

Running Head: EFFECTS OF LEXICAL KNOWLEDGE

The Effects of Lexical Knowledge on Nonword Repetition

by

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Abstract

The present study examined the influence of long-term lexical memory on young children's performances on nonword repetition tasks. Children's responses on a nonword repetition task from a prior study (Metsala, 1999) were analyzed for 3 age groups ($M_{\text{age}} = 51, 70, \text{ and } 78$ months). Syllables from 2-, 3-, and 4-syllable nonwords were entered into a database to determine the lexical status of each syllable (word or nonword) and neighborhood densities (number of similarly sounding words for a target syllable). In addition, errors made on the nonword syllables were analyzed to determine error types (word substituted for nonword target or nonword substituted for word target) and error densities. Findings supported the position that lexical memory influences nonword repetition across the four main hypotheses. First, word syllables within nonwords were repeated correctly more often than nonword syllables for the longest nonwords. Young children were less accurate than the two older groups at repeating nonword syllables, but there were no developmental differences for word syllables. Second, the young and middle groups of children more frequently substituted a word for a nonword target than a nonword for a word target; however, this effect was absent for the oldest group of children. Third, children were more accurate at repeating syllables from dense than sparse neighborhoods for 3- and 4-syllable nonwords. Finally, the mean density of children's errors across each target syllable was higher than the target densities. Results are discussed within the broader context of lexical development and provide further support for the proposition that individual differences on nonword repetition tasks are largely accounted for by children's vocabulary knowledge.

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The Effects of Lexical Knowledge on Nonword Repetition

Nonword repetition is one of the most basic and important language abilities (Gathercole, 2006). Repeating multi-syllabic nonwords is a task in which there is a lot of individual variation during childhood, and it is considered to be one of the most effective predictors of language learning ability. That is, children who have lower nonword repetition scores are slower to learn novel phonological forms of new words (Gathercole, 2006). In further examining this area, researchers can gain a better understanding of the underlying processes, which, in turn, may lead to more helpful interventions in this area.

The explanation of individual differences in children's nonword repetition put forth in the present study arises from accounts of lexical development. These accounts propose increasingly segmented representations of lexical items in long-term memory and have led to a greater understanding of children's development on speech perception and phonological awareness tasks. One model will be further discussed after two main alternate explanations for individual differences on nonword repetition tasks are reviewed.

Nonword repetition has frequently been used as a measure of phonological short-term memory (e.g., Gathercole, 1995; Gathercole & Adams, 1993; Gathercole, Hitch, Service, & Martin, 1997; Gathercole, Willis, Emslie, & Baddeley, 1991, 1992). According to one model, the phonological loop is a subsystem of short-term working memory and its purpose is to encode, maintain, and manipulate linguistic information (Baddeley, 1986). The phonological loop is made up of two components; a subvocal rehearsal of material to maintain information, and a short-term phonological store that keeps the speech-based information in phonological code (Baddeley, 1986). It is this

latter component of the phonological loop in working memory that is referred to in this paper. Nonword repetition tasks involve listening to and repeating aloud made-up words, such as, “hond”, “pennel”, and “empliforvent”. A robust relationship has been found between nonword repetition and vocabulary (e.g., Dollaghan, Biber, & Campbell, 1995; Gathercole, 1995; Gathercole & Adams, 1993; Gathercole et. al, 1997; Gathercole et. al, 1992; Metsala, 1999). That is, children’s vocabulary knowledge and performance on nonword repetition tasks are correlated. There is some debate in the literature concerning the determinants of individual differences in nonword repetition performance and in explaining the relationship between nonword repetition and vocabulary.

Nonword repetition is a complicated language task that involves the support of memory processes. Auditory processing and speech-motor output processes have been suggested as possible explanations for individual differences in nonword repetition and the correlation between vocabulary and nonword repetition (Bowey, 2006; Gathercole, 2006). It has been suggested that hearing deficits can cause poor detection and analysis of sounds that leads to poor performance on nonword repetition tasks (Gathercole, 2006). However, poor hearing does not explain performance differences between short and long nonwords that have been consistently found in past research (see Gathercole et al., 1991). Central auditory processing was also examined as a possible cause for individual differences on nonword repetition. It was proposed that difficulty processing quickly presented stimuli could lead to poor phonological representations which would impede nonword repetition performance (Gathercole, 2006). However, current evidence demonstrates that this explanation does not account for the majority of variability in children on nonword repetition (see Bishop, Bishop, Bright, Delaney, & Tallal, 1999).

Speech-motor output processes have also been implicated as influencing nonword repetition performances. Children who have difficulty planning and executing commands (e.g., poor articulation) may perform poorly on nonword repetition tasks (Gathercole, 2006). However, although difficulty planning and executing commands does constrain performance, it does not explain the vast majority of variability in nonword repetition (see Gathercole & Baddeley, 1990).

There are two positions that have substantial amounts of evidence to explain the correlation between vocabulary and nonword repetition and variation on nonword repetition tasks. One position suggests that nonword repetition is a relatively pure measure of phonological short-term memory capacity which directly impacts vocabulary acquisition (Gathercole, 1995; Gathercole & Adams, 1993; Gathercole et al., 1991; Gathercole et al., 1992). That is, short-term memory capacity determines one's ability to hold a novel phonological form in short-term memory, an important component of learning new words. The second position proposes that individual differences on nonword repetition tasks also reflect the structures of representations in long-term lexical memory (Bowey, 2001; Dollaghan et al., 1995; Metsala, 1997, 1999; Snowling, Chiat, & Hulme, 1991). According to this account, individual differences in nonword repetition are also a result of vocabulary knowledge.

The purpose of the present study was to further explore influences on young children's nonword repetition performance. In particular, this study examined the extent to which long-term lexical knowledge impacts young children's performance on nonword repetition tasks. I took the position that nonword repetition is not a pure measure of phonological short-term memory capacity. Rather, there is a significant impact of

lexical representations on nonword repetition performance (see Bowey, 2001; Metsala, 1999). According to this view, lexical representations become more segmented or organized around the phoneme as a result of vocabulary development. This segmental organization provides a support or scaffold for composing and holding the novel phonological forms in short-term memory. In this paper, two views regarding the development of young children's phonological representations are briefly explained, and one model of lexical development that was used as the context for the hypotheses of this study is reviewed. Next, variables important in this model and in research on adult spoken word recognition are highlighted. This is followed by a review of the research on children's nonword repetition. Next, the hypotheses, method, and results are presented. Finally, the results of the study are interpreted and related to past research in the discussion.

Lexical Development

In the literature on the development of children's speech perception, there are two different accounts on the formation of the phoneme. A phoneme is the smallest unit of speech that, when altered, changes the meaning of a word. The first account is the accessibility position, which states that phonemic segments are present and functional in early infancy, but are not accessible (e.g., on phoneme awareness tasks) until there is some reading experience (e.g., Gleitman & Rozin, 1977). In essence, this theory claims that the phoneme segment is formed very early and does not change; instead, it simply becomes more accessible (Gleitman & Rozin, 1977).

A second view regarding the origin of the phoneme is the emergent position, in which the phoneme arises because of relations between vocabulary size and performance

constraints (Fowler, 1991; Jusczyk, 1997; Metsala & Walley, 1998; Walley, 1993).

That is, as vocabulary size increases, there is a need to distinguish between more similarly sounding words. This increasing need to discriminate among similarly sounding words leads to segmented lexical representations; in turn, changes in representations leads to easier access of the phoneme. According to this position, phonological representations are initially more holistic, and phonemic representations emerge or become more salient with increasing vocabulary. Phonemic awareness in early childhood is limited by the representations and organization of words in the mental lexicon. This position is presented in the Lexical Restructuring Model (LRM), in which spoken word recognition and changes in lexical representations are functions of vocabulary growth (Metsala & Walley, 1998). It is important to note that although LRM is reviewed, empirical evidence bearing on such is beyond the scope of this paper. The model is briefly overviewed next.

Metsala and Walley (1998) proposed the LRM to help explain the way that lexical structures change from infancy through to early and middle childhood (see also Garlock, Walley, & Metsala, 2001; Metsala, 1999; Walley, 2006; Walley, Metsala, & Garlock, 2003). In the LRM, the representations of spoken words in memory become increasingly segmentalized or organized around the phoneme with development (see also Fowler, 1991; Storkel, 2002). This gradual change in representations of spoken words leads to the accessibility of the phoneme for phonological awareness tasks and for reading (Metsala & Walley, 1998).

Vocabulary Development

The first claim of this model is that as vocabulary size increases there is a greater need to distinguish between more words, and this induces a restructuring or re-organizing process from more holistic to segmented representations. Segmented or phonemic representations form the basis of more adult-like recognition (Charles-Luce & Luce, 1990). When infants/toddlers learn to recognize their first words, it is most likely in a relatively holistic manner, such that there is little differentiation and structural organization for words in memory (Fowler, 1991; Metsala & Walley, 1998; Storkel, 2002). This seems to be appropriate given there would be little need to make fine-grained differentiations because infant/toddler's vocabulary knowledge is so limited. Infants and toddlers may have some beginnings of segmented lexical representations for speech perception of highly familiar words, but not for more unfamiliar words (e.g., Walley, 1993). In speech production, similar thoughts are discussed in that whole words, and not segments, are believed to be the differentiating factor for children just beginning to speak, with segments as the discriminating feature later in development (Ferguson, 1986).

There is significant vocabulary growth after the initial vocabulary growth spurt, such that reorganization of the mental lexicon may continue (Metsala & Walley, 1998). A vocabulary growth spurt occurs around two years of age, and there are continual changes over the course of preschool and the early school years (Metsala & Walley, 1998). The first 50 words in a vocabulary are often learned very slowly, but subsequently there is a growth spurt in the number of words that are spoken and understood (Anglin, 1989). Four year-old children have absolute vocabulary sizes of

approximately 2,500 to 3,000 words, first graders around 7,000 to 10,000, and children in grade five know approximately 39,000 to 46,000 words (Anglin, 1989). This illustrates that vocabulary knowledge continues to grow at a significant pace in early and middle childhood. In accordance with this, as more words are learned there is an increase in the number of words that have similar sounding neighbors, and thus, there is an increase in the need for finer discriminations amongst similar words (but see Dollaghan, 1994). It is when this need begins to arise that there is a shift in the use of words to segments as discriminating factors.

Neighborhood Density

The second claim of the LRM is that segmental restructuring is brought on by specific aspects of vocabulary growth. One of these factors is the familiarity of the word to the listener. Familiarity has been examined in two main ways; first, how frequent the listener has heard the word (frequency); second, the average age at which the word enters a child's vocabulary (i.e., age of acquisition; Metsala & Walley, 1998). Words that are heard more frequently by a listener or those acquired at an early age are recognized more quickly and accurately (e.g., Garlock et al., 2001; Metsala, 1997). Within LRM, this has been interpreted to mean that increased familiarity leads to earlier segmentation. Another factor related to vocabulary growth is phonological neighborhoods. A word's similarity neighborhood has been defined as those words that differ by one phoneme substitution, deletion, or addition. The number of similar words forms the neighborhood density of a word (e.g., Charles-Luce & Luce, 1990; Dollaghan, 1994; Dollaghan et al., 1995; Logan, 1992; Metsala, 1997; see also Storkel, 2004). Charles-Luce and Luce (1990) found that with increases in age, neighborhoods become more dense even above what is accounted

for by vocabulary size. As neighborhood density increases throughout the lexicon, there is increasing pressure to differentiate between more similar sounding words (Metsala 1997; Storkel, 2002). It has been suggested that this need for differentiation necessitates representations based on finer-grained units of analyses, such as the phoneme segment. It follows that words that reside in dense neighborhoods (i.e., many similar sounding words) will have a greater pressure to become segmentalized than words in sparse neighborhoods (i.e., few similar sounding words). That is, words that have many similar sounding neighbors or reside in dense neighborhoods will become segmentalized before words that have few similar sounding neighbors (Metsala, 1997; Storkel, 2002). In accordance with this, it is important to note that lexical restructuring does not take place on a lexical-wide basis, but rather in an item-by-item fashion. Given these points, neighborhood density is considered a driving force in the segmental restructuring or re-organization in the mental lexicon.

The variables highlighted in LRM are important in adult models of spoken word recognition. In the neighborhood activation model, a model of spoken word recognition in adulthood, the frequency and neighborhood density of a word affect recognition (Luce & Pisoni, 1998). That is, the ability to recognize a word quickly and accurately is based on how similar the word is to other words, the number of words that closely resemble the word, and how often the words in the neighborhood have been heard (Goldinger, Luce, & Pisoni, 1989). In line with this model, adults' word recognition is better for words that are heard often and have few neighbors, than words that are infrequent but have many neighbors (Goldinger et al., 1989). Words from dense neighborhoods are at a disadvantage because there is a lot of competition for activation.

The third claim of the LRM is that segmental restructuring does not occur all at once, to all of the words in one's vocabulary. Instead, it is gradual and occurs based on factors related to each individual word, such as familiarity, frequency, and the density of the neighborhood in which the word resides (Metsala & Walley, 1998). In support of this claim, Metsala (1999) showed that young children's phoneme awareness performances were better for highly familiar words versus less familiar words. She argued that the greater segmental organization in lexical memory for more familiar words accounts for the difference on phoneme awareness tasks.

Children's Nonword Repetition

It is within the context of changing lexical representations and lexical re-organization that we examine individual differences in children's nonword repetition (NWR) performance. The existence of a strong correlation between NWR performance and vocabulary has been well established (e.g., Dollaghan et al., 1995; Gathercole, 1995; Gathercole & Adams, 1993; Gathercole et al., 1992; Gathercole et al., 1997; Metsala, 1999; Snowling et al., 1991). Two different positions have been put forward to explain this correlation. In the first position, it is proposed that NWR measures phonological short-term memory capacity, and that phonological short-term memory capacity influences vocabulary acquisition. The second position suggests that vocabulary development impacts the structure of lexical representations, and the structure of lexical representations impacts one's ability to construct and hold a novel phonological form in mind. A review of the evidence for each of these positions follows.

Nonword Repetition as a Measure of Phonological Short-term Memory

Initial studies by Gathercole and her colleagues proposed that nonword repetition is a measure of phonological short-term memory (e.g., Gathercole & Adams, 1993; Gathercole et al., 1991; see also Wagner, Torgesen, & Rashotte, 1999). Gathercole and her colleagues have suggested that nonword repetition tasks provide a relatively pure test of phonological memory. This was contrasted with digit or word span, which were not pure because they activated lexical items in long-term memory. In her early research, Gathercole and her colleagues found a strong correlation between nonword repetition and vocabulary. For example, in a longitudinal study, Gathercole and her colleagues (1991) tested one group of children at three different ages. The same group of children was administered a battery of tests three times; at age four, five, and six. Each year, the children were given the same battery of tests to examine nonword repetition, nonverbal intelligence, vocabulary, and word reading. There were two major findings from this study. First, accuracy for nonword repetition tasks decreased as the nonwords increased in length from two to four syllables. This relationship between nonword length and repetition accuracy of nonwords was consistent for all three age groups. Gathercole and her colleagues interpreted these findings to mean that phonological short-term memory capacity constrains nonword repetition performance. That is, as the length of the nonwords increases, there is a greater demand on phonological short-term memory and performance deteriorates. The second major finding from Gathercole and her colleagues' (1991) study was the positive correlation between performance on the nonword repetition tasks and the wordlikeness ratings of nonwords. Twenty undergraduate university students listened to the nonwords and rated how wordlike they were based on a scale

from one (“not like a word at all”) to five (“very like a word”). Mean ratings were assigned to each of the nonwords based on the student’s estimates. The nonwords that were rated as highly wordlike were repeated correctly more often than the nonwords that were rated low in wordlikeness (Gathercole et al., 1991). These findings were interpreted to mean that phonological short-term memory capacity and familiarity (i.e., wordlikeness) influence nonword repetition performance.

Snowling and colleagues (1991) retorted with differing interpretations of Gathercole and her colleagues’ (1991) findings. These authors suggested there is also evidence for the alternative view that long-term lexical knowledge has a significant impact on nonword repetition. Snowling and her colleagues proposed that nonword repetition is more than a simple test of phonological memory. In fact, according to these researchers, it is a task that involves children’s prior lexical knowledge (phonological and prosodic; Snowling et al., 1991). Gathercole et al. (1991) assumed that nonword length had an effect on nonword repetition tasks because of constraints of phonological memory. However, Snowling and her colleagues (1991) argued that the longer the nonwords, the greater the demands on phonological processes, more so than memory. These researchers suggested that the findings could be explained by poor vocabulary knowledge, which leads to an inability to manage the processing demands of nonword repetition tasks. Snowling and her colleagues noted that phonological memory capacity may be a partial explanation for the correlation between nonword repetition and vocabulary, but they brought attention to this second account.

Gathercole and colleagues (1992) made a slight revision to their previous predictions and proposed that both phonological short-term memory and vocabulary

knowledge can affect nonword repetition performances. In a longitudinal study, one group of children was tested at ages four, five, six, and eight. The children were given tests of nonverbal intelligence, vocabulary, phonological short-term memory (nonword repetition), and reading at each age. Gathercole and her colleagues found that at age four, phonological memory was more strongly associated with vocabulary performance one year later than the reverse relationship (Gathercole et al., 1992). However, after age five, this relationship seemed to shift. When the children's scores were compared at ages five and six, and then at six and eight, their vocabulary scores were predictive of phonological memory skills rather than the reverse (Gathercole et al., 1992). The researchers concluded that between ages four and five, phonological short-term memory contributes more to vocabulary development than vocabulary knowledge does to performance on nonword repetition tasks. The researchers explained that this is reasonable given that short-term representations are the basis of more permanent representations in long-term memory. Gathercole and colleagues stated that between ages five and eight, vocabulary development is no longer predicted by nonword repetition performance. They concluded that after age five, children's lexical knowledge influences their nonword repetition performances. Gathercole and her colleagues suggested that it may be as memory skill for words improves, the phonological memory constraints become fewer (Gathercole et al., 1992).

Gathercole (1995) again examined the contributions of phonological short-term memory and lexical knowledge to performance on nonword repetition tasks. In a longitudinal study, one group of 70 children was tested at age four and at age five. At each administration, the battery of tests included tasks to examine nonword repetition,

memory span, vocabulary, nonverbal abilities, and reading. Gathercole found that at both ages four and five, the children's repetition was more accurate for the nonwords rated high in wordlikeness than those rated low in wordlikeness. Further, Gathercole found that repetition accuracy for words rated low in wordlikeness was more strongly correlated with short-term memory span (as measured by a digit span test) than nonwords rated as high in wordlikeness. Additionally, a stronger association was found between vocabulary and performance on nonwords rated low in wordlikeness than high in wordlikeness. Taken together, Gathercole (1995) concluded that repetition of nonwords rated low in wordlikeness is a more pure and sensitive measure of phonological short-term memory than nonwords rated high in wordlikeness, which are influenced by long-term lexical knowledge.

Gathercole and colleagues (1997) set out to show how phonological memory capacity constrains the phonological portion of learning new words. That is, instead of using standardized vocabulary tests to examine vocabulary knowledge, the researchers wanted to get a more detailed look at word learning by varying the amount of phonological information that had to be utilized to learn the words presented. To accomplish this, Gathercole and her colleagues had sixty-five children, aged five years, complete tests of digit span, nonword repetition, vocabulary, nonverbal intelligence, and word learning. There were a total of four tasks to examine word learning. Two of the word learning tasks consisted of the children learning word-word pairs or word-nonword pairs. In the learning phase of the experiment, the researcher presented the pairs and had the children immediately repeat them. In the recall phase, the researcher presented one of the pair's words or nonwords (depending on the condition) and the children were to

recall the associated item. In the other two word learning tasks, the children were to learn meaningful new words presented in a story. These tasks involved the researcher telling the children a story and introducing a new word and definition within the story. The children's knowledge of the new words was later tested when they had to recall the name of the new word in the first task, and the definition of the new word in the second task. Gathercole and her colleagues found that there were strong associations between the children's vocabulary test scores and the four word-learning tasks. That is, children with higher vocabulary scores performed better on the word-learning tasks. In addition to this, Gathercole and her colleagues found that digit span and vocabulary predicted performance on the word-nonword learning test and the recall of names word learning test. This correlation was not found for nonword repetition when vocabulary knowledge was controlled. This was interpreted to mean that children's ability to learn new words was influenced by phonological memory capacity (as measured by digit span) and long-term lexical knowledge. The researchers concluded that the acquisition of new sound patterns is facilitated by both short-term memory capacity and by access to words of similar phonology stored in memory (i.e., lexical knowledge; Gathercole et al., 1997).

Lexical Knowledge and Nonword Repetition

There is additional evidence for the view that lexical knowledge has a significant impact on nonword repetition (e.g., Bowey, 2001; Metsala, 1999; Snowling et al., 1991). Dollaghan, Biber and Campbell (1993) set out to test the hypothesis that the lexical status of nonwords (i.e., if the nonwords contain real word versus nonword stressed syllables) influences performance on nonword repetition tasks. To examine this, Dollaghan and her colleagues (1993) presented 11 boys, nine to 12 years old, with 48 three and four syllable

nonwords. The 48 nonwords were constructed in pairs so that the complexity of the syllables and the placement of the stressed syllable were identical. One item in each pair contained a real word stressed syllable; the other item in each pair contained a phoneme that was altered to transform the real word stressed syllable into a nonword syllable. Each of the children were randomly assigned to one of three 16-item lists to avoid practice effects on the nonword repetition task (i.e., because the pairs were so similar). Results showed that nonwords that had real word stressed syllables were repeated more accurately than nonwords with nonword stressed syllables (Dollaghan et al., 1993, 1995). Dollaghan and her colleagues argued that long-term knowledge impacts nonword repetition performance. The researchers stated that when nonwords have real word syllables, there are then more resources available to apply to the rest of the nonword, which then leads to greater repetition accuracy (Dollaghan et al., 1993).

Dollaghan and colleagues (1995) conducted an error analysis on nonword repetition performance of 30 males ages 9 to 12 years to further examine the influence of lexical knowledge on nonword repetition ability. One hypothesis was that if long-term lexical knowledge influences nonword repetition performance, then nonword syllables would more frequently be replaced with word syllables than the reverse. Dollaghan and her colleagues found that almost six times as many errors resulted in turning a nonword string into a real word string than the opposite. Vowel substitutions were further examined to make a strong argument for the intrusions of long-term lexical knowledge because they are more difficult to explain in terms of perception and articulation. Dollaghan and her colleagues found that in 84 percent of vowel substitutions, nonword strings were changed into real words. The researchers concluded that there is strong

evidence that long-term lexical knowledge has a significant impact on nonword repetition ability.

Metsala (1999) proposed that individual differences in lexical representations affect performance on nonword repetition tasks. Further, she argued that the correlation between vocabulary and nonword repetition performance is largely due to these individual differences in lexical representations. First, as vocabulary size increases, there is pressure for words to become more segmentalized as a way to discriminate between them. This segmented structure or organization, in turn, affects performance on nonword repetition tasks. Groups of four year-olds, five to six year-olds (Experiment one), and three year-olds (Experiment three) completed a series of vocabulary, phonological awareness, digit span, and nonword repetition tasks. Phonological awareness tasks were used as an indication of the degree of segmentation of lexical representations (see also, Bowey, 1996; 2001). With four to six year-olds, phonological awareness and nonword repetition accounted for largely overlapping variance in a measure of vocabulary. In Experiment one, nonword repetition failed to account for variance in vocabulary beyond that accounted for by a measure of phonological awareness (phonological awareness did account for additional variance in vocabulary above that accounted for by nonword repetition). On the other hand, a composite short-term memory span measure (digit and word span tasks) did account for additional variance in vocabulary after that accounted for by a phonological awareness variable. Similarly, for Experiment three, three year-olds' performance on a nonword repetition task did not account for variance in vocabulary beyond measures of phonological awareness; whereas phonological

awareness did account for unique variance in vocabulary beyond nonword repetition, as did a digit span measure.

Metsala concluded that the shared variance between nonword repetition and vocabulary was attributable to individual differences in lexical representations (as measured here by phonological awareness tasks) and not to phonological short-term memory. Bowey (2001) replicated these findings with five year- olds and further examined these relationships over a one year follow-up. She did find that nonword repetition at time one predicted vocabulary one year later after variance associated with time one phonological awareness was removed. Bowey (2001) concluded that:

Overall, these findings show qualified support for the claim that the capacity component of nonword repetition contributes directly to vocabulary in young children. They suggest that the association between nonword repetition and vocabulary in young children may, to a substantial extent, reflect a latent phonological processing ability that is also manifest in phonological sensitivity (p. 441).

Masoura and Gathercole (2005) examined the relationship between nonword repetition and vocabulary knowledge of more advanced language learners. They had Greek children who had been studying English as a second language for an average of three years perform English and Greek nonword repetition tasks and vocabulary tests. The children were presented with an English paired associate learning test with picture-word combinations, and were then tested by having to report the names of presented pictures in English. Masoura and Gathercole (2005) found that the high English vocabulary group performed better on the learning tasks than the low English vocabulary

group. The high and low English nonword repetition groups did not significantly differ on their learning tasks. Also, nonword repetition was highly correlated with English vocabulary knowledge for both the English and Greek measures. Thus, the findings support the position that learning new words is influenced by word representations that are already stored in lexical memory (Masoura & Gathercole, 2005). The researchers noted that the greater the size of the child's vocabulary, the more useful and successful the strategy of using lexical representations from long-term memory will be. Additionally, it was noted that even children with poor phonological learning ability will be able to develop lexical representations in their long-term memories eventually, because exposure of vocabulary in one's native language is so redundant.

Goals of the Present Study

The overall purpose of the present study was to further examine the effects of lexical knowledge on children's nonword repetition performance. One goal of the present study was to investigate several findings from Dollaghan and colleagues (1993, 1995), albeit with a slightly different method, and to extend their work by examining developmental differences. We tested whether real word syllables are pronounced correctly more often than nonsense word syllables on nonword repetition tasks across three age groups. We also examined whether real word syllables would more frequently be substituted for nonword strings than the reverse across the three age groups.

The second purpose of this study was to examine repetition accuracy for syllables that are from dense neighborhoods as compared to accuracy for syllables from sparse neighborhoods. It was expected that syllables from dense neighborhoods would be pronounced correctly more often than syllables from sparse neighborhoods. This was

expected because, according to LRM, the pressure to segmentalize word representations comes from an increase in similarly sounding lexical items. It was hypothesized that words that reside in dense neighborhoods would, therefore, be segmented before words in sparse neighborhoods. It was believed that it should be easiest to recombine phonemes for nonword syllables that draw on these most common phoneme patterns (see Metsala, 1999). Along this same line of reasoning, it was hypothesized that the mean density of error responses would be higher than the density of the nonword target syllables. This was expected because phonemes in dense neighborhoods are most common and most organized, and these patterns should be the easiest for the children to draw on. These findings would provide further evidence of the intrusion of long-term lexical knowledge on nonword repetition performance.

The final purpose of this study was to investigate the interactions of these errors with age. It was expected that older children would pronounce more syllables correctly in sparse neighborhoods than the younger children because of their better defined lexical representations. Alternatively, it was proposed that performance on syllables from dense neighborhoods may have been as well specified for both age groups; therefore, age effects may be reduced for nonword syllables from dense neighborhoods. The hypotheses for this study were:

Hypothesis one: Real word syllables will be repeated correctly more often than nonword syllables (Dollaghan, et al., 1995, 1993). Developmental differences will be greatest for nonword versus word syllables.

Hypothesis Two: Real word responses will more frequently be substituted for nonword syllables than nonword responses substituted for real word syllables (Dollaghan et al., 1995, 1993).

Hypothesis Three: Syllables from dense neighborhoods will be pronounced correctly more often than syllables from sparse neighborhoods. Differences between older and younger children will be more pronounced for syllables from sparse than dense neighborhoods.

Hypothesis Four: The mean density of errors will be higher than the density of target syllables.

Method

Participants

Data collection was part of a larger study, previously reported in Metsala (1999). The data from all of the children across Metsala's (1999) three experiments was included in the present study. The youngest 95 children were recruited from private pre-school settings that primarily served middle class populations in a mid-Atlantic metropolitan area in the United States. The remaining 100 children were recruited from seven Grade one classes in two schools serving low- to middle-class families in the same metropolitan area. English was the first language of most all the children; 22 children did not have English as their first language, but had learned it very early and were fluent speakers of English. There were no parent-reported speech and hearing difficulties (Metsala, 1999).

For the purposes of the current study, the children were divided into three age groups of approximately equivalent sizes. These resulting groups were a Young group ($n = 66$, $M_{\text{age}} = 51.61$ months, range = 36 to 59 months); a Middle group ($n = 65$, $M_{\text{age}} = 70.22$ months, range = 60 to 74 months); and an Older group ($n = 64$, $M_{\text{age}} = 78.05$ months, range = 75 to 84 months).

Procedure

The children were given a battery of standardized tests that included a measure of receptive vocabulary, the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981), and a measure of word reading and letter recognition, the Wide Range Achievement Test-Revised (WRAT-R; Jastak & Wilkinson, 1984). The children also completed a number of phonological awareness tasks (e.g., onset-rime blending task to

form a word or nonword; isolating initial phonemes of words and nonwords; phoneme blending for words), and digit and word span tasks.

All of the participants completed a nonword repetition task taken from Gathercole and Adams (1993). There were a total of 32 nonwords in this task; eight nonwords each of one, two, three, and four syllables (see Appendix A). For the current study, data was examined for two-, three-, and four-syllable nonwords, for a total of 24 nonwords. One-syllable nonwords were not included in this study because of reported problems with acoustic characteristics which led to poor performance on these nonwords (Gathercole et al., 1991). Children were tested individually in a quiet room located within their preschools or schools. Children listened to each tape-recorded nonword and were required to repeat it immediately. A graduate student who had an introductory course in phonology transcribed the children's responses.

Results

Hypothesis One: Real word syllables will be repeated correctly more often than nonword syllables. Developmental differences will be greatest for nonword versus word syllables.

All syllables at least two phonemes in size were examined across the 24 nonwords. The lexical status (i.e., real word vs. nonword) of each syllable was determined by submitting each syllable into the Washington University Speech and Hearing Lab Neighborhood Database (<http://128.252.27.56/neighborhood/Home.asp>). Appendix B shows the number of real word and nonword syllables for each nonword length. Proportion of real word syllables correct was then calculated for each subject by dividing the number of correct word syllables for each nonword length by the total number of word syllable targets for that nonword length. Proportion of nonword syllables correct was calculated for each subject in the same manner; the number of correct nonword syllables for each nonword length was divided by the total number of nonword syllables for that nonword length.

To test whether children performed differently for word versus nonword syllables, a three-way mixed-design ANOVA was completed with age (young, middle, older) as a between-subject variable, and lexical status (word, nonword) and nonword length (two-, three-, four-syllable) as within-subject variables. Results showed main effects of age, $F(2, 192) = 3.60, p < .05$, nonword length, $F(1, 102) = 66.04, p < .01$, and lexical status, $F(1, 192) = 12.28, p < .01$, and interaction effects for Lexical Status x Nonword Length, $F(1, 192) = 26.46, p < .01$, and Age x Lexical Status x Nonword Length, $F(2, 102) = 3.07, p < .05$. Simple F -tests were used to examine the Lexical Status x Nonword Length interaction (see Figure 1). Word syllables were pronounced correctly more often than

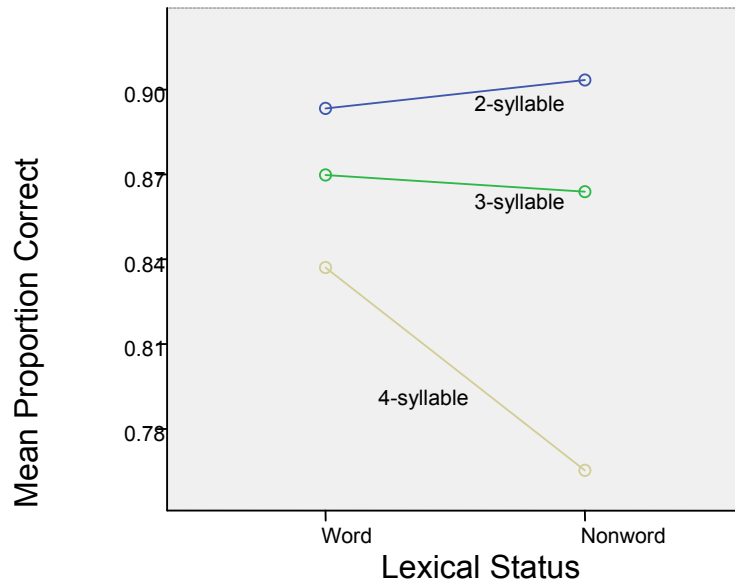


Figure 1. Mean proportion of word and nonword syllables correct for two-, three-, and four-syllable nonwords with word and nonword syllables where higher means indicate better performances.

nonword syllables for four-syllable nonwords ($M = .84, SE = .011$ vs. $M = .77, SE = .012$ for words and nonwords respectively). Word and nonword syllables were pronounced correct equally as often for two- and three-syllable nonwords ($M = .89, SE = .009$ vs. $M = .90, SE = .009$ for two-syllable words and nonwords respectively; $M = .87, SE = .012$ vs. $M = .86, SE = .010$ for three-syllable words and nonwords respectively).

Simple F -tests were used to examine the three-way interaction of Age x Lexical Status x Nonword Length. The Lexical Status x Nonword Length interaction described above was consistent across each age group (see Table 1 for Means and Standard Errors). For all nonword lengths, the young group of children was not as accurate for nonword syllables as the middle and older children, who did not differ from each other ($M = .81, SE = .013$ vs. $M = .86, SE = .013$ vs. $M = .86, SE = .013$ for young, middle, and older groups respectively). For the word syllables, there was no difference in accuracy across the three age groups.

Hypothesis Two: Real word responses will more frequently be substituted for nonword syllables than nonword responses substituted for real word syllables. For each of the real word syllables, the number of times a nonword response was given was calculated for each participant (i.e., the number of errors for a word syllable that were a nonword). These total occurrences were divided by the number of real word syllables (22) to give a proportion of occurrence for each participant (nonword substituted for word). Similarly, for all the nonword syllables, the number of times a real word response was given was calculated (i.e., the number of errors for a nonword syllable that were a real word). This total number of substitutions was divided by the number of nonword syllables (36) to give a proportion of occurrence for each participant (word substituted for nonword).

Table 1

Proportion Means and Standard Errors for the young, middle, and older children on word and nonword syllables for two-, three-, and four-syllable nonwords

| Age | Lexical status | Nonword length | Mean proportion | Standard error |
|--------|----------------|----------------|-----------------|----------------|
| Young | Word | 2-syll. | .85 | .016 |
| | | 3-syll. | .86 | .020 |
| | | 4-syll. | .83 | .019 |
| | Nonword | 2-syll. | .88 | .016 |
| | | 3-syll. | .84 | .016 |
| | | 4-syll. | .73 | .021 |
| Middle | Word | 2-syll. | .90 | .016 |
| | | 3-syll. | .87 | .021 |
| | | 4-syll. | .84 | .019 |
| | Nonword | 2-syll. | .91 | .016 |
| | | 3-syll. | .88 | .017 |
| | | 4-syll. | .79 | .021 |
| Older | Word | 2-syll. | .93 | .016 |
| | | 3-syll. | .88 | .021 |
| | | 4-syll. | .84 | .019 |
| | Nonword | 2-syll. | .92 | .016 |
| | | 3-syll. | .88 | .017 |
| | | 4-syll. | .78 | .021 |

These proportions were submitted to a two-way ANOVA with age (young, middle, older) as a between-subject factor and substitution type (word for nonword, nonword for word) as the within-subject variable. Results showed a main effect for substitution, $F(1, 191) = 11.30, p < .01$, and the Age x Substitution interaction approached significance, $F(2, 191) = 2.81, p = .063$. Overall, more words were substituted for nonword targets ($M = .13; SE = .006$) than the reverse of nonwords substituted for word targets ($M = .10; SE = .009$). Simple F -tests were used to examine the Age x Interaction (see Figure 2).

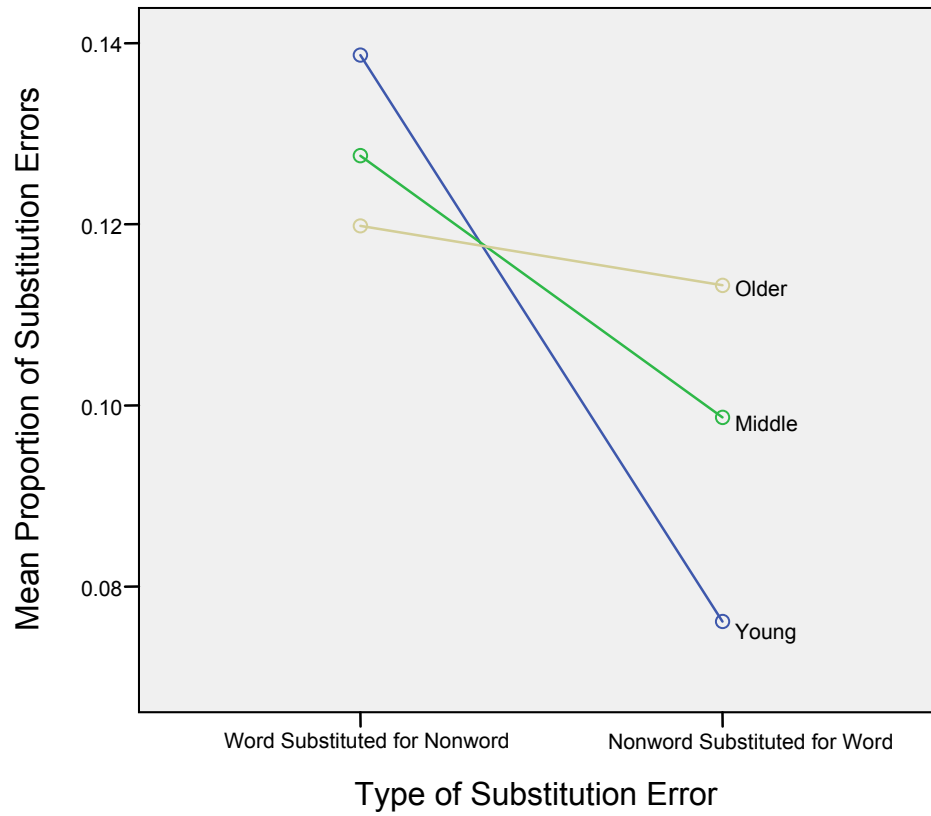


Figure 2. Mean proportion of substitution errors for words substituted for nonwords vs. nonwords substituted for words for children in the young, middle, and older groups where higher means indicate higher number of errors.

The young children showed this effect, $F(1, 191) = 14.10, p < .01, (M = .14; SE = .010; \text{vs. } M = .08; SE = .016$ for words substituted for nonword and nonwords substituted for words respectively), the middle children showed a trend toward this effect, $F(1, 191) = 2.96, p = .09, (M = .13; SE = .010 \text{ vs. } M = .10; SE = .016$ for words substituted for nonwords and nonwords substituted for words respectively), and the effect was absent for the oldest group of children, $F(1, 191) = .15, p = .70, (M = .12; SE = .011 \text{ vs. } M = .11; SE = .016$ for words substituted for nonwords and nonwords substituted for words respectively).

Hypothesis Three: Syllables from dense neighborhoods will be pronounced correctly more often than syllables from sparse neighborhoods. Performance differences between older and younger children will be more pronounced for syllables from sparse than dense neighborhoods.

To obtain the density of the syllables, syllables were submitted into a neighborhood database (Metsala, 1999). A median split technique was used to categorize the syllables as dense or sparse based on the number of neighbors the syllable had. This resulted in 28 syllables categorized as sparse; the mean number of neighbors for these sparse targets was 2.00 (range one to five; $SE = .32$). Thirty syllables were categorized as dense, with the mean number of neighbors 11.17 (range of 6 to 19; $SE = .70$). For each subject, the proportion of correct responses for each of the sparse and dense syllable conditions at each nonword length was calculated (see Appendix C for the number of sparse and dense syllables at each nonword length).

These proportions were submitted to a three-way ANOVA with age (young, middle, older) as a between-subjects variable, and density (sparse, dense) and nonword

length (two-, three-, four-syllable) as within-subject factors. Results indicated main effects of age, $F(2, 192) = 4.77, p < .05$, density, $F(1, 193) = 46.99, p < .01$, and nonword length, $F(1, 192) = 63.88, p < .01$, and an interaction effect of Density x Nonword Length, $F(1, 192) = 13.24, p < .01$.

Post-hoc analyses revealed that the young children's accuracy ($M = .82, SE = .011$) was lower than the middle ($M = .86, SE = .012$) and older children ($M = .87, SE = .012$), and the middle and older children's accuracy did not differ. Contrary to the second part of the hypothesis, age did not interact with density, $F(2, 192) = .56, p = .57$. Simple F -tests were used to examine the Density x Nonword Length interaction (see Figure 3). Results showed that children were more accurate for syllables from dense versus sparse neighborhoods for each of the three- and four-syllable nonwords (see Table 2 for Means and SEs). There was no difference between dense and sparse syllable accuracy for the two-syllable nonwords (see Table 2 for Means and SEs). Further, for syllables from sparse neighborhoods, children were more accurate at each nonword length; that is, for two- vs. three- vs. four-syllable nonwords. For syllables from dense neighborhoods, two- and three-syllable nonwords were equally accurate and more so than four-syllable nonwords (see Table 2 for Means and SEs).

Hypothesis Four: The mean density of errors will be higher than the density of target syllables.

Each error response was submitted to the same Neighborhood Calculation database as the target syllables. Next, for each of the 57 syllables for which errors were made, the mean error density was calculated across participants. The mean density of errors for each syllable was then compared to the target syllables density in a paired

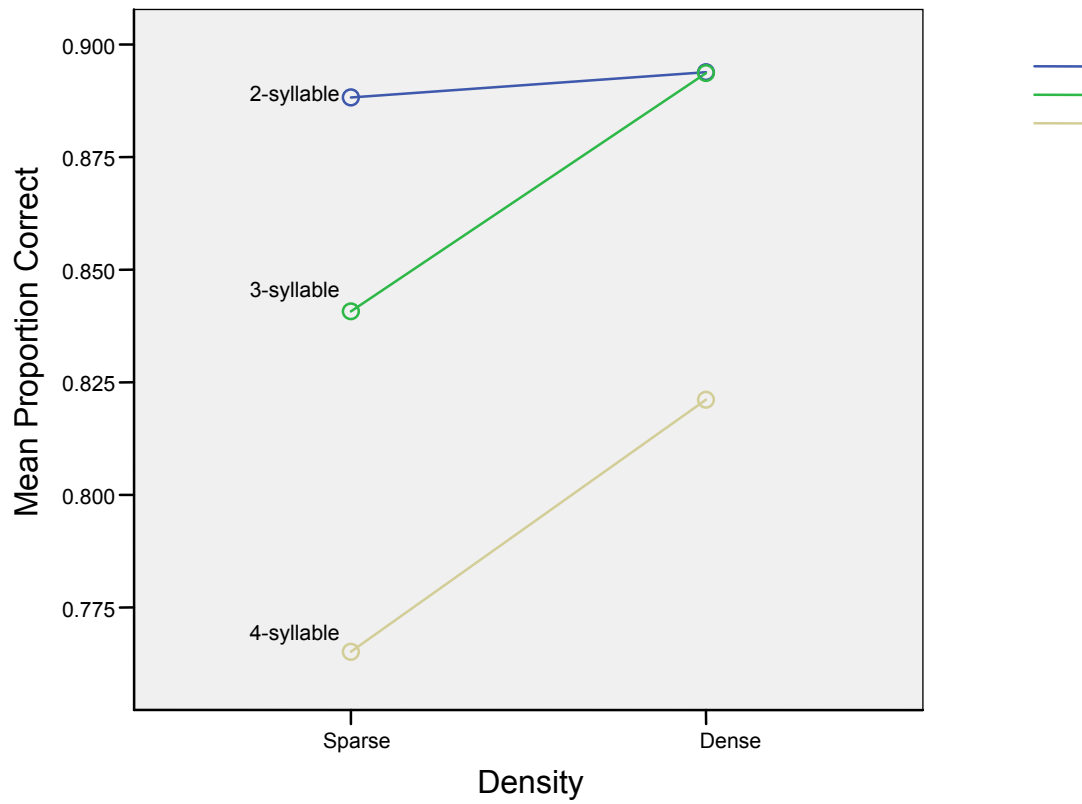


Figure 3. Mean proportion correct for dense and sparse syllables from two-, three-, and four-syllable nonwords in which higher means indicate better performances.

Table 2

Proportion Means and Standard Errors for dense and sparse syllables from two-, three-, and four-syllable nonwords

| Density | Nonword length | Mean proportion | Standard error |
|---------|----------------|-----------------|----------------|
| Sparse | 2-syll. | .89 | .010 |
| | 3-syll. | .84 | .011 |
| | 4-syll. | .77 | .012 |
| Dense | 2-syll. | .89 | .009 |
| | 3-syll. | .89 | .008 |
| | 4-syll. | .82 | .011 |

t-test. Results confirmed the hypothesis; the mean density of the errors was greater than the target densities, $t(56) = -2.36, p < .05$, ($M = 8.16, SD = 3.77$ vs. $M = 6.79, SD = 5.52$ for error and target densities respectively).

Discussion

There is some debate in the literature concerning the determinants of individual differences in nonword repetition performance and in accounting for the correlation between nonword repetition and vocabulary. One position suggests that nonword repetition is a fairly pure measure of phonological short-term memory. This position also proposes that individual differences in phonological short-term memory cause variation in children's vocabulary knowledge (Gathercole, 1995; Gathercole & Adams, 1993; Gathercole et al., 1991; Gathercole et al., 1992). According to this position, an important component of vocabulary acquisition is holding novel phonological forms in short-term memory.

Another position, congruent with the Lexical Restructuring Model (Metsala & Walley, 1998), argues that individual differences on nonword repetition tasks are a result of vocabulary knowledge and reflect underlying lexical representations (Bowey, 2001; Dollaghan et al., 1995; Metsala, 1999; Snowling et al., 1991). Recently, Jones, Gobet, and Pine (in press) presented a computational model that replicated findings from past nonword repetition studies. Jones and his colleagues demonstrated that while phonological short-term memory capacity constrains nonword repetition performance, individual differences can be accounted for by variations in vocabulary knowledge. These findings are in line with the arguments of the second position, that vocabulary knowledge leads to individual differences on nonword repetition tasks.

Accuracy for word syllables in nonwords compared to nonword syllables within nonwords was examined in this study. One purpose of comparing performance on word versus nonword syllables was to demonstrate that holding a nonword in phonological

short-term memory does make contact with representations in lexical memory (Bowey, 2001; Dollaghan et al., 1995; Metsala, 1997, 1999). One contrary position might argue that attention to the nonword task de-emphasizes processing lexical elements of the stimulus (i.e., it is held in phonological short-term memory as a nonsensical string and is not interacting with long-term memory). This position is similar to arguments made in the adult literature concerning attention to lexical versus sublexical aspects of processing (Vitevitch, Luce, Pisoni, & Auer, 1999). However, congruent with the Lexical Restructuring Model, it was proposed that lexical and frequent sublexical patterns are automatically activated and influence repetition accuracy.

Indeed, evidence was found to support this position in that word syllables were pronounced correctly more often than nonword syllables; however, this result was restricted to four-syllable nonwords. Children across the age groups showed more accurate pronunciations for word syllables than nonword syllables for the four-syllable nonwords. This finding is congruent with and extends the work of Dollaghan and colleagues (1993, 1995) in which they showed the presence of a word in a nonword increases the accuracy for the remaining segments of the nonword. The current study further demonstrated that the word syllables themselves were repeated more accurately than the nonword syllables. Dollaghan and colleagues did examine three- and four-syllable nonwords; however, they did not analyze their data by nonword length. The present study did find a Nonword Length x Lexical Status interaction and word syllables in two- and three-syllable nonwords did not show an advantage over nonword syllables in two- and three-syllable nonwords. There are several reasons, both theoretical and empirical, that may explain these results.

The children's response accuracy for two- and three- syllable nonwords was quite high and this may have led to a ceiling effect in that performances were close to perfect (e.g., the proportion correct for two-syllable nonwords was .90 and for three-syllable nonwords was .86), and therefore, there was not a lot of variation in accuracy and the chance of an effect was reduced. Metsala (1999) demonstrated similar effects; lexical status and familiarity effects on phonological awareness tasks were found only for the more difficult task of phoneme blending and not on the less difficult onset-rime blending task. Additionally, the effect was most robust for the youngest children. Also, Metsala (1999) examined the effect of neighborhood density on phonological awareness (i.e., onset-rime blending and phoneme blending) and found that there was an effect of neighborhood density on the phoneme blending task, but not the onset-rime blending task. That is, on the more difficult phonological awareness task (i.e., phoneme blending), children performed better for words from dense versus sparse neighborhoods. This effect was not seen for the less difficult task, onset-rime blending. Thus, past research has also found that the influence of lexical variables is greatest for more demanding tasks relative to the age of sample. When one is efficient at a task, the ability to perform even more difficult nonword syllables is demonstrated and the facilitative effect of lexical knowledge is not evident.

Developmental differences were also examined for word versus nonword syllable accuracy. Previous research did not examine age in relation to lexical status (e.g., Dollaghan et al., 1993; 1995). Indeed, developmental differences were found to be greatest for nonword versus word syllables. Younger children were poorer than the two older age groups for nonword syllables, but the groups performed equally as well for

word syllables. One reason for this may be that repeating nonwords depends on compiling phonemes across lexical items. That is, representations in phonological short-term memory need to be compiled across different lexical items for nonword syllables, and this is easier for older children than younger because older children have better organized lexicons. In contrast, across ages, lexical representations can support repetition of word syllables equally well. Metsala (1999) gave a similar argument when she stated that nonwordlike items stress the lexicon more so than wordlike items because they have to be compiled from sublexical units, such as individual phonemes, as opposed to larger (e.g., lexical) representations.

Dollaghan and colleagues (1995) conducted an error analysis on repetition performance for nonwords with stressed word and nonword syllables. Dollaghan and her colleagues categorized the errors into one of four categories; word substituted for a nonword, nonword substituted for a word, nonword substituted for a nonword, and word substituted for a word. She divided each of these subtotals by the total number of errors to get a proportion of errors. These researchers proposed that lexical information would intrude on the nonword repetition task and would result in more frequent word substituted for nonword error types than other error types. Indeed, this was precisely what her results supported; words were substituted for nonwords six times more frequently than the reverse.

For this study, a similar argument was proposed, but tested in a slightly different way. The number of times that a nonword was substituted for a word (or a word was substituted for a nonword) were calculated and divided by the total number of word (or nonword) targets. In addition, the current study examined developmental differences,

which Dollaghan and colleagues did not. Indeed, word responses were more frequently substituted for nonword targets than nonword responses for word targets. This effect was strongest for young children, followed by middle children, and absent for older children. Increases in vocabulary knowledge allow nonword structures to be better held in phonological short-term memory (e.g., Jones et al., in press). Additionally, the more holistic or less segmental representations proposed to be characteristic of younger children would imply that they have less flexibility of smaller, segmental units and more intrusion of larger lexical or whole-word units. Therefore, younger and middle children demonstrated intrusions of whole words more frequently than the reverse due to less flexibility with smaller, sublexical units. Older children, on the other hand, were better able to construct representations in phonological short-term memory that were truer to the speech input, or made errors substituting small units, not whole words (and therefore the absence of the lexical error substitution effect).

Effects for neighborhood density have been found relative to a number of different tasks (see Walley et al., 2003). Metsala (1999) found that children performed better on the onset-rime blending (less difficult phonological awareness task) versus phoneme blending (more difficult task) for words from sparse neighborhoods, but performed equally well across the phonological awareness tasks for words residing in dense neighborhoods. She reported that children also did better on phoneme-blending tasks for words from dense versus sparse neighborhoods. Similarly, Goswami and DeCara (2000) found that five and six year-olds performed better on rime judgments for words from dense versus sparse neighborhoods.

Gathercole, Frankish, Pickering, and Peaker (1999) examined phonotactic probabilities to investigate the influences on speech processes, expecting that high probability words would result in faster and more accurate recall. Phonotactic probability refers to the “frequency a segment or particular sequence of segments will occur in a given position in a word or syllable” (p. 307, Vitevitch, Luce, Pisoni, & Auer, 1999). Gathercole and her colleagues found that words were better recalled than nonwords and that performance was better on high probability nonwords than low probability nonwords. This result is relevant to density because density has been shown to be highly correlated with phonotactic probability (e.g., Vitevitch et al., 1999). One likely difference between the two is that phonotactic probability has a sublexical focus, while density has a lexical focus (Vitevitch et al., 1999).

Consistent with the current results, density was found to effect nonword repetition performance and it interacted with nonword length. Specifically, syllables from dense neighborhoods were repeated more accurately than syllables from sparse neighborhoods for the three- and four-syllables nonwords. This effect of density was not evident for syllables from two-syllable nonwords. These findings are similar to those for lexical status, in that the effect was only significant for the longer nonwords. There were fewer errors overall for the two-syllable nonwords than the three- and four-syllable nonwords. Since performances were almost perfect on syllables from two-syllable nonwords, there was little variability in the accuracy and the effect of density was not present. Additionally, as past research has demonstrated, the influences of neighborhood density are greatest for more demanding tasks relative to age (Goswami & DeCara, 2000;

Metsala, 1999). Therefore, the facilitative effect of density is not seen on the syllables from the two-syllable nonwords because the efficiency level on the task is so high.

Recently, Jones et al. (in press) presented a computational model to explain the findings of past research studies on nonword repetition. According to their model (EPAM-VOC), phonological short-term memory capacity acts as a bottleneck and therefore constrains nonword repetition. However, the model accounts for individual and developmental differences on nonword repetition tasks without the inclusion of variation in phonological short-term memory. In fact, in accordance with Metsala (1999), Jones and his colleagues demonstrated that individual differences on nonword repetition tasks can be accounted for solely by differences in vocabulary knowledge. Accordingly, EPAM-VOC modeled performance variation across differing nonword lengths. At first, the EPAM-VOC model does not have any phonemic knowledge built up. At this early stage, it is easier to master shorter nonwords because not as much phonological knowledge is needed to learn the shorter nonwords. Longer nonwords are more phonologically demanding and so require more phonemic input built into the model before they can be mastered (Jones et al., in press). That is, with increased phonemic and word knowledge, there are more developed structures than at earlier stages and the longer nonwords can be represented by fewer structures, which results in better performances with time. A similar explanation can be applied to both the lexical status and density effects evident only on the longer nonwords. At the early stages when there is not as much phonemic or lexical knowledge, and the long nonwords have not been mastered as the shorter ones have, the longer nonwords are more prone to the influences of lexical status and neighborhood density to support their performances. Importantly, the EPAM-

VOC model did not include lexical and density effects, but the findings and explanations put forward here are consistent with their working model.

To further examine the effects of neighborhood density, the mean density of errors was compared to the density of target syllables. This type of error analysis, to the best of our knowledge, has not been conducted in previous research on density effects. It was proposed that the mean density of errors would be higher than the density of the target syllables because it was expected that phoneme patterns in dense neighborhoods are most common and most organized, and these patterns should be the easiest for the children to draw on (Metsala, 1999). This is consistent with the expectation that long-term lexical knowledge would intrude upon nonword repetition performance and affect the responses given. Indeed, this hypothesis was confirmed in that the mean density of the errors was higher than the density of the target syllables, supporting the theory that the children were able to draw on lexical memory, and that density does impact responses on nonword repetition tasks.

This study contributed to the field of psycholinguistics in that it confirmed Dollaghan et al.'s (1993, 1995) findings (though examined and analyzed in a different manner) and extended the results to look at developmental differences in relation to lexical status and error types on nonword repetition tasks. Additionally, neighborhood density has not been previously examined in the context of nonword repetition performance and the results illustrate that there are important influences of density on nonword repetition. Our findings are also consistent with one recent computational model, EPAM-VOC. Again, we argue, as do Jones and colleagues (in press), that individual differences in nonword repetition performance are primarily due to lexical

knowledge and that support for this position was demonstrated throughout the hypotheses examined in the present study.

One limitation that should be noted is that unlike Dollaghan and colleagues (1993, 1995), the nonwords used in this study were not specifically designed to examine lexical status (nor neighborhood density effects). While the nonwords did serve the purposes of testing our hypotheses, future studies may examine these effects in a factorial design where lexical status and density are fully crossed. Further, in the literature on adults' spoken word recognition, phonotactic probability and neighborhood density are proposed to effect different levels of representations (see Vitevitch et al., 1999). These could be examined in children's nonword repetition performances. That is, nonword repetition tasks may be one avenue for testing whether the effects of phonotactic probability and neighborhood density can be differentiated in children.

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Appendixes

Appendix A

The 32 nonwords that participants were required to repeat in Metsala's (1999) study

| One-syllable | Two-syllable | Three-syllable | Four-syllable |
|--------------|--------------|----------------|----------------|
| Sep | Pennel | Commerine | Penneriful |
| Nake | Rubid | Barrazon | Loddenapish |
| Tull | Diller | Doppelate | Fenneriser |
| Thip | Bannow | Thickery | Woogalamic |
| Hond | Hampent | Frescovent | Blonterstaping |
| Grall | Glistow | Trumpetine | Stopograttic |
| Smip | Sladding | Brasterer | Contramponist |
| Clird | Tafflest | Skiticult | Empliforvent |

Appendix B

Number of real words and nonword syllables in the two-, three-, and four-syllable nonwords used in this study

| Word length | Lexical status of syllable | Number of syllables |
|----------------|----------------------------|---------------------|
| Two-syllable | Word | 8 |
| | Nonword | 8 |
| Three-syllable | Word | 5 |
| | Nonword | 12 |
| Four-syllable | Word | 9 |
| | Nonword | 16 |

Appendix C

Number of dense and sparse syllables in the two-, three-, and four-syllable nonwords used in this study

| Word length | Density | Number of syllables |
|----------------|---------|---------------------|
| Two-syllable | Dense | 9 |
| | Sparse | 7 |
| Three-syllable | Dense | 8 |
| | Sparse | 9 |
| Four-syllable | Dense | 13 |
| | Sparse | 12 |
