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Learning novel words: Detail and vulnerability of initial representations for children with specific language impairment and typically developing peers

Mary Alt *, Rachael Suddarth

Department of Speech, Language, and Hearing Sciences, University of Arizona, P.O. Box 210071, Tucson, AZ 85721-0071, United States

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ABSTRACT

This study examines the phonological representations that children with specific language impairment (SLI) and typically developing peers (TD) have during the initial process of word learning. The goals of this study were to determine if children with SLI attended to different components of words than peers, and whether they were more vulnerable to interference than peers. Forty 7- and 8-year-old children, half with SLI, took part in a fast mapping, word learning task. In addition to producing the word, there was a mispronunciation detection task that included mispronunciations of the target word in the initial position, final position or that modified the word's syllable structure. Children with SLI showed a different learning profile than peers, demonstrating stronger representations of the word-initial phonemes, but less information about word-final phonemes. They were more prone to interference overall, but especially from word-final foils. Children with SLI did not demonstrate less-defined phonological representations, but did attend to different features than TD children, perhaps in an attempt to compensate for problems learning longer words. The greatest weakness of children with SLI appears to be their susceptibility to interference, particularly for word-final information.

Learning outcomes: Readers will be able to: (1) explain what children attend to when learning new words; (2) state the pattern of recognition and production performance for both children with SLI and their typical language peers; and (3) identify specific parts of novel words that are most susceptible to interference in children with SLI.

1. Introduction

Many children with specific language impairment (SLI) have documented deficits in vocabulary development (e.g., Mainela-Arnold, Evans, & Coady, 2008; Nash & Donaldson, 2005; Sheng & McGregor, 2010; van der Lely, 2005) and word learning (Alt & Plante, 2006; Alt, Plante, & Creusere, 2004; Kiernan & Gray, 1998; Gray, 2003, 2004, 2005; Rice, Buhr, & Oetting, 1992; Rice, Oetting, Marquis, Bode, & Pae, 1994). In general, children with poor vocabulary are likely to have difficulty learning new words (Nash & Donaldson, 2005). However, in order to provide focused therapy, it is not enough to know that a child is not as proficient at word learning as his or her peers. Word learning is not an all-or-nothing proposition. Therefore it is important to determine what parts of a word a child has encoded in order to know which aspects are salient to that child, and which need additional emphasis. Because there is a difference in word learning performance between children with typically developing language and children with SLI, it is possible that there is a difference between what is and

* Corresponding author. Tel.: +1 520 626 6180, fax: +1 520 621 9901.
E-mail addresses: malt@email.arizona.edu (M. Alt), rachaels@arizona.edu (R. Suddarth).

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is not salient to word learning in the two groups. It also might be the case that a child with SLI initially encodes information as well as peers, but then is more vulnerable to interference, resulting in an incorrectly specified phonological representation. This paper will address the characteristics of performance on a novel fast mapping task by children with and without language impairment, to provide insight into (a) what parts of a word children attend to when learning novel words and (b) their ability to withstand interference during fast mapping, the initial phase of word learning. This sort of knowledge may allow for targeted intervention to help strengthen word knowledge.

1.1. What is needed for word learning?

Theories of word learning may be fairly diverse in their specifics, but are all quite similar in that they highlight the multi-factorial processes required to learn words. For example, Hollich, Hirsh-Pasek, and Golinkoff (2000) characterize the word learning process as the ‘‘emergent product of multiple factors, including cognitive constraints, social-pragmatic factors, and global attention mechanisms’’ (p. v). Bloom and Markson (1998) note that word learning involves, among other things, the need to make associations. Other views associate word learning with capacities such as the ability to make associations, to use syntactic cues and to use theory of mind (Bloom & Markson, 1998). Learning a new word begins when an association is made between phonetic input that is then paired with a corresponding action or object in the environment. This initial input is referred to as fast mapping and involves an incomplete representation of the word (Carey, 1978; Carey & Bartlett, 1978). Fast mapping is the starting point in word learning. For complete lexical acquisition, subsequent learning through additional exposures that strengthen the initial association is required (e.g., Gray, 2003). The continued exposure that creates a more robust association is known as slow mapping (Carey, 1978). For the purpose of this study, we are concerned with the process that is involved in learning a *lexical label*, not the specific semantic information associated with that label.

1.2. How do typically developing children process words?

Obviously, in order to make the association between phonetic input and its corresponding action, object, or idea, one must be able to process the phonetic form of words. Therefore, there is considerable interest in how children, both those with typical language skills and those with SLI, process words. One main question is: what types of information are salient to learners? Some researchers have examined how different acoustic stimuli need to be from one another for children to perceive a difference. For example, Swingley and Aslin (2002) found that fourteen-month-old infants were able to recognize mispronunciations of the initial segments of common words. Swingley and Aslin did not determine if the infants perceived the difference at the level of phonetic segment, or as an overall acoustic difference. Regardless of the level of speech perception, the key point is that even infants are able to perceive subtle differences in words.

There is evidence that typically developing preschoolers attend to different types of cues to encode words (Gerken, Murphy, & Aslin, 1995). In Gerken et al.'s study, children were asked to judge whether stimuli were the same or different than a target word. The stimuli varied (among other things) in terms of the number of features by which they differed from the target word. Not surprisingly, in 3 of the 4 experiments they ran, children made more identification errors when stimuli differed from the target by a single feature, compared to when stimuli differed by two features. However, these results were tempered by the position in which the difference occurred. Children made more identification errors when stimuli differed by two features within a single segment compared to a single feature difference that occurred on multiple segments of a word. In other words, children were attending to phonetic details as well as more holistic word segment information. Therefore, the number of differences between a target and a foil and the placement of those differences within the word can affect word learning in typically developing children.

McNeill and Hesketh (2010) used a cross-sectional design with children from ages 4 to nearly 6 to look at developmental changes on performance on mispronunciation detection tasks. They were interested in the types of information that were salient to children with primarily typical language of different ages. In general, consonant deletions were easier for children to notice than consonant substitutions. This suggests that preschool children may have less-detailed phonological representations of words early on, even though they are able to make distinctions about part-word differences. Maillart, Schelstraete, and Hupet (2004) conducted an auditory lexical decision task that examined different types of phonological processing in a task that included typically developing children aged 5–9. Their subjects were more likely to correctly reject pseudowords that manipulated the number of syllables in a word than pseudowords in which only ‘slight modifications’ (e.g. addition or deletion of a phoneme) had occurred.

Another feature that can affect how children process a word is prosody. Kehoe (2001) reviewed several studies examining influences on children's speech production. One of the findings relevant to the current study was that, when producing multi-syllabic words, young children were most likely to keep stressed syllables and word-final syllables (even those that were unstressed) compared to other types of syllables in other positions. So, position in a word, as well as segmental and phonetic information are salient features in word processing to typically developing language learners. Because within-word position is important to word processing, it might be a factor in word learning as well. Certainly, Slobin (1973) suggested that paying attention to the ends of words was a universal ‘operating principle’ for children learning language. This study examines the importance of within-word position in fast mapping. These studies reported above show us that typically developing children appear to be tuned to fine-grained phonetic differences in words from infancy. However, they appear to use different levels of processing (e.g. phonetic, segmental, and positional information) to make decisions about whether or not two similar-sounding words are in fact the same. It is possible that manipulations of segmental information are more salient for younger children than those based on phonetic changes only.

1.3. Word processing in children with SLI: possible problems

As established earlier, children with SLI are not as good at word learning as peers (e.g. Kan & Windsor, 2010). They evidence problems with accuracy in word recognition (Edwards & Lahey, 1996) and naming (Lahey & Edwards, 1996; Leonard, Nippold, Kail, & Hale, 1983) compared to their typical language peers. These word learning deficits are seen in both fast mapping (Alt, 2011) and slow mapping (Rice et al., 1992, 1994).

One possibility is that children with SLI do not process words as effectively as unimpaired peers due to phonological processing deficits. Studies in word processing indicate that there may be a phonological deficit in some children with SLI (Maillart et al., 2004; Mainela-Arnold et al., 2008; Seiger-Gardner & Brooks, 2008). For example, the children with SLI in Maillart et al.'s (2004) study, like the typically developing children, found it easier to correctly reject words with missing syllables compared to words with 'fine-grained' differences. However, the children with SLI were less accurate at correctly rejecting pseudowords with fine-grained differences compared to children with typical language. This finding suggests that children with SLI and children with typical language have a similar pattern of incremental processing. However, children with SLI are differentially impacted by fine-grained differences in words. This points to underspecified phonological representations that impact word processing when compared to children with typical language.

Other researchers have speculated that children with SLI have weak or underspecified underlying phonological representations of words (e.g. Edwards & Lahey, 1996, 1998; Maillart et al., 2004). Factors that influence these phonological representations include working memory (e.g. Gathercole, Willis, Emslie, & Baddeley, 1992), phonological similarity (e.g. Henry, 1991), neighborhood density, and phonotactic probability (e.g. Storkel, 2004; Storkel, Armbrüster, & Hogan, 2006). Phonological similarity, neighborhood density, and phonotactic probability are item-specific factors. However, problems with working memory could serve as an additional subject-based factor that may exacerbate any word learning differences between children with SLI and unimpaired peers.

Other studies have examined phonological processing in children with SLI as related to within-word position. Criddle and Durkin (2001) asked children to detect changes in novel morphemes that were attached to real words. For example, the morpheme "zeeb" was attached to the word "ride" – "ridezeeb." Variants of the morpheme included weeb, zeek, zark, and wark. Children with SLI were not as accurate at detecting change as their unimpaired peers when the morphemes appeared in nonfinal utterance positions, but there was no group difference for utterance-final position. Children with SLI were less likely than peers to notice subtle changes to the morphemes than their peers were, which was interpreted as evidence of less precise phonological processing. However, the problems children with SLI have may not be related to the degree of the change in the word, but rather to the position in the word in which the change occurs. In this case, children with SLI may have been following the pattern of improved salience for word-final syllables seen in typically developing children (e.g. Kehoe, 2001). This would be in contrast to Leonard's (1992) finding that children with SLI often omit grammatical morphemes, which are often unstressed, and thus less salient.

Non-word repetition tasks are a traditional measure of phonological processing. Nonword repetition tasks are scored as percent phonemes correct or total number correct (no phoneme errors) (Estes, Evans, & Else-Quest, 2007). These two scoring metrics typically do not provide information that would indicate where the breakdown in word processing is occurring, or the specific nature of the breakdown – only that it has occurred. Despite the lack of detail derived about the nature of the word processing involved in this task, children with SLI consistently perform worse than peers on these tasks (for a review, see Estes et al., 2007). This suggests that children with SLI have difficulty with phonological processing.

A child's ability to use phonological processing is particularly important due to the hypothesized relation between phonological processing and word learning. The lexical restructuring hypothesis outlines the relationship between holistic and incremental representations in word learning (Metsala & Walley, 1998; Walley, 2005). A word's representation in the mental lexicon changes over time from a relatively holistic representation to a more detailed and segmented representation. It is hypothesized that this change is driven by the acquisition of additional vocabulary words. (However, see Swingley & Aslin, 2000 for evidence that suggests this learning may not be as vocabulary-driven as previously suggested.) As vocabulary increases, lexical items become stored in a more segmented way, because with more words, there is a greater need for detailed contrasts between words. The increase in the sublexical knowledge of lexical items makes children more efficient at incremental processing. Therefore, as a child's vocabulary increases, his or her phonological processing skill increases (Metsala, 1999). It follows that a child with poor vocabulary skills may be hindered in his or her growth in incremental processing.

Gathercole et al. (1992) found that between 4- and 5-years of age, children's phonological memory skills appeared to exert a direct causal influence on vocabulary growth. This finding supports phonological content in working memory, presumably incremental information, being used for constructing lexical representations of new words. After the age of 5, vocabulary knowledge determined later vocabulary knowledge, and phonological memory was no longer a predictor. However, children with SLI often show language skills that are similar to younger children. For example, Munson, Kurtz, and Windsor (2005) found that school-aged children with SLI responded to patterns of phonotactic frequency in the same way as younger children. If children with SLI function like typically developing, but younger children, then school-aged children with SLI might still rely on incomplete or impoverished phonological processing for learning novel words.

A second possibility is that children with SLI may have intact initial phonological processing, but are simply more vulnerable to interference. Children with SLI exhibit a similar pattern of incremental processing as children with typical language, but are more prone to interference in processing (Mainela-Arnold et al., 2008; Seiger-Gardner & Brooks, 2008). Seiger-Gardner and Brooks (2008) found that children with SLI showed an onset priming effect in an incremental processing task where school-aged children had to name words while listening to auditory distracters. Despite the fact that all children showed the predicted pattern, the profiles of the two language groups were not identical. Specifically, the children with SLI showed evidence of more phonological interference than their unimpaired peers. So, although children with SLI are able to process incremental details about words, their representations may be more fragile than peers, thus undoing some of the learning that has occurred.

Similarly, Mainela-Arnold et al. (2008) found that children with SLI exhibited a similar pattern of performance on a gating task, but performance was not equivalent to typical language peers. For children with SLI, acceptance for the target word came later than their peers. This suggests that, despite being able to process the beginning of words incrementally, the initial representations of children with SLI were less stable than peers. The participants with SLI may have been more prone to interference from lexical neighbors as well as being vulnerable to competition from phonologically unrelated words that they were unable to suppress (Mainela-Arnold et al., 2008).

Just as there are few studies examining the level of detail of the initial lexical representation in novel word learning, there are few studies that look directly at how children with SLI are able to retain or recall newly learned words in the face of interference. Some of the studies that look at interference include typically developing older children or adults (Conlin & Gathercole, 2006), or suggest lexical interference as a problem source without directly testing hypotheses related to interference (e.g. Gathercole, 2006; Mainela-Arnold et al., 2008). Even the studies that do examine interference do not often use an actual word learning paradigm.

One possibility for weaker representations and increased interference has to do with the multi-factorial nature of word learning mentioned earlier, combined with a limited capacity for learning in children with SLI (e.g. Just & Carpenter, 1992; Leonard, 1998). As the demands of the word learning task increases, so does the possibility for discrepancies in achievement between children with SLI and unimpaired peers. For example, Alt (2011) tested Baddeley's (2003) model of working memory to see if children with SLI had difficulty with encoding information into the phonological loop. Children with SLI in that study could learn shorter words as well as unimpaired peers, but were notably worse on longer words. The interpretation was that children with SLI had problems with initial encoding into the phonological loop, but that those problems only emerged in the context of limited capacity – in other words, when the longer words made the task difficult enough for differences to emerge. In this context, we might expect to see weaker phonological representations when capacity is taxed. We might also expect to see greater interference in children with SLI, given that resisting interference requires an increased cognitive load.

1.4. Word processing and the implications for word learning

The studies we have just reviewed show us that children with SLI are not as good at word processing as their peers. From studies on word learning we know what types of words might be difficult for children to learn (e.g. Kan & Windsor, 2010). For example, verbs are harder than nouns, longer words are more difficult than shorter ones, and words with high phonotactic probability and high neighborhood density can make word learning easier (e.g. for fast mapping, see Alt, 2011) or more difficult (e.g. for slow-mapping, see Gray & Brinkley, 2011) depending upon the learning context. These types of findings are important and certainly provide a window into understanding the word learning process. However, more information is needed about the initial processing in word learning. Factors that influence word processing and could affect word learning include underspecified phonological representations and interference. Determining what early representations consist of in children with and without language impairment is critical to understanding the deficits exhibited by children with SLI in lexical acquisition, and key in determining how to structure intervention. In addition, retention and recall of the lexical representation when faced with interference is not often considered in fast mapping paradigms, and thus we do not have information on how children retain what they may have learned in the process of word learning.

Although the literature has a long history of information about phonological knowledge related to serial recall tasks and nonword repetition tasks, there is less information on how people perform when they are actually learning novel words. Differing task demands could change the way that people perform, and findings that are accurate related to recall tasks might not apply given the demands of word learning. Specifically, there may be differences in the types of memory support that is available for recalling words that are already lexicalized compared to words that are in the initial stages of encoding. This may be particularly relevant for the amount of phonological detail we might expect as relevant to the lexical restructuring hypothesis (e.g. Metsala & Walley, 1998). A second key difference is that many other experimental tasks (understandably) try to limit interference. However, word learning outside of the laboratory is challenging, with many possible sources of interference and the task we propose will be able to directly measure the influence of interference during fast mapping.

1.5. Current study and hypotheses

There is ample evidence that children with SLI have problems learning words, and there is evidence that they show differences compared to unimpaired peers in how they process known words. What is missing is information about how children process novel words during the initial stages of word learning. Clearly, what children attend to is complicated, with possible interactions between segmental information, phonetic information, positional information, and morphological information. Information about what children attend to during novel word learning has the potential to impact treatment for children who struggle with word learning. Most of the evidence points to children being able to process sublexical components of novel words, but with differing patterns of performance depending upon *where* manipulations of the novel word occur. In addition, it appears that the new words children with SLI learn may be more vulnerable to interference than the new words of unimpaired peers. Thus, we chose to manipulate positional information and word length, while controlling for overall stress patterns and morphological information.[1] Therefore, our three main research questions are:

(1) Are there specific parts of novel words (initial position, final position, syllable structure) that are more difficult for children with SLI to learn, compared to peers?
(2) Once children with SLI have an initial lexical representation, how prone are they to interference from lexical foils?
(3) If children with SLI show differences in learning patterns or greater susceptibility to interference, will these differences be magnified when children are asked to learn longer words?

To address these questions, school-aged children with and without SLI learned novel words in a fast mapping scenario. First, the children judged the accuracy of the novel word and its foils, and then they produced the novel word. Foils manipulated the number of syllables in a word, and the consonants in the word-initial and word-final position.

2. Method

2.1. Participants

Twenty children with specific language impairment (SLI) and 20 typically developing (TD) peers who were matched individually for age (±6 months) and sex, and as a group for maternal level of education participated in this study. All participants were between the ages of 7 and 8 years old and were native English speakers as per parent report. These children also participated in Alt (2011). Inclusion criteria for the impaired group included a standard score of less than 85 on the Clinical Evaluation of Language Fundamentals-IV (CELF-IV), which yields a sensitivity of 100% and specificity of 82% (Semel, Wiig, & Secord, 2003).[2] Both groups also needed to pass a hearing screening, be free from any additional diagnoses, and demonstrate typical nonverbal cognitive skills (standard score >75) on the Kaufman Assessment Battery for Children-II (Kaufman & Kaufman, 2006). The two groups of participants were not significantly different from one another in terms of nonverbal intelligence. They were significantly different from one another on measures of language, receptive vocabulary (Peabody Picture Vocabulary Test-IV; Dunn & Dunn, 2007), word reading (Test of Word Reading Efficiency; Torgesen, Wagner, & Rashotte, 1999), and speech (Goldman-Fristoe Test of Articulation-2; Goldman & Fristoe, 2000). Means and standard deviations for all standardized test measures are located in Table 1. Despite significantly better performance by the TD group on the Goldman-Fristoe Test of Articulation-II, all of the children had the ability to produce the nonwords presented in this study. The types of errors evidenced in both the SLI and TD groups were mild articulation errors, such as distortions. No participant evidenced a speech sound disorder (e.g. evidence of phonological patterns including the use of substitutions and omissions), as determined by a certified speech-language pathologist.

2.2. Procedures

The procedures for this study followed all rules of the University of Arizona's Institutional Review Board. After receiving parent permission and participant assent, children were given a hearing screening and standardized tests in language, nonverbal intelligence, and speech to verify their eligibility for the study. Eligibility was also based on information from a parental questionnaire, and children with a history of impairments other than SLI were excluded from the study. Children were tested for word reading ability and receptive vocabulary as descriptive measures. These tests were administered in a quasi-random order, with the hearing screening always coming first. A certified speech-language pathologist administered all standardized tests related to study inclusion, and teams of trained research assistants administered descriptive tasks and the experimental tasks.

2.3. Experimental task

The experiment began with a training session. Participants were required to pass the training in order to continue on to the main task. First, the training introduced the participants to the story line, in which a paleontologist (Dr. Bones) and his hapless assistant (Joe) are going on an expedition to catalogue dinosaurs. Joe is extremely forgetful and even has trouble remembering his own name. Dr. Bones becomes annoyed with Joe's forgetfulness, so children are asked to help Joe so he does not get into trouble.

The training then exposed children to three scenarios that approximated the actual experimental task, but that used known animals and incrementally decreased feedback. For example, children saw an animated dog walk across the screen, as it was labeled by Dr. Bones (e.g. "Look, it's a dog! I see a dog!). Participants were then asked to judge the accuracy of Joe's

[1] Although phonotactic probability was also manipulated for the original word learning task, for this particular analysis, we had no theoretical questions related to phonotactic probability, and thus, it is not investigated in terms of our results.

[2] One child in the impaired group had a CELF-IV score of 88. However, this child was still receiving speech language services, and an additional certified speech language pathologist judged his language skills as impaired.

Table 1
Participants' demographic features and means and standard deviations on standardized tests.

	SLI		TD	
	Mean	Standard deviation	Mean	Standard deviation
Age	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	97.20	11.94	105.05	3.36
K-ABC-II	95.35	13.34	103.80	13.74

* Significantly different at .007 or less.

productions of the animal's label one at a time (e.g. ''Is it a fog? Is it a dog? Is it a frog? Is it a bat?'') and then to produce the name of the animal (e.g. ''What's its name?). Children responded using a button press for the recognition task and verbally for the production task. Initially, feedback was given after each question (e.g. ''Right! You chose 'no' because it was not called a fog.''), but after two trials, feedback was only provided for incorrect responses (e.g. ''Oops, you chose yes, but it was not a fog. Watch again.''). All participants passed the training portion of the experimental task. After completion of the training, participants proceeded to the main task.

The main task was a fast mapping paradigm of 24 novel animated dinosaurs with 24 novel names. Children were asked to fast map a dinosaur's name and demonstrate that mapping through a word recognition task followed immediately by a word production task. Children were exposed to an animation of a novel dinosaur and its name. The name was heard two times in short carrier phrases (e.g., ''I see a X''; ''Wow! It's a X''). Dinosaur images and names were paired randomly and the lexical labels (dinosaur names) were presented in random order. All stimuli were pre-recorded and presented through the use of DirectRT software (Jarvis, 2006) using a laptop computer and headphones.

After the initial exposure to the animated dinosaur and its corresponding name, participants were asked to judge four versions of the dinosaur's name for correctness. The versions included the actual name, a name in which the initial syllable had been modified, a name in which the final syllable had been modified, and a name in which the number of syllables in the name had been modified. All four names were presented in random order. Children responded to one name before being presented with the next name and were not given feedback on their responses. Children indicated their decision about the correctness of a name by pressing a large button on a button box that corresponded to YES (for the correct name) or NO (for an incorrect name). The YES and NO buttons were counterbalanced across subjects. Children were not explicitly told that there were one correct and three incorrect choices. After the children heard the four names, Joe asked the children to name the dinosaur they just saw.

2.4. Design

This study was designed to measure the influence of various foils on a child's recognition and production of newly fast-mapped lexical labels in order to determine the parts of a word that were learned in greatest detail in initial lexical representations and the susceptibility of these initial mappings to interference. The experimental task was the same as in Alt (2011). Twenty-four novel lexical labels were orthogonally varied by length (2-syllable vs. 4-syllable) and phonotactic probability (frequent vs. infrequent). For this study, phonotactic probability was not a variable of interest. Therefore, analyses were collapsed across this condition. There were two types of responses required from the participants, receptive and expressive.

2.4.1. Recognition portion

For each lexical label, the children had to make a judgment about the accuracy of the real label and three phonologically related foils. The dependent variable was the hit rate for correct accepts of the real label combined with the correct rejection rate for each of the foils. The independent variables were group, foil type (word-initial, word-final, syllable modification, or real label) and word length (short, long). The data were analyzed with a mixed 2 (Group) $\times$ 4 (Foil type) $\times$ 2 (Word Length) ANOVA.

2.4.2. Production portion

After hearing the real label and three foils, the children were asked to say the name of the dinosaur they just saw. This approach allows analysis of how a type of foil could interfere with the production of the dinosaur's name. Only the effect of the foils on production was measured, because only foils would be hypothesized to cause interference. The dependent measure was the number of words where one could verify that the child's production had been influenced by a foil presented in the recognition phase.

2.5. Stimuli

The nonword stimuli are included in Appendix B. These are the same stimuli used in Alt (2011). Phonotactic frequency was computed for each nonword using summed biphone probabilities obtained through the Phonotactic Probability

Calculator (Vitevitch & Luce, 2004). There was a statistically significant difference between the probability of words in the high and low phonotactic probability groups. Some of the stimuli were originally included in Munson et al. (2005). The nature of the modification for foils differed by position. For initial or final foils, we made decisions that allowed us to follow English phonotactic rules. For example, adding consonants to initial position syllables often resulted in nonwords that followed English phonotactic rules, while adding consonants to word-final syllables often violated English phonotactic rules. Therefore, most of the word-final foils involved consonant deletion, while the word-initial foils contained both consonant deletions and additions. Syllable modification foils differed according to word length. The choice for syllable deletion for 2-syllable words was based on (a) trying to avoid creating a real word and (b) balancing first and second syllable deletion. For the 4 syllable words, syllable deletions were targeted for the 2nd and 3rd syllables, with the intention of keeping the broadest components of the word envelope intact. In all cases, the foils were produced with standard English stress patterns.

The novel dinosaurs were animated (using Adobe Flash) and pilot tested to ensure they did not evoke common names. Each novel dinosaur was notably different from the other dinosaurs and differed along dimensions of shape, colors, body pattern, and size. (See Appendix C.)

2.6. Scoring

In the recognition task, children were asked to make a decision about whether a particular label was an accurate representation of a dinosaur's name. Responses were recorded via button press. Accuracy of the response was automatically recorded by the computer.

In the production task, children were asked to produce the dinosaur's name, because Joe simply could not remember it. Responses were digitally recorded for later transcription. The names children produced were transcribed off-line by certified speech language pathologists or graduate students who had been trained in phonetic transcription. Each transcription was scored for the percent of consonants correctly produced (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997). One hundred percent of the transcriptions were double-scored by either the first author, or another certified speech language pathologist. Discrepancies were resolved by the use of a third listener. Inter-rater reliability averaged 93.7% with a range of 83.33–100% agreement.

2.6.1. Determination of interference

If the child's production matched the target characteristics of the foil, then the production was said to be influenced by the input. For the word-initial foil manipulation, the target characteristics were either a consonant deletion or consonant addition. In the word-final foil manipulation, the target characteristic was the deletion of the final consonant. For the syllable modification foil manipulation, the target characteristic was the deletion of the second or the third syllable; the remaining production had to be correct in such a way that it was clear what syllable was missing. If a child's production showed evidence that it had the target characteristics of two foils (e.g. word-initial foil and syllable modification), then the production was considered to be influenced by multiple foils. In order to count as having been influenced by a foil, the child's production had to match the manipulated part of the foil exactly. For example, a child would only be counted as having been influenced by a word-initial foil for/vugim/if their production was/vrugim/, not/ugim/or/vlugim/. Each word the child produced was either determined as having been influenced or not influenced by a foil presented in the recognition phase.

3. Results

A mixed design ANOVA was conducted for the recognition portion of the task to determine what parts of a word a child attended to. Correct rejections of foils that manipulated different parts of words (e.g. word-initial, word-final, syllable structure) would be indicative of attention to those parts of the newly learned word. For each type of foil, we calculated the hit rate (real label) or correct rejection rate (foils), and these levels of accuracy were included in the analyses. We did not use d-prime because we were interested in the performance on each individual choice. Although participants heard 4 choices for each label, they were not made aware that there were 3 incorrect choices and 1 correct choice for each label. In addition, they did not receive feedback on their answers, so earlier responses should not have influenced subsequent responses.

3.1. Recognition portion

The first ANOVA had group (SLI, TD) as the between-group measure and foil type (real label, initial modification, final modification, syllable modification) and word length (short, long) as the within group variables. With an alpha level set at $p = .05$, there were main effects for foil type ($F(3, 114) = 28.40$, $p < .001$, $\eta_p^2 = .42$) and word length ($F(1, 38) = 17.78$, $p < .001$, $\eta_p^2 = .31$), but no effect for group ($F(1, 38) = 1.058$, $p = .31$, $\eta_p^2 = .027$). These main effects were modified by interactions. Specifically, there was an interaction between group × foil type ($F(3, 114) = 8.72$, $p < .001$, $\eta_p^2 = .18$). Post hoc test using Tukey HSD showed that the SLI group was less accurate than the TD group on the rejection of word-final foils ($p = .037$), but more accurate than the TD group on rejection of word-initial foils ($p = .024$). Percentage of hit rates and correct rejection rates for each participant group are reported in Fig. 1. Despite predictions related to group and limited capacity in term of word length, there was no significant interaction between group and word length ($F(3, 38) = .797$, $p = .377$, $\eta_p^2 = .02$). The interaction between group × length × foil type approached, but did not reach significance ($F(3, 114) = 2.24$, $p = .086$,

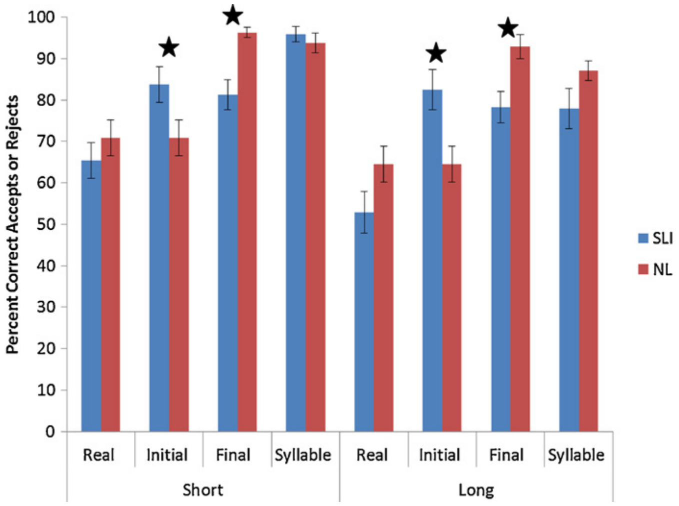

Fig. 1. Percentage of hit rates of the real label and correct rejections of each foil by word length for each group on the recognition portion of the experimental task. ★Significant at $p < .05$.

$\eta_p^2 = .05$). We used planned comparisons to examine the relation between performance on word-final foils and syllable-modified foils relative to word length by group. Findings were that the between group differences were significant for word-final foils for both short ($F(1, 38) = 14.88$, $p < .001$) and long nonwords ($F(1, 38) = 9.28$, $p = .004$). There were no between group differences for syllable-modified foils for either short ($F(1,38) = .48$, $p = .48$) or longer words ($F(1,38) = 2.84$, $p < .09$).

An additional significant interaction was found for foil type × word length ($F(3,114) = 3.44$, $p = .01$, $\eta_p^2 = .083$). However, given that our hypotheses were centered on between-group differences related to these within-group factors, this difference was not further explored.

3.2. Production portion

To determine the effect of interference on word production, a mixed design ANOVA was run with group as the between-group variable (SLI, TD) and word length (short, long) and error type (word-initial, word-final, syllable structure, multiple errors) as the within-group variables. Recall that a word would only be counted as having an error if the error was identical to the modification in the foil (e.g. if the word-final foil was a consonant omission, there must have been the same consonant omission in the word-final position of the child's production). There were main effects for group ($F(1, 36) = 18.72$, $p < .001$, $\eta_p^2 = .34$), word length ($F(1, 36) = 11.79$, $p < .001$, $\eta_p^2 = .24$), and foil type ($F(1, 36) = 32.29$, $p < .001$, $\eta_p^2 = .47$). Out of the 24 words children were asked to learn, the average number for which there was evidence of interference was 5.94 (SD = 2.81) for the SLI group compared to 2.55 (SD = 1.98) for the TD group. These effects were qualified by an interaction between group and foil type ($F(3, 108) = 3.86$, $p = .01$, $\eta_p^2 = .09$) and length × foil type ($F(3, 108) = 4.97$, $p = .002$, $\eta_p^2 = .12$). Using an unequal N Tukey HSD (due to the omission of data for two of the SLI participants caused by equipment failure), we clarified the nature of the interaction between group and foil type and found that the SLI group ($X = 1.72$, SD = .34) was influenced by word-final foils significantly more than the TD group ($X = .80$, SD = .56) ($p < .001$). The length by foil interaction was clarified to show that all children showed evidence of greater interference on word-final foils on long, versus short words. The number of words influenced by foils at each word length, for each participant group, is located in Fig. 2. A three-way interaction between group, word length, and foil type approached, but did not reach significance ($F(3, 108) = 2.36$, $p = .07$, $\eta_p^2 = .06$).

4. Discussion

4.1. Evidence for diagnosis specific performance

The literature clearly shows that children with SLI do not learn words as well as peers (e.g. Kan & Windsor, 2010). Importantly, there are components of word learning in which children with SLI perform as well as peers. For example, they can learn shorter words (Alt, 2011) and process sublexical information (Seiger-Gardner & Brooks, 2008). However, different parts of the word being learned may be more vulnerable than others for children with SLI. We tried to determine if there were specific parts of a word that would be more difficult for children with SLI to learn than peers. Our findings for the recognition task provided evidence that children with SLI were attending to different types of features than their unimpaired peers. The children with SLI were noticeably worse at correctly rejecting word-final foils. However, they were better than the TD group at correctly rejecting word-initial foils, and performed the same on syllable-modified foils. Although the two groups differed in terms of the foils that they were most vulnerable to, these differences were not split along lines of (possible) sublexical detail. Given these findings, it is hard to argue that the children with SLI simply had underspecified phonological

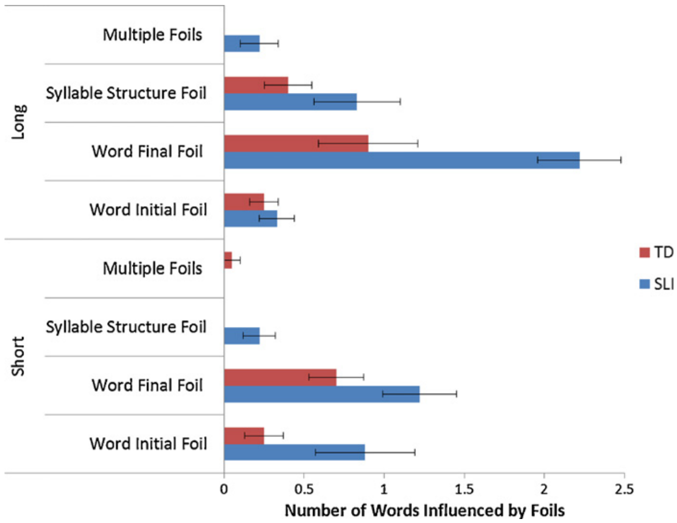

Fig. 2. Average number of words (this is out of 24 words total. The maximum number of errors per word length would be 12) influenced by foils for each group, presented by word length.

representations compared to TD peers. In fact, the children with SLI were even better than their unimpaired peers on correctly rejecting word-initial foils. This is in contrast to Criddle and Durkin's (2001) finding. The difference may be due to the fact that Criddle and Durkin asked children to learn novel morphemes, which, in English, most often occur in word-final position. The appearance of these morphemes in word-initial position may have been unexpected and therefore disrupted learning. Our study asked children to learn a sequence of phonemes and pay attention to the manipulation of individual phonemes. This appears to be a qualitatively different learning task.

The key finding is that children with SLI appear to be attending to different parts of novel words than unimpaired peers. There are several explanations for this finding. First, performance may have been affected by the types of changes made to word-initial and final foils. Word-initial foils used a combination of consonant substitutions and deletions, while word-final foils were primarily made using consonant deletion. This was done to ensure all foils followed English phonotactic rules. However, McNeill and Hesketh (2010) found that typically developing children were more likely to recognize consonant deletions compared to substitutions. Therefore, word-final foils should have been easier to recognize.

Even though each foil had some change on the prosodic structure of each word, each word and foil still followed English patterns for stress and prosody. All evidence points to the fact that in terms of salience, final syllables should have precedence. This assumes that children with SLI will be able to use typical patterns of prosody for learning. However, there is conflicting evidence about both the success of children with SLI and adults with a history of language learning disabilities when using prosody cues in learning. Preschool children with SLI have been shown to demonstrate appropriate sensitivity to prosodic cues, particularly those involving syllable stress – a task which is most relevant to the current study (Plante, Bahl, Vance, & Gerken, 2011). In contrast, Fisher, Plante, Vance, Gerken, and Glattke (2007) found that children with SLI were not able to discriminate as well as unimpaired peers when determining whether or not two sentences were the same based on prosodic cues. In this same study, adults with a history of language learning disabilities could successfully complete this task (Fisher et al., 2007). However, Bahl, Plante, and Gerken (2009) found that adults with a history of language learning disabilities could not learn the rules of an artificial language based on stress patterns, although adults without a history of impairment were able to do so. It may be the case that the prosodic or phonemic cues which are salient to unimpaired learners are simply not as salient to children with SLI. Given the mixed evidence for prosodic performance for children with SLI, the prosody account is not fully convincing.

A second alternative is that children with SLI pay close attention to word-initial phonemes in order to compensate for a limited working memory capacity. Some authors have suggested that children with SLI have a limited capacity for learning (e.g. Just & Carpenter, 1992; Leonard, 1998). If phonological working memory capacity is an issue for these children, then attention to the initial phonemes may be a strategy, whether overt or covert, to maximize their limited working memory capacity. Children with SLI would attend to the first few phonemes they hear, at the expense of the last few. The fact that we saw use of this strategy regardless of word length makes sense in that a child would never know in advance how long a novel word will be. In English, attention to word-initial information this is not necessarily a bad option. Most word roots appear early in a word, whereas word endings tend to carry morphological details. Although morphemes are undoubtedly important for full comprehension of a word, they are not nearly as salient for gross comprehension as word roots. Recall that there is something of a disparity in the literature regarding the salience of word final syllables. Although literature shows that word-final syllables tend to be salient (e.g. Kehoe, 2001) especially for morphemes (e.g. Slobin, 1973), children with SLI often omit word-final grammatical morphemes, which were presumed to be less salient (Leonard, 1992). Viewing problems with word final changes as an effect of poor phonological working memory moves the focus of the problem away from saliency or grammar, and back to one of working memory. Our study did not require children to learn bound morphemes, so we cannot rule out the effect of grammar. However, it is certainly a possibility that the well-documented problems with word-final morphemes seen in children with SLI may be influenced by phonological working memory.

4.2. Evidence of interference

Our second hypothesis was that children with SLI would be more vulnerable to interference than unimpaired peers. Our task was set up so that children heard a real label and three phonologically based foils before they were asked to produce the name of a novel word. This presents a situation that could lead to interference in producing the novel word. All learners showed some evidence of interference from phonological foils. However, children with SLI were disproportionately affected by foils, particularly word-final foils, compared to TD peers. The children with SLI showed evidence of interference on roughly 25% of the words, compared with only 10% for unimpaired peers. There are two interpretations for this finding. One is that the SLI group had underspecified phonological representations that were easily replaced by the foils. However, if this were the only explanation, we might have expected to see a main effect for group in the recognition task; we did not. A second explanation is that, regardless of the level of specification of the phonological representation, the SLI group is more vulnerable to interference from foils. Newly learned information is likely to be more vulnerable to interference than established information (Mainela-Arnold et al., 2008). However, if a child's new words are more than twice as likely to be vulnerable to incorrect phonological cues, then it is not a leap to see how this could lead to overall poorer word learning.

The SLI group's particular problem with word-final foils suggests that their representations are not equally vulnerable across a word. There are places where the children with SLI did just as well or better than the TD group. This means that children with SLI do not simply have poorly represented information overall. The fact that word-final foils continue to be a problem in the production phase provide converging evidence for the findings in the recognition task.

4.3. Do longer words exacerbate fast mapping problems?

Word length is an issue for all English word learners, with longer words posing greater challenges than shorter words (e.g. Baddeley, Thompson, & Buchanan, 1975). In terms of accuracy, children with SLI show greater deficits compared to unimpaired peers when learning longer words (Alt, 2011). Hollich et al. (2000) note the cognitive constraints inherent in word learning, and we have already mentioned the idea that children with SLI may have a limited capacity for language learning compared to peers (e.g. Just & Carpenter, 1992). Therefore, we wondered if the use of longer words, which requires greater cognitive and linguistic resources, would exacerbate any differences in the parts of words children with SLI attend to, or increase interference.

In terms of the parts of the word that children attended to, word length did not have a significant effect on between group differences. A length by group interaction was not identified. Thus, we can conclude that the additional cognitive load of learning longer words does not appear to change salience of the parts of words children with SLI attend to.

There was greater interference for word-final foils on longer words, but this was true for all children, not just those with SLI. Visually, it appears that the SLI group is driving this difference, but the statistics show that this is only a trend, and is not significant. There are other visual trends that suggest that word length may increase the vulnerability of information about syllable structure for children with SLI. Therefore, we suggest that the increased demands of learning longer words may have an effect on what parts of a word are more vulnerable to interference specifically for children with SLI. However, this study did not have the power to demonstrate this conclusively. Even if these differences exist, they are likely not a primary contributing cause to word learning differences between children with SLI and unimpaired peers.

4.4. Limitations of the study

Although we aimed to gauge what parts of words children attend to in novel word learning situations, our assessment is far from complete. Due to challenges with achieving reliable ratings of vowel production, we did not examine children's recognition or production of vowels or knowledge of medial syllables. It is possible that differences in these parts of words might contribute to the fast mapping profile. Sutherland and Gillon (2007) suggested that subtle difference in vowels increased the difficulty of their nonword learning task. This will need to be examined in a future study.

A second limitation is that our modifications for word-initial and final consonants differed in that our initial changes tended to be phoneme additions and our final changes tended to be phoneme deletions. The stimuli modifications were constructed to mirror English phonotactic patterns. It is possible that some of the differences we found in the recognition and production of word-final modification foils were really due to the nature of the modification (deletion) rather than the position of the modification in the word. However, this seems unlikely given McNeill and Hesketh's (2010) findings that children noticed consonant deletions more readily than consonant substitutions.

5. Conclusions

This study has added to the field's knowledge of children's initial phonological representations by examining those representations (both in terms of recognition and production) in a fast mapping paradigm. The use of a fast mapping paradigm in this context is unique and adds to what we know about how words that are not already lexicalized are processed. Overall, children with SLI appear to have access to the same level of phonological detail about words that children with TD do during fast mapping. On a recognition task, children with SLI show both strengths and weaknesses. However, children with SLI encode different components of novel words than unimpaired peers. Children with SLI were more successful at correctly rejecting word-initial foils than unimpaired peers, but were less accurate at rejecting word-final foils. The two groups showed equivalent accuracy when foils modified the number of syllables in a word. These differences may be due to a compensation for a limited capacity for learning (i.e. protection against long words) or an inability to use prosodic cues in the same way as peers. On a production task, the novel word representations of children with SLI were far more vulnerable to interference than children with typical language skills, with evidence for particular difficulty with word-final foils. The length of the word to be learned did not significantly influence the position of the modification that was attended to. The results from this study suggest that children with SLI may be using slightly different encoding strategies than unimpaired peers even when they are learning words successfully. Current models of limited capacity do not provide for a specific mechanism for children to compensate for the limitation. Future work may be able to uncover more information about these putative strategies and their mechanism.

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Appendix A. Continuing education

1. Children with SLI showed the same pattern of foil rejection as their typically developing peers.
   a. true.
   b. false.
2. Children with SLI were better than unimpaired peers at correctly rejecting:
   a. word initial foils.
   b. word final foils.
   c. syllable modification foils.
   d. b and c.
3. Children with SLI were worse than unimpaired peers at correctly rejecting:
   a. word initial foils.
   b. word final foils.
   c. syllable modification foils.
   d. a, b and c.
4. Which of the following statements reflect the results regarding interference?
   a. children with SLI demonstrated the same amount of interference as unimpaired peers.
   b. children with SLI only demonstrated more interference than unimpaired peers on long words.
   c. children with SLI demonstrated more interference than unimpaired peers.
   d. children with SLI demonstrated less interference than unimpaired peers.
5. A possible strategy employed by children with SLI to compensate for phonological working memory deficits, overtly or covertly, is to attend to:
   a. final phonemes because word endings can carry morphological details.
   b. final phonemes because these are more salient prosodically.
   c. initial phonemes because they never know how long a new word will be.
   d. initial phonemes because that is where syntactic information typically appears in English.

Appendix B. Stimuli used in the receptive and expressive portions

Low frequency stimuli			
Nonword	Initial change	Final change	Syllable modification
vugim	vrugim	vugi	vug
nəfæm	əfæm	nəfæ	fæm
kɛfuʃ	klɛfuʃ	kɛfu	kɛf
tedaum	tredaum	tedau	daum
bedæg	bledæg	bledæ	dæg
paugəb	plaugəb	paugə	paug

Appendix B (*Continued*)

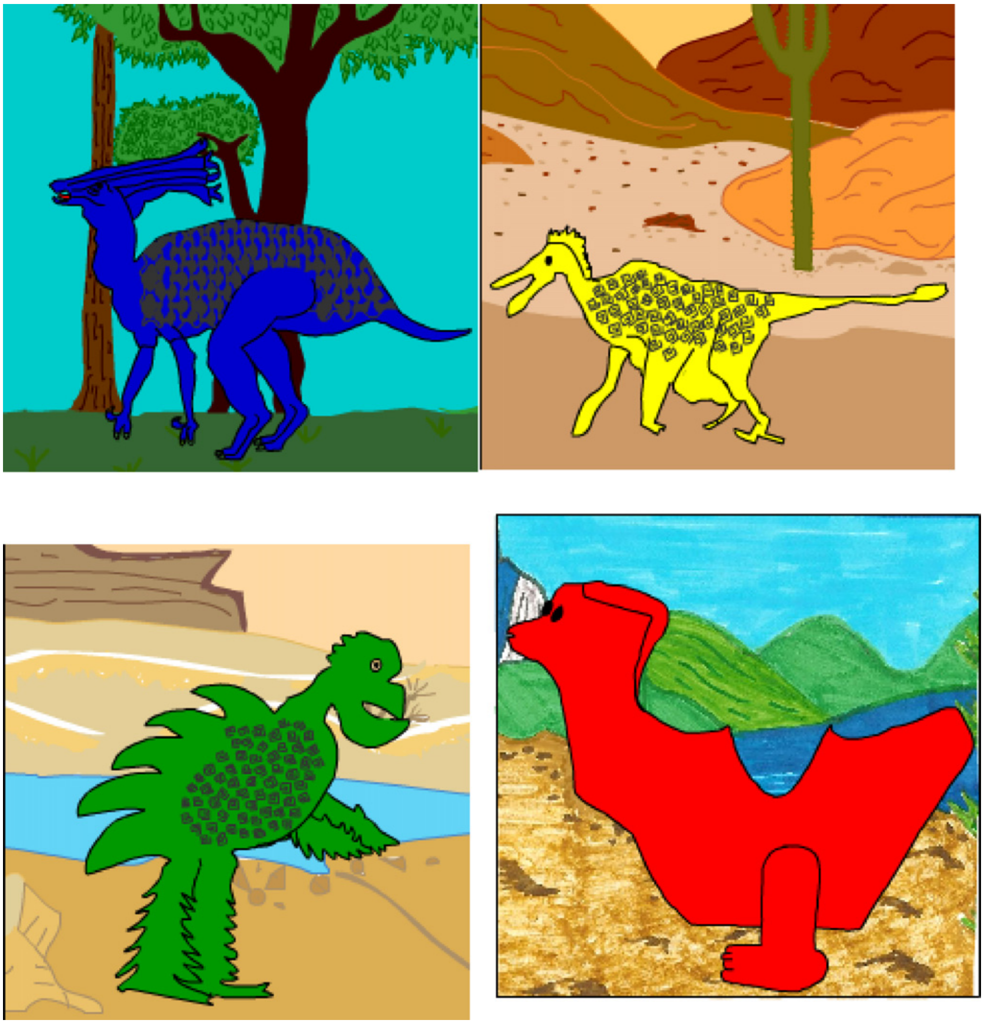
Low frequency stimuli

Nonword	Initial change	Final change	Syllable modification
zʊfetʃoðɛd	ʊfetʃoðɛd	zʊfetʃoðɛ	zʊtʃoðɛd
joiwɛʃaʒoik	oiwɛʃaʒoik	joiwɛʃaʒoi	joiwɛʒoik
vufætʃazəʃ	ufætʃazəʃ	vufætʃazə	Vutʃazəʃ
dedʒʊkivan	dredʒʊkivan	dedʒʊkiva	dedʒʊvan
gɛʃetoigefip	grɛʃetoigefip	gɛʃetoigefi	gɛtoigefip
nikoigefip	ikoigefip	nikoigefi	nikoifip

High frequency stimuli

Nonword	Initial change	Final change	Syllable modification
nokɛn	okɛn	nokɛ	nok
bIkuf	bIIkuf	bIku	kuf
mæbɛp	æbɛp	mæbɛ	mæb
tɛkɛt	trɛkɛt	tɛkɛ	kɛt
sæsIn	stæsIn	sæsI	æs
tanəg	tranəg	tanə	nəg
voinəfesæt	oinəfesæt	voinəfesæ	voifesæt
kisɚtaləm	krisɚtaləm	kisɚtalə	kisɚləm
monitɚkif	onitɚkif	monitɚki	motɚkif
wæketIsIt	æketIsIt	wæketIsI	wækesIt
kefɚmæsən	krefɚmæsən	kefɚmæsə	kemæsən
kIsəsaʃəm	krIsəsaʃəm	kIsəsaʃə	kIsəʃəm

Appendix C. Examples of dinosaurs used in the experimental tasks



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