

Running Head: WORD LEARNING

An examination of children's word learning as a function of frequency of presentation,  
phonological neighborhood density, vocabulary, and nonword repetition

by

Megan Hebert

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### **Abstract**

The present study examined variables important in the development and organization of long-term phonological representations in order to better understand how these impact children's word learning. Children 4 through 7 years of age listened to stories which contained target nonwords, and then completed tasks to test for word learning. The nonwords were from dense or sparse lexical neighborhoods and were presented two or four times in the story. Children also completed a receptive vocabulary test and a nonword repetition task. For the first word learning task, there was a significant effect of frequency and the neighborhood density by frequency interaction approached conventional levels of statistical significance ( $p = .055$ ). Children learned words from dense neighborhoods better only for the lower frequency condition. The current study also examined the contributions of children's vocabulary knowledge and nonword repetition to learning for words from each of dense and sparse neighborhoods. Findings support the proposal that lexical representations from existing vocabulary knowledge make an important contribution to word learning for items from both sparse and dense neighborhoods.

**Table of Contents**

Abstract.....2

Table of Contents .....3

List of Tables and Figures .....4

Introduction .....5

    Lexical Representations in Adults .....5

    Lexical Representations in Children .....6

    Lexical Acquisition .....9

        Effects of Neighborhood Density on Lexical Acquisition .....9

        Effects of Word Frequency on Lexical Acquisition.....12

        The Relationship between Vocabulary Knowledge and Word Learning .....14

        Nonword Repetition .....17

    Present Study .....19

Method .....21

    Participants .....21

    Procedure.....22

    Results .....24

        Effects of Neighborhood Density, Frequency, and Vocabulary .....24

        Predictors of Children’s Word Learning .....25

Discussion.....26

References .....33

**List of Tables and Figures**

## Table 1

Means and standard deviations of children's word learning scores on word learning task one.....38

## Table 2

Means and standard deviations of children's word learning scores on word learning task two.....39

## Table 3

Correlations of predicting and outcome variables of children's word learning .....40

## Table 4

Summary of hierachical regression analysis for variables predicting word learning of sparse and dense neighborhoods .....41

## Figure 1

Mean proportion of correct responses for word learning task one .....42

## Introduction

One important aspect of developmental research on language acquisition is how children learn the phonological forms of words and how the mental lexicon is organized. Studies have focused on the organization of phonological representations in both children's and adults' mental lexicons. In particular, researchers have studied speech perception and spoken word recognition, spoken word production, and lexical acquisition toward delineating how lexical representations are formed and organized in lexical memory (Charles-Luce & Luce, 1990; Dollaghan, 1994; Metsala and Walley, 1998). To date, there is impressive consensus on understanding the organization of the adult lexicon, which is presumed to be the end point of development; however, the child mental lexicon is less understood and organizational principles more controversial (e.g., Logan, 1992; Storkel, Armbrüster, & Hogan, 2006). The present study is designed to contribute to understanding how children acquire novel phonological words through examining variables thought to be important in the development and organization of long-term phonological representations of lexical items.

### Lexical Representations in Adults

In the adult lexicon, it is presumed that phonological properties of words are organized into neighborhoods based on lexical similarity (e.g., Luce & Pisoni, 1998) or organized into groups of phonologically similar words. A lexical neighborhood is most frequently defined as the number of words that differ from a given word by a single phoneme addition, substitution or deletion. This organization of lexical items is thus proposed to be based on phoneme units within the adult lexicon (e.g., Charles-Luce & Luce, 1990; Luce and Pisoni, 1998). Words that differ from a target word in this way are described as "neighbors" and the number of neighbors a target word has determines its neighborhood density. For example, neighbors of the word *pit* would

include *bit*, *pot*, *spit*, *pig*, and *it*, among others (Charles-Luce & Luce, 1990; Logan, 1992).

Models of adult spoken word recognition suggest that words are categorized as residing in dense (many similar sounding neighbors) or sparse (few similar sounding neighbors) neighborhoods.

Research with adults support the assumptions concerning the organizational structure of the mental lexicon and the phonemic basis of lexical representations. Studies on spoken word recognition in adults have found that adults recognize and repeat words from high density neighborhoods slower and less accurately than words from sparse neighborhoods (e.g., Luce & Large, 2001; Vitevitch & Luce, 1998; 1999). Studies addressing speech production have reported that words from dense neighborhoods facilitate production and result in fewer errors than production of words from sparse neighborhoods (Vitevitch, 1997; 2002). These findings suggest that words in more dense neighborhoods have more competition and thus slower recognition (high density disadvantage). However, for speech production, words in dense neighborhoods experience a facilitory effect due to additional activation from many neighbors (high density advantage). There is an impressive body of research which supports models of the adult lexicon as organized into similarity neighborhoods based on phonemic representations and which play an important role in the process of recognizing and producing spoken language.

### **Lexical Representations in Children**

Despite the well-depicted structure of the fully developed adult lexicon, lexical representations and processing are not as well understood for children (e.g., Logan, 1992; Storkel, Armbrüster, & Hogan, 2006). Toward illuminating the acquisition of novel phonological forms, I will first briefly examine one model of the organizing factors in the development of children's mental lexicons. Two competing positions concerning the origins of the phonemic segment--the smallest unit of sound in language that affects meaning-- are relevant to this paper.

The first position states that the phoneme is present and functional in early infancy and there is not much change in lexical representations with development. The job in early childhood is to become aware or gain access to these implicit processing units for use in reading acquisition (e.g., Gleitman & Rozin, 1977, as cited in Metsala & Walley, 1998).

The “emergent position” argues that the phoneme is not inherent or static. Instead, the phoneme emerges during development due to vocabulary growth and performance constraints (e.g., Fowler, 1991 as cited in Garlock, Walley, & Metsala, 2001; Jusczyk, 1997; Metsala, 1997; Walley, 1993; Metsala & Walley, 1998). In accordance with this position, Metsala and Walley (1998) proposed the lexical restructuring model (LRM), which claims that lexical representations change throughout development. The first assertion of this model is that infant’s lexical representations are initially holistic but become increasingly segmental (adult-like) as vocabulary grows (e.g., Jusczyk, 1997). When infants and toddlers begin to learn words, their vocabulary is limited; it is, thus, possible that they may distinguish words based on a more holistic manner (contrasts larger than phonemic segments). As vocabulary continues to grow substantially over early childhood, it becomes increasingly difficult to differentiate between more and more similar words. As a result, the representations become increasingly segmental in order to discriminate words from one another quickly and accurately.

A second assertion of the LRM (Metsala & Walley, 1998) argues that restructuring does not depend exclusively on vocabulary size, but also depends on the familiarity and phonological similarity relations of individual lexical items. Familiarity is influenced by the amount of exposure of a word (frequency) and the age at which the word is acquired (age of acquisition). Words that are heard more frequently and are acquired earlier are assumed to undergo restructuring earlier than infrequently-heard words or later-acquired words. Under this model,

neighborhood density plays an important role in determining the structure of lexical representations and/or the organization of the mental lexicon. Recall that we can think of words as residing in dense (many neighbors) or sparse (few neighbors) neighborhoods. As areas of the mental lexicon grow more dense, it is more difficult to distinguish between many similar neighbors. As a consequence, word representations become more segmental or phonemically organized. Due to the high number of similarities and likely confusion of representations in dense neighborhoods, the LRM suggests that words residing in dense neighborhoods are segmentally restructured earlier than words residing in sparse neighborhoods. The third assertion in the LRM (Metsala & Walley, 1998) is that the reorganization of the lexicon does not occur all at once, but in a gradual, protracted manner. That is, word-specific segmental restructuring or organization occurs as words are acquired and depends on factors such as word familiarity, age of acquisition, and neighborhood similarity relations amongst the words a child knows.

One study may help to illustrate the principles discussed in terms of organizing principles of children's mental lexicons. Storkel (2002) examined how the structure of preschool children's developing lexicon differed from adults' fully developed lexicon and what development occurred over the early childhood years. Children from 3 through 6 years of age were given a two-alternative forced-choice task in which they were asked whether a presented test word matched a standard word. Standard words were selected from different neighborhood densities (sparse vs. dense) and test words varied by type of similarity or neighborhood membership to the target word (identical vs. phoneme-similarity vs. manner-similarity vs. place-similarity) and position of overlap for neighborhood membership (onset + nucleus vs. rime). Results indicated that words in dense neighborhoods were organized by phoneme similarity in onset + nucleus and rime



positions of overlap; words in sparse neighborhoods were organized by phoneme similarity in the onset + nucleus position of overlap but by manner similarity in the rime position of overlap. Storkel (2002) argued that her results showed that words in dense neighborhoods were more segmental (adult-like) for the rime position than words in the sparse neighborhoods. Her findings also suggested that the onset + nucleus position was more prone to restructuring earlier than the rime position. Storkel noted that these findings supported Metsala and Walley's (1998) LRM claim that representations become phonemically-based or organized with development, particularly as neighborhoods become more crowded.

### **Lexical Acquisition**

**Effects of neighborhood density on lexical acquisition.** The organization of similarity neighborhoods in the lexicon may influence lexical acquisition. In particular, learning words from dense neighborhoods may facilitate lexical acquisition because existing lexical representations strengthen the newly-created lexical representation (Storkel, 2004). Words from dense neighborhoods are thought to be learned easier due to the fact that there are more similar words already stored in the lexicon, meaning that more sounds and sound combinations are more readily available to aid learning (Coady & Aslin, 2004). On the other hand, density impedes recognition in adult spoken word processing, and may hinder lexical acquisition in children. In an investigation of the effect of neighborhood density on word learning in adults (Storkel, Armbruster & Hogan, 2006), participants were exposed to stories which presented nonwords from dense and sparse neighborhoods one, four, and seven times in stories. Word learning was measured through a picture naming task. Overall, adults learned more words from dense than sparse neighborhoods and performance increased over number of exposures. In addition, Storkel and colleagues also examined partial and complete correct responses separately

to determine whether neighborhood density is more critical in earlier or later stages of word learning. Responses were considered partially correct if two of three phonemes were identified correctly. Results indicated that partial responses were not influenced by neighborhood density, but complete responses were. These findings led the researchers to suggest that neighborhood density may have a more critical role in the later stages of word learning than the earlier stages.

Storkel and Rogers (2000) examined whether dense neighborhoods facilitated lexical acquisition for children. Children aged 7, 10 and 13 years heard novel nonwords seven times that were from either dense or sparse neighborhoods. Nonwords were taught in a lecture setting with pictures of the referents projected on a screen. Following a seven-minute delay, children were tested using a referent naming task; that is, children were asked to match a given nonword to its picture. Results indicated that 10- and 13-year-old children learned more nonwords from dense than sparse neighborhoods. However, there was no effect of neighborhood density on performance for the 7-year-old children. This suggested that 7-year-olds may not rely on existing lexical representations for word learning; however, Storkel and Rogers suggested this lack of an effect may have been due to methodological errors. Younger children may not have been familiar with the learning setting in which the words were presented --in a lecture setting on a classroom overhead. For future studies, it was suggested that alternative or more measures of word learning may see similar results in younger children. These authors also suggested that the words were presented too many times; with minimal exposure, the effect of neighborhood density may have been more robust across all groups (but see Storkel et al., 2006).

Storkel (2001) conducted a similar study with 3- to 6-year-old children. The children were taught nonwords from dense and sparse neighborhoods through orally presented stories. Children were exposed and tested on the target nonword after one, four, and seven exposures,

and were tested again after a one week delay. Children's word learning was measured using referent identification (choosing one of three pictures that corresponded with a given nonword), form identification (choosing one of three nonwords that corresponded with a given picture), and picture naming (naming a nonword that corresponded with a given picture without given choices). Children were also given a receptive vocabulary test and an articulation test. Unlike Storkel and Rogers' (2000), Storkel (2001) found that all preschool children learned more words from dense than sparse neighborhoods across all tasks and number of exposures. In addition, on the referent learning task the neighborhood density advantage increased with increasing scores on the receptive vocabulary test. These findings are consistent with Metsala and Walley's (1998) lexical restructuring model in that dense neighborhoods may strengthen new lexical representations. Children with larger vocabularies in this young age group were more able to draw on existing lexical structures for these dense neighborhoods. Overall however, Storkel (2001) did not find a correlation between vocabulary knowledge and word learning.

In the studies reviewed this far, neighborhood density has been shown to be a factor influencing lexical acquisition in experimental tasks. Naturalist studies have also examined neighborhood density. Storkel (2004) noted that past experimental studies of word learning have controlled for word length and frequency, lexical characteristics that are known to influence word learning (Storkel, 2001; Storkel & Rogers, 2000). Frequency is positively correlated with neighborhood density (dense neighbors have higher frequencies) and word length is negatively correlated with neighborhood density (i.e., longer words have fewer lexical neighbors). Storkel (2004) argued that since previous studies on neighborhood density controlled for these characteristics (e.g., Storkel, 2001), it is possible that the effect of neighborhood density on lexical acquisition may not have an effect in a naturalistic setting. Storkel (2004) examined this

possibility using two naturalistic databases of words known by children and tested whether neighborhood density, word frequency, or word length predicted at what age a word would be acquired. Findings showed that overall, words from dense neighborhoods were acquired earlier than those from sparse neighborhoods; this finding supports the notion that new lexical representations are influenced by existing lexical knowledge. Storkel (2004) also found that neighborhood density predicted age of acquisition for short but not longer words, and for low frequency but not high frequency words. Thus, she suggested that neighborhood density may not be as influential on longer and more frequent words.

Hollich, Jusczyk, and Luce (2002) conducted a study on 17-month-old children to examine the effects of neighborhood density on word learning. Before testing word learning, children were presented with either a high-density or low-density list of nonwords for two minutes to organize similarity-based neighborhoods of the target word. The high-density list consisted of 12 phonetic neighbors of the target word and the low-density list consisted of few phonetic neighbors of the target word in addition to foils. Results indicated that children learned the target word only when few neighbors were presented (low-density/sparse condition). Hollich et al., therefore suggested that 17-month-old children learn words from sparse neighborhoods better than words from dense neighborhoods, proposing the continuity with adults' spoken word recognition competition effect (neighborhood density disadvantage). These results are opposite to previously describe word learning studies (Storkel, 2001; Storkel & Rogers, 2000) and nonword repetition studies described in more detail below (e.g. Metsala & Chisholm, 2010), and reinforce the need for more research in the area since conclusions are not in accord.

**Effects of word frequency on lexical acquisition.** Studies have shown that children are able to associate the phonological properties of a novel word with its referent with as little as one

exposure (Dollaghan, 1985; 1987). This ability allows children to efficiently and rapidly learn new words by forming representations and building a lexicon (Storkel, 2001), and is referred to as “Fast Mapping”. Although children can make associations between phonological properties and referents with minimal exposure, it has been shown that increasing the exposure (frequency) of a word will enhance learning (e.g., Storkel, 2001; 2004).

Along with the frequency advantage on word learning, there is also evidence that frequency may interact with neighborhood density in children’s processing of spoken words. In a gating task, Metsala (1997) had child and adult participants listen to increasingly longer acoustic-phonetic segments of monosyllabic words that were from dense or sparse neighborhoods. Metsala found that less acoustic information was needed for high frequency words from sparse neighborhoods, while the opposite effect was found for low frequency words. Metsala (1997) proposed that this frequency by neighborhood density interaction was due to the facilitative role of both factors in driving segmental restructuring or organization. Low frequency words in dense versus sparse neighborhoods are recognized with less input because they would be more segmentally represented and recognition could occur on the basis of word-partial information. On the other hand, all high frequency words may have become phonemically organized – dense words will encounter more competition and, therefore, show a disadvantage in the recognition process. Storkel’s (2004) naturalistic word learning study also showed an interaction between neighborhood density and frequency. Similar to results with spoken word recognition, neighborhood density predicted the age at which a word was acquired only for low frequency words.

Despite initial findings of an interaction between frequency and neighborhood density in spoken word recognition and naturalistic examinations of vocabulary knowledge, the interaction

between these two variables in word learning studies is less clear. On the one hand, Storkel and Rogers (2000) attributed their lack of effect of neighborhood density on 7-year-olds word learning to the possibility of too many exposures. Children were exposed to the stimuli seven times and it was proposed that this over-exposure may have minimized the impact of neighborhood density; however, Storkel (2001) failed to find an interaction of neighborhood density and number of exposures (one, four, and seven times for each item). The current study examines these two factors and one prediction is that the neighborhood density advantage for word learning may only be influential with minimal exposure to words; a greater number of exposures may facilitate learning for all words and make the neighborhood structure less relevant.

**The relationship between vocabulary knowledge and word learning.** As stated previously, it has been suggested that with increasing vocabulary knowledge, increased pressure to discriminate among similarly sounding lexical alternatives drives segmental organization of children's mental lexicons (Metsala & Walley, 1998). It has, therefore, been proposed that children with larger vocabularies will have better access to segmental structures in lexical memory that can support the learning of new phonological forms, just as such structures for learning words in dense neighborhoods may be more readily available than for new words from sparse neighborhoods. The relationship between neighborhood density and vocabulary has been researched in nonword repetition and word learning studies (e.g., Edwards et al., 2004; Masoura & Gathercole, 1999; 2005; Metsala, 1997; Munson et al., 2005), but the combined effects of vocabulary knowledge and neighborhood density on children's novel word learning are still unclear.

Edwards, Beckman and Munson (2004) studied the effects of phonotactic probability on 3- to 8-year-old children's and adults' nonword repetition. Phonotactic probability refers to the frequency by which an individual sound (phoneme) and a sequence of sounds (phonemes) occur in a given position in a word, and it is highly correlated with neighborhood density (Vitevitch & Luce, 1999). In their investigation, Edwards et al. paired 44 multi-syllabic nonwords together that had either a two-phoneme sequence that was likely (high phonotactic probability) or unlikely (low phonotactic probability) to appear in the English language. Participants repeated the nonwords and their accuracy of repetition of the experimentally manipulated two phoneme sequence was measured. Edwards et al. found that repetition accuracy was better for words with high versus low phonotactic probability sequences. In addition, they found that the advantage for high probability sequences decreased with increasing expressive vocabulary knowledge.

Similarly, Munson, Edwards and Beckman (2005) found that children performed better repeating high phonotactic probability sequences and the high phonotactic probability advantage decreased as vocabulary knowledge increased. As discussed in Edwards et al. (2004) and Munson et al. (2005), these findings suggest that as vocabulary increases and representations in the lexicon become more phonemically organized, the effect of phonotactic probability becomes less influential. Children with larger vocabularies have greater representations of words and are able to make more phonological generalizations. Children's lexicons contain more words with high phonotactic probability sequences; therefore, when presented with such sequences there are many words that can aid in repetition. Low phonotactic probability sequences are not as available in the lexicon to aid in repetition, resulting in more difficult and less accurate production. As previously mentioned, phonotactic probability and neighborhood density are highly correlated. Due to this correlation, it is possible that neighborhood density and vocabulary

may have a similar relationship to phonotactic probability and vocabulary. It is possible that the effect of neighborhood density may become less influential as vocabulary increases.

Inconsistencies in the research are further discussed in a later section and expectations for this study outlined then.

Metsala and Chisholm (2010) examined the relationship between neighborhood density and vocabulary on children's nonword repetition. They found a higher neighborhood density advantage for children in a low vocabulary group versus those in a high vocabulary group. Children repeated 2-, 3-, and 4-syllable nonwords with constituent syllables from dense or sparse neighborhoods. To determine vocabulary knowledge, children were given a receptive vocabulary test and were then divided into high and low vocabulary groups. Metsala and Chisholm (2010) suggest that their finding may be due to the possibility that children with larger vocabularies know more words from sparse neighborhoods and are able to make analogies to those words to support more accurate repetition. Another suggestion for the relationship between neighborhood density and vocabulary knowledge involves phonological memory capacities. Metsala and Chisholm suggested that children with better phonological memories may not rely as much on phonological representations (e.g. neighborhood density) as children with poorer phonological memories. Children with larger vocabularies are presumed to have better developed phonological memories and may not rely on phonological representations to aid in nonword repetition. Lastly, it may also be possible that as vocabularies increase, children rely on analyzing all input phonemically. If this is true, children would analyze all nonwords similarly despite neighborhood density.

In regard to word learning, the neighborhood density and vocabulary knowledge interaction is less clear. In Storkel's (2001) study, no interaction between neighborhood density



and vocabulary knowledge was found. Overall, results showed that children's word learning had a high neighborhood density advantage regardless of vocabulary knowledge; however, she did find a relationship between neighborhood density and receptive vocabulary for one measure of learning. For the referent learning task, the high neighborhood density advantage increased as receptive vocabulary knowledge increased. This finding is inconsistent with results from previously discussed nonword repetition studies, which found the opposite relationship (Edwards et al., 2004; Metsala & Chisholm, 2010; Munson et al., 2005). Storkel (2001) suggests that her findings may be due to the effect of dense neighborhoods strengthening new lexical representations and this effect becomes more robust as vocabulary increases.

The relationship between word learning and vocabulary knowledge has also been examined in studies of learning foreign language. Masoura and Gathercole (2005) examined whether existing vocabulary knowledge of a foreign second language influenced learning of new words in that language. Eighty Greek-speaking children who were learning English as a second language participated in the study. English vocabulary knowledge was measured and high and low vocabulary groups were created. Children repeated nonwords and similarly a high and low nonword repetition accuracy groups were created. Children were asked to learn eight English picture-word pairs and were later tested on recall. Results indicated that children in the higher English vocabulary group were able to recall more words learned, indicating that vocabulary knowledge enhanced word learning. However, there was no significant difference between the high and low nonword repetition accuracy groups, although vocabulary knowledge and nonword repetition were correlated. These results suggest that word learning may be supported by existing representations in the lexicon. Given these findings, it is assumed that vocabulary knowledge may predict children's word learning.

**Nonword Repetition.** As mentioned, nonword repetition is a measure of the ability to repeat novel phonological forms, and has been declared as one of the most crucial language abilities (for review see Gathercole, 2006). Although the task may appear simple, children show large variation in this ability throughout childhood, and as a result, nonword repetition is a strong predictor of language acquisition (Gathercole, 2006). Children who perform poorly on nonword repetition tasks are generally slower at learning language. Individual differences of nonword repetition and its relationship with vocabulary acquisition have been thoroughly studied and a number of different theories have been proposed as explanations (e.g. Gathercole, 2006; Gathercole, Willis, Emslie, & Baddeley, 1992; Metsala and Chisholm, 2010). Two possibilities are discussed below.

The first position claims that individual differences of nonword repetition are due to phonological loop capacity. The phonological loop encodes, maintains and manipulates linguistic information, working as a subsystem of the short-term memory (Baddeley, 1986 as cited in Gathercole, 2006). One component of the phonological loop maintains speech-based information in phonological form, which is referred to as the short-term phonological store (Baddeley, 1986 as cited in Gathercole, 2006). The capacity of an individual's phonological loop impacts ability for nonword repetition, since the novel phonological form must be held in memory before repetition. As a result, nonword repetition has been used as a direct measure of phonological short-term memory (e.g. Gathercole, 1995; Gathercole & Adams, 1993; Gathercole, Willis, Emslie, & Baddeley, 1991; 1992). The crucial ability to hold novel phonological forms in the memory for nonword repetition is also important for learning new words and, according to this position, accounts for the relationship between the two variables (Gathercole, 2006). This perspective might suggest that learning words from sparse versus dense neighbourhoods may

rely more on short-term memory since they have less similar sounding word neighbours. If this is true, then learning words from sparse neighbourhoods would be highly related to nonword repetition.

The second position proposes that nonword repetition tasks are additionally influenced by existing lexical representations in the long-term lexicon. That is, lexical representations from existing vocabulary knowledge contribute to individual differences on nonword repetition tasks. It is argued that as the vocabulary grows, lexical representations are re-organized and facilitate nonword repetition and word learning (e.g. Bowey, 1996; 2001; Edwards, Beckman, & Munson, 2004; Metsala, 1999; see also Metsala & Chisholm, 2010; Snowling, Chiat, & Hulme, 1991). The re-organization due to vocabulary size is responsible for the relationship between vocabulary acquisition and nonword repetition (Metsala & Chisholm, 2010). Similar to this position, Jones, Gobet and Pine (2007) attribute differences of nonword repetition to vocabulary knowledge and underlying lexical representations. They developed a computational model that demonstrates individual differences of nonword repetition can be attributed to differences in vocabulary knowledge. They argue that children with greater vocabularies are able to hold nonword structures in their short-term memory better than children with smaller vocabularies, and would argue that word learning, regardless of neighborhood density, is best predicted by vocabulary knowledge. The present study will explore the relationship between nonword repetition and existing vocabulary knowledge, and examine whether these factors will predict unique variance in younger children's word learning across words of differing neighborhood densities. I will examine this relationship to support the position that vocabulary knowledge contributes to individual differences on nonword repetition tasks.

**Present Study**

This study is designed to examine lexical factors that influence children's word learning. Children's word learning was examined as a function of the neighborhood density of the novel phonological form and the frequency of presentation of the novel word. The associations between children's performance on this word learning task, vocabulary knowledge, and nonword repetition was also examined. Children were taught the nonwords through stories. The nonwords were heard two (low frequency) or four times (high frequency) and resided in either dense or sparse neighborhoods. Children's vocabulary knowledge was measured and high and low vocabulary groups were created. Children were also given a test of nonword repetition and two forced-choice tasks to measure word learning.

The first goal of the study was to further examine the effect of neighborhood density on young children's word learning. Recall that an effect of neighborhood density on word learning was found for children 3- to 6- years-old (Storkel, 2001) but was absent in one study for 7-year olds (Storkel & Rogers, 2000). It is hypothesised that there will be a significant main effect of neighborhood density such that children will learn more words from dense than sparse neighborhoods. This reasoning follows from the notion that existing lexical representations will strengthen the newly created lexical representation during word learning (Storkel, 2004).

A second goal of the present study was to determine whether neighborhood density and frequency interact in children's learning of novel phonological forms. Past research examining these two factors has led to inconsistent findings across a number of tasks. Studies of spoken word recognition and naturalistic word learning have found an interaction between these variables (Metsala, 1997; Storkel, 2004); however, Storkel (2001) failed to find the interaction in 3- to 6- year-old children's word learning. It is predicted that there will be an interaction between

neighborhood density and frequency. Similar to Metsala's (1997) spoken word recognition study and Storkel's (2004) naturalistic word learning study, it is predicted that the neighborhood density advantage will be greater for low frequency words.

A third goal was to examine the effects of current vocabulary knowledge on the magnitude of the word learning advantage for words from dense vocabularies. Although Storkel (2001) failed to find an interaction with 3- to 6- year-old children's word learning, many studies of nonword repetition and word learning have reported such an interaction (e.g., Edwards et al., 2004; Munson et al., 2005; Metsala & Chisholm, 2010). For the current study, I expect that there will be a greater neighborhood density advantage for children with lower versus higher performance on a receptive vocabulary measure.

Studies of nonword repetition and vocabulary knowledge have shown a correlation between the two variables and each correlate with word learning (Gathercole & Baddely, 1989; Masoura & Gathercole, 2005; Storkel, 2001). The final goal of the present study was to determine if these factors each predict unique variance in young children's word learning and whether this contribution was consistent across words of differing neighborhood densities. Given the varying theoretical models to account for these previously reported associations, it was unclear whether both nonword repetition and vocabulary knowledge would account for unique variance in dense versus sparse neighborhood word learning. Since sparse words have less similar sounding word neighbours, a short-term memory perspective may suggest that these words rely more on short-term memory, thus, more highly correlated to nonword repetition. On the other hand, Jones et al. (2007) would relate learning of sparse words to vocabulary and, thus, predict vocabulary to be the best predictor of words from dense and sparse neighborhoods.

## Method

### Participants

Data for the present study was previously collected by Metsala for the purposes outlined in this proposal and has not been previously analyzed or reported. Participants were 30 children recruited from private preschool centres that served primarily upper middle class populations. Children ranged in age from 49 to 77 months. According to the children's parents, none of the children had any history of speech, language, or hearing difficulties, and all spoke English as their first language.

### Procedure

All children were tested individually in a quiet room within their preschool setting. Each child heard four short stories and then completed two experimental tasks, and also completed receptive vocabulary and nonword repetition tasks. In the short stories, a total of 32 consonant-vowel-consonant target nonwords were selected for word learning. The target nonwords were from either dense or sparse neighborhoods. Neighborhood density was calculated similarly to previous research (e.g., Metsala, 1999; Metsala & Chisholm, 2010). The syllables were entered into a database of 918 monosyllabic words from Webster's dictionary. This database has been used for research with adults but is also advantageous for research with children because each word was rated by adults as high familiarity (a 6 or above on a 7-point familiarity scale; Luce, 1986). The number of neighbor-words in the database that differed from the target syllable by one phoneme deletion, substitution, or addition was calculated. A median split was conducted to form nonwords from sparse or dense neighborhoods. The categorizations of nonwords as dense or sparse were checked with a second database (Storkel & Hoover, in press). Using the median

split technique, all nonwords fell into the same category as the original scheme ( $M = 5.06$ ,  $SD = 2.294$  and  $M = 18.13$ ,  $SD = 4.145$ , for words from sparse and dense neighborhoods, respectively).

The experimenter read four short stories aloud. Each story contained eight of the target nonwords, four of which were from dense neighborhoods and four of which were from sparse neighborhoods. Half of the nonwords from dense and sparse neighborhoods were presented four times in the story, while the other half were only presented twice. The target nonwords were rotated through the different stories.

Children's word learning was measured using two forced-choice tasks. The first task required children to listen to a nonword and indicate whether or not they heard it in the story by pointing to a happy face (they heard it), or pointing to a sad face (they did not hear it). The target nonwords were presented in random order along with foil nonwords. Children were awarded one point if they answered the question correctly. The second task required children to listen to two nonwords and indicate which one they heard in the story. The nonwords were presented twice with foils (16 items). One of the foils for each target nonword rhymed with the target nonword (*beell/geel*). For the second foil, half of the dense and sparse nonwords were presented with foils with the final phoneme changed (*koice/koide*), and the other half were presented with foils with the middle phoneme changed (*dake/doke*). Children were awarded one credit if they answered correctly.

The nonword repetition task was taken from Gathercole and Adams' (1993) study. Children listened to 32 nonwords, eight of each one, two, three, and four syllables, through tape-recorded presentations. After each nonword was presented, each child was required to repeat the

nonword immediately. The children's responses were transcribed and scored as either correct or incorrect.

To measure receptive vocabulary, children were given the standardized Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981). On this test, children are required to point to one of four pictures that match a given word. Their responses were marked as correct or incorrect. For the purpose of this study, a median split was conducted on children's PPVT-R scores to establish high and low vocabulary groups.

## Results

### Effects of Neighborhood density, Vocabulary, and Frequency

After listening to each story, children first completed task one which required them to listen to a nonword and indicate whether or not they heard it in the story. There is a 50% chance that children will answer an item correctly; therefore, mean performance levels above .5 (or raw scores above 4) represent children's learning the nonwords. Children's accuracy scores were submitted to a three-way analysis of variance (ANOVA) for a mixed design with vocabulary group (high vs. low) as the between subject factor, and neighborhood density (dense vs. sparse) and frequency (high vs. low) as within subject factors (see Table 1).

Results from the ANOVA indicated that there was a main effect of frequency,  $F(1, 28) = 5.462, p > .05$ . Overall, words presented more frequently were correctly identified as being in the story more often than words presented fewer times ( $M = 6.13, SE = 0.23$  vs.  $M = 5.53, SE = 0.28$ , respectively). This main effect of frequency, however, was qualified by a Frequency x Neighborhood Density interaction which approached conventional levels of statistical significance,  $F(1, 28) 3.993, p = .055$ . Simple F-tests revealed that children identified the more frequently presented nonwords better than the less frequently presented nonwords only for those



targets from sparse neighborhoods. Further, there was an effect of neighborhood density only for the low frequency words (see Figure 1). Children correctly identified more nonwords from dense neighborhoods as having been in the story than nonwords from sparse neighborhoods ( $M = 5.93$ ,  $SE = 0.288$  vs.  $M = 5.133$ ,  $SE = 0.376$ , respectively); however, there was no effect of neighborhood density for the nonwords that were presented more frequently ( $M = 6.0$ ,  $SE = .286$  vs.  $M = 6.267$ ,  $SE = .258$ , respectively). Finally, there was no main effect of vocabulary group and vocabulary group did not interact with any other factor.

A parallel ANOVA for a mixed design was conducted for the second word learning task for which children listened to two nonwords and indicated which nonword of the pair was heard in the story (See Table 2). The ANOVA revealed that there was a main effect of vocabulary group,  $F(1, 28) = 4.295$ ,  $p < .05$ . Participants with higher vocabularies learned more words than children with lower vocabularies ( $M = 11.633$ ,  $SE = 0.552$  vs.  $M = 10.02$ ,  $SE = 0.552$ , respectively). There were no effects of the within subject variables for this task, and no interactions of any variable with vocabulary group.

### **Predictors of Children's Word Learning**

Contributors to children's word learning were examined separately for learning the nonwords from dense and sparse neighborhoods. The research questions addressed through these analyses were whether children's vocabulary knowledge and nonword repetition each predicted unique variance in children's word learning, and whether this contribution was consistent across words of differing neighborhood densities. A composite variable was created for each child's learning of the nonwords from sparse neighborhoods by adding together the number of correct responses to sparse targets for tasks one and two. Similarly, to create the composite score for learning the nonwords from dense neighborhoods, the number of correct responses was summed

for the dense cells across tasks one and two. Zero-order correlations amongst the variables entered into these regression equations are shown in Table 3. As can be seen in Table 3, both age and vocabulary scores were significantly related to the composite word learning variables for both sparse and dense neighborhood conditions. Performance for learning the nonwords from dense neighborhoods was predicted using a hierarchical multiple regression. As can be seen in Regression 1 (see Table 4), age was entered as the first step and predicted 14.7 % of the variance in performance. Children's nonword repetition was entered as the second step, but did not predict significant unique variance. Finally, PPVT-R raw scores were entered as the last step and predicted 14.2 % unique variance in children's word learning beyond age and nonword repetition.

Performance on learning nonwords from sparse neighborhoods was also examined using a hierarchical regression analysis (Table 4; Regression 2). Similar to Regression 1, age predicted 29.9 % of the variance in performance, nonword repetition did not predict significant unique variance, and PPVT- R raw scores predicted 12.8 % unique variance beyond age and nonword repetition (see Table 4).

### **Discussion**

The present study was designed to further examine the effects of neighborhood density on young children's word learning, and to determine whether neighborhood density would interact with frequency of presentation and children's vocabulary knowledge in learning novel phonological forms. The current study examined these questions by presenting children, divided into lower and higher vocabulary groups, nonwords that resided in dense or sparse neighbourhoods, that were heard two (low frequency) or four (high frequency) times. This study also set out to determine if children's vocabulary knowledge and nonword repetition ability each

predicted unique variance in word learning and to test whether such contributions were consistent across words from differing neighborhood densities. To examine this question, children's performance was collapsed across learning tasks for each of nonwords from sparse and dense neighborhoods, and hierarchical regression analyses were used to examine the relative contributions of each age, vocabulary knowledge, and nonword repetition ability.

It was hypothesised that children would learn more nonwords from dense than sparse neighborhoods, due to existing lexical representations in dense neighbourhoods strengthening the newly created lexical representation during word learning (Storkel, 2004). It was also expected that the neighborhood density advantage would be more pronounced for words presented fewer times because both frequency and neighborhood density are proposed to facilitate segmental representation, as in studies of spoken word recognition (Metsala, 1997). The results of word learning task one found a main effect of frequency and this was qualified by the interaction between frequency and neighborhood density, which approached conventional levels of statistical significance ( $p = .055$ ). Children identified more nonwords from dense neighbourhoods as having been in the story than from sparse neighborhoods only for the condition for which the words were presented twice. Similarly, frequency of exposure benefitted children's learning only for those items from sparse neighborhoods.

This finding supports the proposal that phonemic organization may be facilitated by both neighborhood density and word frequency. Within this context, segments of representations of words from dense neighbourhoods are more readily available to comprise the representation for the novel phonological form. Thus, words from dense neighbourhoods are learned better than words from sparse neighborhoods with less frequent exposure. However, greater number of exposures facilitates learning for all words, regardless of neighborhood density. This finding is

consistent with previous studies of spoken word recognition, and naturalistic word learning (Metsala, 1997; Storkel, 2004). In a study of spoken word recognition, Metsala (1997) found that low frequency words from dense versus sparse neighbourhoods were recognized with less input. Similarly, Storkel (2004) found that neighborhood density only predicted age of word acquisition for low and not high frequency words. These results are consistent with the proposed lexical restructuring model (Metsala & Walley, 1998). Both frequency and neighborhood density are seen to drive segmental representation/organization. Words from dense neighbourhoods have increasing pressure to become more segmentalized to aid differentiation as the lexicon increases. As a result, words from dense neighbourhoods are segmentalized earlier than words from sparse neighbourhoods, facilitating word learning particularly for low frequency words.

For the second word learning task, there was no effect of neighborhood density or frequency which may have been due to the nature of the task. Children were required to choose from two nonwords and to indicate which one they heard in the story. The foils used in this task only differed by one phoneme from the target nonword. The task may have been too difficult for the children to differentiate which nonword was heard in the story because the foils were too similar to the target nonwords. That is, children's representations of the words after two and four exposures may not have been as finely encoded as would be required for making these minimal contrast distinctions. It is possible that the effects of frequency and neighborhood density may have arisen if the word learning task required the children to learn the nonwords to a certain criterion or with numerous additional exposures. An alternate word learning task, such as requiring children to produce the phonological form (i.e. look at a picture and name it), has been an additional task that has shown sensitivity to neighborhood density in the past (e.g., Storkel, 2001; Storkel & Rogers, 2000).

A third goal of the study was to determine if neighborhood density would impact children's word learning differently depending on whether children had relatively higher or lower vocabulary knowledge. Munson et al. (2005) and Edwards et al. (2004) found that the phonotactic probability advantage for children's repetition of multisyllabic nonwords decreased as expressive vocabulary knowledge increased. Metsala and Chisholm (2010) found similar results in that dense neighborhood advantage for syllables within nonwords was greater for children with lower versus higher vocabularies. Based on these results it was predicted that the neighborhood density advantage for word learning would be greater for children with lower versus higher vocabularies.

In the current study, vocabulary group did not interact with neighborhood density on children's word learning. This finding is consistent with Storkel's (2001) previous word learning study. The lack of interaction may indicate that all children, regardless of vocabulary knowledge, learn words in a similar manner, even as children with higher vocabularies learn words more quickly, as found in task two. Children of varying vocabularies may have the same access to segmental structures in the lexical memory, or may not be relying on phonological representations to analyze words. However, it is also possible that the present study's vocabulary groups did not differ enough in existing vocabulary knowledge to detect a significant difference. That is, most children in the current study had vocabularies within the Average range. Perhaps with larger group differences on vocabulary knowledge, an interaction with neighborhood density may have been observed.

The final goal of the present study was to determine if nonword repetition and vocabulary knowledge would each predict unique variance in young children's word learning and whether this contribution would be consistent across words from differing neighborhood densities.

Performance on learning words from dense neighbourhoods was predicted by age and vocabulary knowledge. Age predicted 14.7 % of the variance, while vocabulary knowledge predicted 14.2 % unique variance beyond age and nonword repetition. Performance on learning nonwords from sparse neighborhoods was also predicted by age and vocabulary knowledge. Age predicted 29.9 % of the variance in performance, while vocabulary knowledge predicted 12.8 % unique variance beyond age and nonword repetition. Nonword repetition did not predict significant variance for performance on learning nonwords from dense or sparse neighbourhoods. Congruent with Jones et al.'s (2007) theory and the LRM (Metsala & Walley, 1998), vocabulary was the best predictor of learning both dense and sparse words. This finding further supports that lexical representations from existing vocabulary knowledge contribute to individual differences on word learning tasks. As vocabulary grows, the lexical representations are re-organized and facilitate nonword repetition and word learning (e.g. Bowey, 1996; 2001; Edwards, Beckman, & Munson, 2004; Metsala, 1999; see also Metsala & Chisholm, 2010; Snowling, Chiat, & Hulme, 1991).

Similar to the current findings, Jones et al.'s (2007) created a computational model, EPAM-VOC, which accounts for children's word learning without reference to individual differences in short term memory. The model simulates children's vocabulary acquisition and demonstrates the interaction between phonological short term memory and long term memory. From exposure to phoneme sequences, EPAM-VOC gradually develops knowledge of these in long term memory for words (lexical memory). With increasing knowledge of such lexical units, the amount of information that can be held in the phonological short term memory increases. The long term representations of the phoneme sequences (words) can be retrieved to aid with learning the new phonological sequences when these correspond to parts of words already learned.

Therefore, the amount of information that can be stored in the phonological short term memory is dependent on the availability of similar phonological segments in the long term lexical memory. Phonological short term memory is seen as the bottleneck of word learning, rather than the driving force, and vocabulary knowledge is seen as the primary driving force. The model has been shown to be consistent with results from past studies of nonword repetition (Gathercole, 1995; Gathercole & Adams, 1993) and also simulated nonword repetition results conducted by Jones and colleagues. Congruent with Metsala and colleagues' restructuring model, EPAM-VOC predicts that words from dense than sparse neighbourhoods will be more readily learned due to the similar phoneme sequences stored and readily available to store the new phonological form. Vocabulary growth or increasing phonological representations in the long term memory contributes to nonword repetition performance and language learning. The present study appears consistent with this computational model as findings showed that vocabulary knowledge was the best predictor of children's learning performance of words from both dense and sparse neighbourhoods.

One limitation of the present study is that the effects of neighborhood density and phonotactic probability were not differentiated. As previously noted, neighborhood density and phonotactic probability are highly correlated; therefore any effects of neighborhood density are confounded with phonotactic probability. In fact, Storkel (2001) findings showed that there was a high phonotactic probability advantage with children's word learning. Given that the high phonotactic probability sequences were also nonwords from dense neighbourhoods and the low phonotactic probability sequences were also nonwords from sparse neighbourhoods, it cannot be determined which factor is responsible for the advantage. Future studies might design nonwords that could differentiate effects due to each factor. Future studies may also want to examine the

learning of novel phonological forms, while differentiating the effects of neighborhood density and phonotactic probability in a variety of age groups. Storkel, Armbrüster, and Hogan (2006) have begun to examine these differentiating effects in word learning studies with adults; however studies of such are needed to delineate these effects with children. The findings from the present study also suggest that including the frequency of presentation as a variable in children's word learning is necessary, as it appears to interact with neighborhood density.

The present study contributes to our understanding how children acquire novel phonological forms through examining variables thought to be important in the development and organization of long-term phonological representations. The neighborhood density and frequency interaction support current developmental models in that it appears that both factors drive phonemic organization of the lexicon. The current study also contributes to developmental models through examining the contributions of children's vocabulary knowledge to learning words from each of dense and sparse neighborhoods. Findings support the notion that lexical representations from existing vocabulary knowledge make an important contribution to word learning for items from both sparse and dense neighborhoods.



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Table 1

*Means (standard deviations) of Children's Word Learning Scores on Word Learning Task One*

Neighborhood density	Frequency	
	High	Low
Low Vocabulary		
Dense	5.67 (1.543)	6.00 (1.558)
Sparse	6.20 (1.320)	5.00 (2.070)
High Vocabulary		
Dense	6.33(1.589)	5.87 (1.598)
Sparse	6.33 (1.496)	5.27 (2.052)

*Note:* Out of a total of 8 possible correct.

Table 2

*Means (standard deviations) of Children's Word Learning Scores on Word Learning Task Two*

Neighborhood density	Frequency	
	High	Low
Low Vocabulary		
Dense	10.47 (2.62)	10.40 (2.95)
Sparse	10.00 (2.20)	9.20 (2.57)
High Vocabulary		
Dense	11.67 (2.74)	11.73 (2.37)
Sparse	11.73 (2.08)	11.40 (2.47)

*Note:* Out of a total of 16 possible correct. Chance performance would be a raw score of 8, or 50% correct.

Table 3

*Correlations of Predicting and Outcome Variables*

	Age	Vocabulary	NWR	Word Learning Sparse	Word Learning Dense
Age	1.00				
Vocabulary	.346	1.00			
NWR	.188	.243	1.00		
Word Learning Sparse	.568**	.544**	.204	1.00	
Word Learning Dense	.420*	.490**	.068	.732**	1.00

*Note:* Vocabulary = PPVT-R raw scores; NWR = nonword repetition accuracy scores; Word Learning Dense = composite score for accuracy on dense targets for tasks 1 and 2; Word Learning Sparse = composite score for accuracy on sparse targets for tasks 1 and 2. \* $p < .05$ ; \*\* $p < .01$



Table 4

*Summary of Hierarchical Regression Analysis for Variables Predicting Word Learning of Sparse and Dense neighbourhoods*

Predictor	<i>B</i>	<i>SE B</i>	$\beta$	$\Delta R^2$
Regression 1				
Step 1				
Age	.314	.129	.420*	.176
Step 2				
NWR	-.025	.401	-.011	.000
Step 3				
Vocabulary	.154	.066	.409*	.142
Regression 2				
Step 1				
Age	.400	.109	.568*	.323
Step 2				
NWR	.214	.339	.101	.010
Step 3				
Vocabulary	.138	.055	.386*	.128

*Note:* Vocabulary = PPVT-R raw scores; NWR = nonword repetition accuracy scores. \* $p < .05$

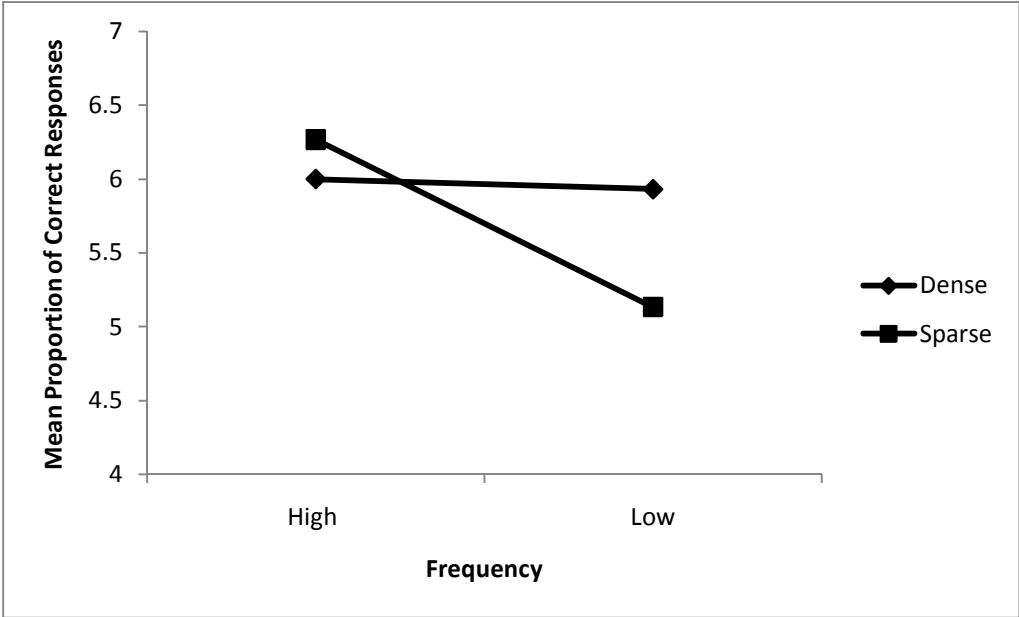


Figure 1. Mean proportion of correct responses for word learning task one