of a laptop computer and watched and listened as the stimuli were presented using DirectRT software (Jarvis, 2006). Each child was asked to fast-map a novel lexical label to a novel animated dinosaur after hearing its name two times in short carrier phrases (e.g. "Look! It's a X"). The individual dinosaurs and their labels were paired randomly. The conditions (high v. low phonotactic probability and short v. long delay to response) were presented randomly, and were not blocked. After the dinosaur had been presented children always proceeded to the recognition portion of the task. This was a mispronunciation detection task. Children heard either the real name of the dinosaur or a phonologically-related foil and had to press a button to indicate if the name they heard was correct. As soon as the button was pressed, the child was presented with the next choice. The real name and foils were presented in random order. Participants had to provide an answer for each choice when it was presented. They made decisions about each choice independently and did not need to remember or weigh the four choices against each other. They were also not explicitly told the ratio of correct to incorrect choices. Participants received no feedback on this portion of the task. This helped to ensure that decisions participants made about a label's correctness were not influenced by previous decisions about other variations of that label. Immediately after their four choices were made, participants were asked to produce the name of the dinosaur. The exact timing between the mispronunciation detection task and the production task varied according to how quickly

each participant responded to the four choices of the mispronunciation detection task. They also received no feedback on this portion of the task. Children were told that the character in the story who was asking all these questions was quite forgetful, and he needed their help so he would not get in trouble with his boss. This helped make the task more pragmatically appropriate and all children were able to complete the task and appeared to be engaged in it.

2.4 Stimuli

Twenty-four nonwords were created for this task. The high and low phonotactic probability nonwords were then tested for probability using the Phonotactic Probability Calculator (Vitevitch & Luce, 2004). Each lexical label was 4-syllables in length. Phonotactic probability for nonwords was calculated based on the summed biphone probability of all biphones within a nonword. There are no pre-defined cut-offs for what makes a word high or low probability. Therefore stimuli were classified as high or low probability nonwords based on their position above or below the median level of probability for the potential set of nonwords. The average difference between the high ($X = 1.02$) and low ($X = 1.00$) phonotactic probability nonwords was statistically significant ($T(df, 22) = 4.91, p < .001$). Stress for all nonwords was produced with typical Standard American English stress patterns. Some of the nonwords used were part of the stimuli set for the Munson, Kurtz, and Windsor (2005) study. Foils were created that manipulated either the initial phonemes of the label, the final phoneme of the label, or the number of syllables in the label. All of the novel dinosaurs were created using Adobe Flash. Dinosaurs were tested to make sure that they were not easily nameable.

In the short delay response condition, children were moved directly to the response screen after viewing and hearing the name of the novel dinosaur. In the long delay condition, after the dinosaur was presented, the characters rode in their jeep through the same background (e.g. desert landscape, mountain landscape) that the dinosaur was presented in for 10 seconds. No new lexical items or images were presented during this time. We chose to use the same background images to keep participants focused on the task and to reduce the possibility of visual interference.

2.5 Scoring

The dependent variable for the mispronunciation detection task was the number of correct accepts or rejections for a given lexical label. Responses to correct and foil stimuli were combined in order to create an overall index of the strength of the participants' word learning. Given that each label required the child to make 4 choices, a perfect score would be 4 (1 correct accept and 3 correct rejects). Children's responses for the expressive portion of the task were recorded using a microphone so that the productions could later be analyzed for accuracy. We scored for percent of consonants correctly produced for each trial (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997). Each production was double-scored by trained speech language pathologists, and discrepancies were resolved using a third listener. Inter-rater reliability was 92.15% with a range of 81.6–99.16% agreement.

The presence of vocal rehearsal was defined as a child audibly repeating the name of a dinosaur any time before he or she was required to make a response on the mispronunciation detection task. This ranged from a child rehearsing the name immediately after it was presented the first time, to a first rehearsal occurring just prior to the presentation of the mispronunciation detection task. Vocal rehearsal was judged as either present or absent, given the lack of specification in the literature related to the influence on the amount of vocal rehearsal that would be predicted to influence performance. Additionally, there is evidence that a single instance of vocal rehearsal can lead to clear short-term gains, even for children with SLI (Gill, Klecan-Aker, Roberts, & Fredenburg, 2003). Children were given

no explicit instructions about the use of vocal rehearsal, and were given no feedback for either using or not using this strategy. Research assistants recorded the use of vocal rehearsal if they heard it live, during a session. However, final assessments were made by listening to the digital recordings of each session. A determination of vocal rehearsal was made for each lexical item to be learned for each participant. Double scoring regarding use of vocal strategies was completed for 20% of the participants for each task. Reliability averaged 97.8%.

3. Results

3.1 Accuracy

An ANOVA was conducted for the recognition task, which required mispronunciation detection, in order to determine the effect of time to response and phonotactic probability on word learning for the TD and SLI participants. Group (SLI, TD) was the between group measure and time to response (Short Delay, Long Delay) and Phonotactic probability (High, Low), were the within group variables. As expected, the SLI group was less accurate than the TD group ($F(1, 38) = 17.34, p < .001, \eta_p^2 = .313$). There was no main effect for time to response ($F(1, 38) = 3.05, p = .08, \eta_p^2 = .074$) or for phonotactic probability ($F(1, 38) = .93, p = .33, \eta_p^2 = .023$). In addition, there was no evidence for the predicted interaction between group and time to response; there was no decline in performance for the children with SLI with the 10 second delay ($F(1, 38) = .375, p = .54, \eta_p^2 = .009$). There were also no significant interactions between group and phonotactic probability ($F(1, 38) = .12, p = .72, \eta_p^2 = .003$) or for a three way interaction of group, phonotactic probability, and time to response ($F(1, 38) = .54, p = .46, \eta_p^2 = .014$). See Table 2.

Given the design of the task, it was possible that the effect of a time delay might be muted given that the timing delay between answering the first and fourth question on the mispronunciation detection task was not equivalent. Specifically, the first response occurred immediately, but subsequent responses included longer delays. To address this issue, we analyzed the mispronunciation detection task data in two additional ways. We collapsed over phonotactic probability due to the lack of effect on this factor in the previous analysis. First, we ran paired t-tests to compare participants' first responses in the short delay versus long delay conditions. These were the truest examples of the effect of time to response on accuracy. There was no delay effect for either group (TD $t = -1.04, p = .30$; SLI $t = .310, p = .75$). See Table 3.

To look at this issue in another way, we used an ANOVA with Group (TD, SLI) as the between variable and Response Order (1st, 2nd, 3rd, 4th) as the within group variable for the short delay condition, only. Because participants were asked to judge four variations of each of the 24 words, there were 24 data points for each participant for each Response Order position. A main effect for Response Order would make us question the findings of our first test of time to response. As in the first analysis, there was only an effect for Group ($F(1, 38) = 17.52, p < .001, \eta_p^2 = .315$). There was no main effect for response order ($F(3, 114) = 1.47, p = .22, \eta_p^2 = .037$) and no interaction between group and response order ($F(3, 114) = .598, p = .61, \eta_p^2 = .015$). See Figure 1.

We also conducted an ANOVA to examine the effect of time to response and phonotactic probability on the production of novel words for both the SLI and TD participants with Group (SLI, TD) as the between group measure and time to response (short delay, long delay) and Phonotactic probability (High, Low) as the within group variables. Two findings predicted in the literature held true: children with SLI were less accurate than peers ($F(1, 38) = 15.79, p < .001, \eta_p^2 = .293$) and words with high phonotactic probability patterns were produced more accurately than those with low phonotactic probability ($F(1, 38) = 48.40, p$

$< .001$, $\eta_p^2 = .56$). There was no main effect for time to response ($F(1, 38) = .024$, $p = .878$, $\eta_p^2 = .024$). Additionally, the predicted interaction for time to response and group was, again, not significant ($F(1, 38) = .677$, $p = .415$, $\eta_p^2 = .017$). There was no group by phonotactic probability effect ($F(1, 38) = .32$, $p = .57$, $\eta_p^2 = .008$), and no three way interaction between group, phonotactic probability and time to response ($F(1, 38) = 2.59$, $p = .11$, $\eta_p^2 = .064$). (See Table 2).

3.2 Vocal Rehearsal

Given no effect of time to response, it was important to determine what the participants were doing to prevent the decay of the phonological representations. Therefore, a mixed ANOVA was conducted to examine the use of vocal rehearsal for both groups (SLI, TD) across conditions of time to response (short delay, long delay) and phonotactic probability (High, Low). There were 24 nonwords to learn, so the maximum score for use of vocal rehearsal was 24. There were no main effects or interactions (Group ($F(1, 38) = 1.74$, $p = .194$, $\eta_p^2 = .043$); Time to response ($F(1, 38) = .743$, $p = .393$, $\eta_p^2 = .019$); Phonotactic probability ($F(1, 38) = .122$, $p = .728$, $\eta_p^2 = .003$). Seventeen of 20 children with SLI and 15 of 20 children with TD used the strategy. On average, the children with SLI who used vocal rehearsal used it for 45.83% of the novel words (range 4%–95%) and the children with TD who used the strategy used it for 31.66% of the novel words (range 4%–91%).

Given that both groups used the strategy at equivalent rates, our next question was how effective the strategies were. Based on the lack of differences in strategy use across conditions, we collapsed across items for subsequent analyses. For each child we grouped the items for which vocal rehearsal had been used and calculated the percent of items that were correct. We then calculated the accuracy for the items for which vocal rehearsal was not used. We used paired t-tests to compare the percentage of items correct when children used vocal rehearsal compared to when they did not use vocal rehearsal. We did not include children who did not use vocal rehearsal at all in these calculations. Each group was compared separately. There was no benefit of using vocal rehearsal for either group for the production task (SLI $t = -.16$, $p = .25$; TD $t = .352$, $p = .72$). (See Figure 2). However, there was a benefit to using vocal rehearsal for the mispronunciation detection task, but only for the TD group (See Figure 3). (SLI $t = -2.73$, $p = .78$; TD $t = -2.11$, $p = .04$).

4. Discussion

4.1 Decay of the Memory Trace

This investigation examined two factors which may impact the fast mapping word learning abilities of school-age children, including degradation of the memory trace with time and spontaneous vocal rehearsal of the novel words. These processes were explored in typically developing children and children with SLI, who typically struggle on these types of word learning tasks. We also examined how these two mechanisms may manifest as a function of the phonotactic probability of the nonwords to be learned. Therefore, both degradation of the memory trace and vocal rehearsal were evaluated when children were presented with low phonotactic probability and high phonotactic probability nonwords.

As expected and consistent with prior literature (e.g., Alt, 2011; Gray, 2003; Rice, Buhr & Oetting, 1992; Rice, Oetting, Marquis, Bode & Pae, 1994) children with SLI performed worse than the typically developing children on both the recognition and production word learning tasks. Furthermore, both groups performed significantly worse in producing novel words that were of low phonotactic probability relative to those that were of high phonotactic probability. This is also consistent with prior research findings (see Alt, 2011, Gathercole et al., 1999; Gathercole & Pickering, 1999; Storkel, 2001; 2003; Storkel &

Maekawa, 2005). Logically, activating and implementing phonotactic motor sequences which are similar to words that are already in the child's repertoire, as is the case with high phonotactic probability words, is likely easier than words which are dissimilar to motor sequences previously produced. The use of motor sequences may indeed partially explain the results, as phonotactic probability influenced performance on the word production but not word recognition. This finding is consistent with other studies that have manipulated phonotactic probability and found effects on the production of words but not their recognition (Alt, 2011; Alt & Plante, 2006; Storkel, Maekawa, & Hoover, 2010; Storkel & Rogers, 2000; however c.f. Gray & Brinkley, 2011; Storkel & Lee, 2011; Storkel & Maekawa, 2005). However, the fact that some studies have found effects of phonotactic probability in recognition tasks means that the effect cannot be driven solely by ease of articulation. For example, Roodenrys and Hinton (2002) argue that lexical processing is involved in serial nonword recall, suggesting that the phonotactic probability effect may result from an interplay with working memory and long-term lexical storage. It is entirely possible that several factors are at play. The seemingly contradictory findings related to phonotactic probability to date most likely reflect the complicated nature of this factor. Direct comparison across studies is difficult due to differences in task (e.g. fast-mapping v. slow mapping), age of participants (e.g. adults, school-aged children, preschoolers), and how phonotactic probability is measured (e.g. whole word or biphone segment within a word), among other features. Our findings, however, do suggest that when school-aged children fast map difficult words, phonotactic probability has a stronger effect on word production than word recognition. Whether this result is due, in part, to the articulatory gain associated with producing familiar sequences remains to be determined.

We know that children with SLI are worse at fast-mapping long, novel words compared to unimpaired peers. However, does time to response, which taxes memory, make a difference in how children fast map novel, long words? For receptive fast mapping, in the context of a mispronunciation detection task, the answer appears to be no, although some may suggest that there is a nonsignificant trend in the direction of yes. However, the more important question was whether or not children with SLI would be particularly vulnerable to any effect of decay. Although the overall effect of time to response may have verged on significant ($p=.08$), the interaction between time to response and group was clearly nonsignificant ($p=.54$). Even though children with SLI were much worse at the task overall, there was no difference between their performance on testing after a short delay versus testing after a long delay (10 sec), indicating that they were able to hang onto the few phonemes they had without succumbing to memory trace decay. One could argue that they had difficulty due to problems with initial encoding. This is a likely scenario. However, the question was not: are children with SLI worse at learning longer words than unimpaired peers? We know they are. Despite having poorer initial encoding than TD peers, children with SLI do learn something about the nature of new words in a fast-mapping scenario. The question was: would their word learning difficulties be exacerbated by a time delay before they were asked to demonstrate their knowledge? If this were the case, we would expect the delay condition to yield significantly worse performance compared to the initial response condition. There was no evidence for this scenario. We know from Alt (2011) that these children have difficulty with initial encoding and that longer words are more challenging for them. However, children seem to be fairly tenacious in holding on to the information that they have encoded. They did not show evidence of exacerbated degradation of the phonetic information over time. This lack of delay effect was apparent when the comparison was the short versus long delay condition and when the comparison was whether the correct nonword was the first, second, third, or final item presented.

For the production portion of fast mapping, there was also no effect of time to response for either the TD or SLI group. This indicates that, like receptive fast mapping of novel words,

accuracy in the production of nonwords does not appear to be influenced by an increased delay. In addition, the children's production accuracy of the nonwords, although affected by the phonotactic probability, was not impacted by the time prior to production. This finding provides further evidence that children, regardless of language status, maintain the portions of the nonwords that they have encoded over time.

The results from both the recognition and production tasks suggest that the passage of time by itself is not enough to contribute to significant forgetting. This finding is in line with recent research investigating the mechanisms of what leads to forgetting. Several groups of researchers have found that interference plays a larger role in forgetting than the passage of time alone (Berman et al., 2009; Lewandowsky, Duncan & Brown, 2004; Lewandowsky, Oberauer, & Brown, 2009). Time, alone, is not enough to cause forgetting. Barrouillet, Bernardin, Portrat, Vergauwe, and Camos (2007) use the time-based resource-sharing model to try to explain the difference between the simple passage of time versus the cognitive load of the task. A task that includes interference or something else that demands cognitive load and thus focus of attention, is more likely to lead to forgetting than a task in which the only "load" is that of retention from time passing. In the long delay to response condition of our task, there was no interference. Knowing that interference can happen across modalities (Barrouillet et al. 2007), the design of the delay condition was intentionally visually uncluttered. Children were not exposed to any new aural or visual stimuli. Given this setup, it is not surprising that there was not a decrement in performance on the delay condition for the typical group. Even the SLI group was able to maintain the information they had over a delay, thus suggesting that decay of memory trace in this group is not simply a function of forgetting. Future research focusing on conditions involving interference, shifting attention, or higher cognitive loads during the delay condition are more likely to find between group differences.

One might argue that the exposure to four versions of the lexical label during the mispronunciation detection portion of the task interfered with performance on the production task. This is certainly a possibility. However, given the significant difference in task demands, it would be challenging to interpret a comparison of the mispronunciation detection task (no interference) and the production task (possible interference). This is a worthy avenue for future research to help clarify. Significantly, interference of this sort does not affect the interpretation of our main question.

4.2 Vocal Rehearsal

Given the lack of effect observed for increased time to response for the participants in this investigation, we would expect the children to be engaging in a rehearsal process to maintain the phonological representations of the nonwords that they did encode in their working memory systems. Therefore, a time delay might not be problematic because children may use the time to engage in rehearsal strategies in an effort to maintain the newly learned information. There are several points that could influence whether or not this argument holds for the strategy of vocal rehearsal. Our first question was whether or not children with SLI would use this strategy as often as peers. This seems particularly important, given that both groups were resistant to decay. There were no differences between groups in how frequently the strategy was used or in the number of children in each group who used vocal rehearsal. This is promising. However, use of vocal rehearsal cannot fully account for the supposed protection this strategy offers. First, children used the strategy for less than half of all items. Second, there were differences in how effective the use of those strategies was based on the nature of the task. There were positive effects for use of strategy on the mispronunciation detection task, but not on the production task. This finding should likely not be generalized to most mispronunciation detection and production tasks, but is likely to be specific to this study, where the mispronunciation detection task always preceded the

expressive task, likely influencing the production task. The key point is that the strategy was not equally effective for tasks with different demands.

Importantly, there was only evidence that the use of vocal rehearsal was effective for the children with TD. When children with TD used vocal rehearsal on the mispronunciation detection task, they were more accurate than when they did not use the strategy. It changed the nature of their performance from having more incorrect response to having more correct responses. However, there was no difference in accuracy for the children with SLI. The SLI group's performance is unchanged despite their use of vocal rehearsal; they do not appear to benefit from it and thus show evidence of a utilization deficiency. At the same time, their performance was not impaired when they used vocal rehearsal. In fact, there is a visual, though statistically insignificant, trend towards the use of vocal rehearsal being helpful for them on the production task. Therefore, these results are equivocal in terms of use of rehearsal and cannot confirm (Kirchner & Klatzky, 1985) or deny (Gathercole & Baddeley, 1990; Gillam, Cowan, & Day, 1995), the presence of rehearsal deficits in children with SLI.

Why was vocal rehearsal, which typically appears to be a positive strategy at least for serial recall tasks (e.g. Keeny, Cannizzo, & Flavell, 1967; Kennedy & Miller, 1976; Kirchner & Klatzky, 1985) so ambiguous in this study? First, as mentioned earlier, the study design makes it difficult to accurately examine the effects of vocal rehearsal on the production task. The mispronunciation detection task required children to compare different versions of a label to the representation they had recently learned. This required metalinguistic ability, and the ability to hold several representations in mind. It appears that the benefits of vocal rehearsal (for the TD group) were reaped while engaging in this task. However, the nature of the task may have interfered with additional rehearsal, and thus limited the effect of the strategy on the following task. Importantly, most of the work on rehearsal has been with serial recall tasks. These tasks are different from word learning tasks, and task demands may play a role in the difference.

Another key component to effective strategy use is the ability to evaluate the usefulness of the strategy, which appears to follow a developmental continuum (Cox, Ornstein, Naus, Maxfield and Zimler, 1989). Kennedy and Miller (1976) observed that children are not always good at evaluating the usefulness of a strategy, and may stop using an effective strategy if they are not explicitly told that it is effective. The similar rates of strategy use for the children with typical and impaired language in this study might argue against a frank monitoring deficit for older children with SLI, at least with respect to vocal rehearsal. However, the lack of adjustment of the use of the strategy to the difficulty of the task implies that even the TD children might benefit from improved strategy monitoring.

Another possibility that deserves consideration is that either group may have been using other covert, unmeasured strategies that contributed to the differences in performance. Although Cox et al. (1989) found the use of multiple strategies to be helpful to learners in a sorting task, it is possible that covert strategies employed may have influenced performance. As Kirchner and Klatzky (1985) point out, the helpfulness of a strategy depends on the child's processing resources and task demands. In this investigation, it is possible that children with SLI were engaging in covert strategies that were counterproductive to the task or that the children with typical language were recruiting covert strategies that positively influenced their performance.

However, given the evidence that children with SLI and TD were similar in their rate of use of vocal rehearsal, it is unlikely that impaired children were using some random, counterproductive strategy. If additional strategies were recruited by the children, it is likely that the children with SLI may have used the same covert strategies (e.g. silent rehearsal) as

their peers, but used them less effectively. Kirchner and Klatzky (1985) rightly point out that the use of a strategy for a child with a language impairment could be counterproductive if the use of that strategy saps cognitive resources from an already limited capacity system.

4.3 Clinical Implications

School-aged children with SLI are poor word learners compared to peers. However, in this investigation, they did not appear to have specific deficits relative to decay of the memory trace for even a 10-second delay. Based on our results, they are sensitive to phonotactic patterns in the same manner as TD peers. Clinically, this suggests that word learning strategies that focus on helping children increase memory span may not be as valuable as those that ensure the material to be remembered is encoded in a detailed and accurate manner. Also, knowing that children with SLI can retain information over an uninterrupted span can be an asset that clinicians can take advantage of in their intervention efforts.

That said, the current study focused on a time delay that limited interference and thus had a relatively low cognitive demand. It is certainly possible that children with SLI might be more prone to simple forgetting given tasks that include more interference. When a learning environment is distracting, clinicians should not assume that forgetting will not be an issue. In addition, although the results of this investigation suggest that forgetting of new words does not appear to occur after a long, 10 second duration for both groups of children, it is still possible that children with SLI may forget words sooner than their TD peers with more extended periods of time. Future work is needed in order to clarify this issue.

Although we expected to find between group differences in strategy use, children with SLI spontaneously used the strategy of vocal rehearsal at a similar rate as their peers, but did not benefit in the same way as their TD peers. We operationalized vocal rehearsal as either being present or absent because our purpose was to determine if the use of spontaneous vocal rehearsal was beneficial to performance, not how much rehearsal is needed in order to benefit word learning. It is feasible that the benefits gleaned from vocal rehearsal manifest only following repeated oral repetitions of the words to be learned. However, evidence against this potential explanation comes from a study by Gill et al (2003), who found that children with SLI benefit from vocal rehearsing oral directions one time following their presentation. It is possible that rehearsal is an additive process, and measuring the number of instances of vocal rehearsal would be beneficial to sorting out the mechanism underlying vocal rehearsal in word learning. Another suggestion for the poor performance in the SLI group is that the performance cost of strategy use or the use of covert strategies may explain differences in performance. Additional research will be needed to answer these questions. Neither group adjusted their use of the strategy to the task demands, implying that all children might benefit from explicit instruction and practice on strategy use. Recall that the words children were asked to learn were fairly difficult 4-syllable words. These are likely to be more akin to the academic vocabulary words children learn than to the shorter, more common vernacular words children add to their lexicons as part of conversation.

While strategy use might not fully explain between group differences in performance, there is enough evidence to suggest that strategy use contributes to performance on tasks and is a worthy factor of consideration. Clinicians who are thinking about training children to use strategies, however, may want to proceed with caution. There are certainly instances where it may be useful to teach a child to use a strategy peers seem to be using with success. However, the child should be closely monitored to ensure that the use of the strategy is not counterproductive. Importantly, children may benefit from explicit and repeated practice using strategies. Practice may make the strategy use more automatic over time, and thus ultimately require less processing capacity. In addition, explicit attention to the task provided by such instruction may help children learn to evaluate the effectiveness of the

strategy and increase their metacognitive decision-making skills. In fact, previous work with children with SLI has found that training them to use a rehearsal strategy and a combined rehearsal/visualization strategy for following oral directions actually improved their ability to follow oral directions as evidenced by performance on a norm-referenced test (Gill et al., 2003). Given the limited research to date, however, more work needs to be done before clinicians can feel comfortable making specific recommendations about strategy use, particularly for children with SLI.

4.4 Conclusions

School-aged children are able to hold onto newly formed lexical representations for several seconds without deterioration of that representation, at least in a condition where interference is kept to a minimum. The use of vocal rehearsal does not fully explain why there is no deterioration effect. Although TD children did show improved performance with the use of vocal rehearsal on a mispronunciation detection task, children with SLI did not, despite using the strategy at the same rate as their peers. Despite this, their performance did not deteriorate over time. This is not to say that children with SLI have no problems with memory decay. However, at least in a fast-mapping paradigm that limited opportunities for interference, it points to the fact that the passage of time alone is not likely to be the major source of difficulty for this population. Future work should examine other factors that may contribute to the maintenance of the memory trace. Our findings indicate that vocal rehearsal is a beneficial strategy for TD children, but its benefit for the SLI population, at least with respect to word learning, is questionable. Future work, however, is needed prior to making a definitive determination on the spontaneous use and benefit of vocal rehearsal to word learning and the impact of vocal rehearsal training on word learning outcomes.

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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.

Research Highlights

- We examine the effects of time to response on word learning in children with Specific language impairment and unimpaired peers.
- There was no evidence for decay of the memory trace for either group.
- Both groups used the strategy of vocal rehearsal at an equivalent rate, however, only the unimpaired peers benefitted from the use of the strategy.
- Neither group showed evidence of adjusting use of vocal rehearsal based on task difficulty.
- Words with high phonotactic probability were easier for both groups of children to learn, adding to the literature for the effects of phonotactic probability on school-aged children.

Figure 1.
Percent of accurate accepts/rejects on mispronunciation detection task for each group by response order in short delay condition.

Figure 2.
Comparison of accuracy based on use of vocal rehearsal: Production task

Figure 3.
Comparison of accuracy based on use of vocal rehearsal: Mispronunciation detection task

Table 1

Participants' Demographic Features and Means and Standard Deviations on Standardized Tests

	SLI (10 boys)		TD(10 boys)	
	Mean	Standard Deviation	Mean	Standard Deviation
Age in months	91.25	5.50	93.95	6.45
Maternal Level of Education	13.26	2.15	14.15	1.89
* CELF-IV	72.35	12.49	105.15	8.49
* PPVT-IV	88.45	8.27	108.70	15.31
* TOWRE	89.50	14.15	103.05	10.84
* GFTA-II	97.20	11.94	105.05	3.36
K-ABC-II	95.35	13.34	103.80	13.74

* significantly different at $p < .007$

All other comparisons were not significant at $p = .05$

Note: CELF-IV= Clinical Evaluation of Language Fundamentals-4th edition, PPVT-IV= Peabody Picture Vocabulary Test- 4th edition, TOWRE=Test of Word Reading Efficiency, GFTA-II=Goldman Fristoe Test of Articulation, 2nd edition, K-ABC-II= Kaufman Assessment Battery for Children- 2nd edition.

Table 2

Means and standard deviations for the percentage of correct responses on both tasks by group, phonotactic probability, and time to response.

Mispronunciation Detection Task				
Short Delay		Long Delay		
	High Phonotactic Probability	Low Phonotactic Probability	High Phonotactic Probability	Low Phonotactic Probability
SLI	64.58% (12.5%)	66.45% (17.41%)	65.83% (17.95%)	62.5% (18.79%)
TD	82.5% (9.0%)	81.66% (10.91%)	80.41% (10.62%)	78.12% (7.75%)
Production Task				
SLI	64% (10.68%)	52.16% (13.43%)	59% (13.42%)	54% (12.4%)
TD	73% (13.19%)	64.5% (10.72%)	75.5% (13.21%)	64.16% (12.88%)

Table 3

Means and standard deviations for percent correct for each group on the first response to the mispronunciation detection task in the short delay versus long delay condition.

	Short Delay		Long Delay	
	Mean	SD	Mean	SD
SLI	64.58%	15.5%	65.83%	23.16%
TD	81.25%	14.75%	77.08%	11.08%