THE RELATIONSHIP BETWEEN PHONOLOGICAL WORKING MEMORY,
PHONOLOGICAL SENSITIVITY, AND INCIDENTAL WORD LEARNING

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ABSTRACT

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Rapid learning of novel vocabulary is crucial to overall success in language acquisition. While the exact mechanisms underlying the acquisition of the lexicon remain under investigation, it is well known that children are able to form rapid initial associations between novel words and their referents during everyday experiences. This ability is referred to as incidental word learning, a process by which a learner makes a sparse initial representation of a word in lexical memory, following only a brief exposure. The cognitive abilities needed to succeed at this task were investigated, specifically by examining the role of working memory and phonological sensitivity in novel word learning by 4-year-olds who were typically developing. It evaluated two competing models, the phonological loop model proposed by Baddeley and colleagues (Baddeley & Hitch, 1974), and the lexical restructuring model of Metsala (Metsala & Walley, 1998; Metsala, 1999). Forty 4 year olds were administered a test of nonword repetition (to investigate phonological working memory), rhyming and phoneme alliteration tasks (to investigate phonological sensitivity), and an incidental word learning task, via a computer-based presentation of a cartoon story. A multiple regression analysis revealed that nonword repetition scores did not contribute significantly to incidental word learning. Phonological sensitivity scores were significant predictors of incidental word learning. These findings provide support for a model of lexical acquisition in which phonological knowledge plays an important role.
To
My Amma, Appa, Ammamma, &
Sethu
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CHAPTER 1

Introduction

Lexical acquisition forms an important aspect of language acquisition. An average American or British high school graduate has a receptive vocabulary of about 60,000 words (Bloom, 2000). This rapid acquisition of words can be attributed to a process called fast mapping or incidental word learning, which entails sparse lexical-semantic storage of words following only a brief exposure their phonological forms and referents. These incomplete representations are later elaborated and refined during the extended phase of lexical acquisition (Bloom, 2000). Incidental word learning is a complex process that encompasses phonological processing, memory for a novel lexical item, choosing the correct referent, and making a connection between a word and its referent. Some studies have investigated the ability of children to choose the correct referent, and to make a connection between the novel lexical item and the appropriate referent (for example, Carey & Bartlett, 1978; Dollaghan, 1985, 1987).

The memory for a novel lexical item, which is required for word learning, has been investigated with models of working memory. The working memory appears to play an important role in incidental word learning by storing the phonological information for a novel lexical item. Working memory refers to the temporary storage and manipulation of information required for complex cognitive tasks, including speech and language. The “phonological loop” model by Baddeley and Hitch (1974) and the “Functional working memory” model by Just and Carpenter (1992) are the two most prominent models of working memory. According to the “phonological loop” model by Baddeley and Hitch, working memory is a multi-component system consisting of the central executive, the visuo-spatial sketchpad and phonological loop. The phonological loop is a key component of this model for lexical acquisition. It is involved in
the phonological storage and rehearsal of novel phonological segments required for learning words. On the other hand, the Functional working memory (FWM) model developed by Just and Carpenter views working memory as a storage-limited system in which the storage and processing components of the system share a common set of cognitive resources. Whenever the processing or storage demands exceed the available cognitive resources, there is a trade-off between storage and processing leading to diminished storage or processing. The FWM can be considered as a functional equivalent of the central executive component of the phonological loop model, which is also involved in the storage and processing of information required for complex cognitive tasks such as executive functions (Just & Carpenter, 1992). The major difference between the two models is that the FWM model does not posit the existence of a separate, dedicated aspect of memory devoted solely to a specific task.

The proponents of the phonological loop model have used a nonword repetition task to test phonological working memory. Nonword repetition involves the repetition of nonsense words that have no correspondence with real English words. It has been construed that nonword repetition involves the activation of purely phonological processes such as encoding, storage, and retrieval, independently from lexical knowledge. According to this model, both nonword repetition and word learning are constrained by phonological working memory. That is, learning novel words that the child has never heard before and repeating nonwords, which sound unlike any words in the child’s existing lexicon, require encoding and processing of novel phonological codes and are constrained by phonological working memory. Because of the common phonological memory shared by these two tasks, Baddeley and colleagues have argued for the existence of a direct relationship between phonological working memory and word learning (Gathercole, 2006). There is some evidence showing a direct correlation between nonword
repetition and vocabulary knowledge in children, and nonword repetition and novel word learning in children as well as adults (Gathercole, Willis, Emslie & Baddeley, 1992; Gathercole & Baddeley, 1989a; Gathercole & Baddeley, 1990a; Vallar & Papagno, 1993). Some evidence, however, contradicts these findings. Beyond 5 years of age, nonword repetition failed to predict subsequent vocabulary knowledge in children, whereas children’s vocabulary knowledge was able to predict performance on nonword repetition (Gathercole et al., 1992).

Unlike the Phonological Loop Model, Metsala and Walley (1998) offered an alternative view of the relationship between nonword repetition and vocabulary size. This view, called the lexical restructuring model, theorized that although phonological working memory, as measured by nonword repetition, has a role to play in vocabulary acquisition, it is not seen as an inherent capacity, but rather one subject to development over time. Metsala (1999) and Bowey (1996, 2001) have suggested that nonword repetition tasks used to measure phonological working memory, and phonological sensitivity tasks (such as phoneme identity) used to measure knowledge and awareness of segmental information, share common latent phonological processes. These processes are hypothesized to include speech perception, phonological representation, phoneme memory, and retrieval of the phonological representation from memory. They propose that development of phonological processing is driven by a child’s vocabulary development. That is, an increase in a child’s vocabulary would lead to increasingly detailed phonemic representations, which are necessary for efficient phonological processing. They contend that it is because of this influence of vocabulary on the child’s phonological processing that vocabulary was a significant predictor of nonword repetition (which requires phonological processing) and nonword repetition failed to predict vocabulary knowledge in the investigations by Baddeley and colleagues in older children. Investigations by Metsala (1999) and Bowey
(1996, 2001) have shown that both nonword repetition and phonological sensitivity tasks are good predictors of children’s lexical acquisition. Nonword repetition was however not as strong as phonological sensitivity tasks in predicting vocabulary knowledge.

Incidental word learning is a complex process and it is important to understand some of its cognitive underpinnings. Studies investigating these cognitive processes have focused on the relationship between phonological working memory and phonological sensitivity on vocabulary size measured by standardized tests such as the Peabody Picture Vocabulary Test or PPVT (Gathercole et al., 1992; Metsala, 1999, Bowey, 2001). One study of Dutch-speaking 5-year-old children explored the role of phonological memory and phonological sensitivity in an experimental word-learning paradigm (de Jong, Seveke, & van Veen, 2000). There have been no studies to date that have investigated the interaction between phonological knowledge and phonological memory during the initial stages of new word learning in 4-year-old children. It is not known whether the findings of studies using formal vocabulary test results and controlled word learning tasks as measures of lexical abilities of children would hold for children learning words in a more naturalistic, incidental word learning task. Because it is a different construct from vocabulary size (Metsala, 1999), there may be different factors that promote success in short term (incidental) word learning versus the long term acquisition that is reflected in vocabulary size. It is not known whether either nonword repetition or phonological sensitivity offer any unique contribution to incidental word learning, or whether both nonword repetition and phonological sensitivity tasks have significant and independent contributions to incidental word learning. The aim of the current study is to explore the potential interaction between phonological working memory and phonological sensitivity in the incidental word learning of 4-year-old children.
CHAPTER 2

Review of the Literature

Word Learning: General Background

The process of lexical acquisition is one of the most important aspects of language learning. An average American or British high school graduate has a receptive vocabulary of approximately 60,000 words. In order to hit the 60,000-word mark by high school, they have to learn 3,750 new words every year, or 10 words every day or 1 word every waking 90 minutes (Bloom, 2000). The process of word learning however, does not take place in a linear fashion, as suggested by the statistics above. For instance, when children are 2 years old they learn about one word per day and when they are 3 years they learn about two words every day (Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994). Lexical acquisition has been investigated extensively, in order to better understand this vital and complex process. While early work focused on inventories based on diaries and language samples (e.g., Goldfield & Reznick, 1990; Miller, 1981), in recent decades emphasis on experimental investigation of word learning processes has become prominent (see Bloom, 2000, for a review).

Challenges in Word Learning

Children face many challenges during lexical acquisition. The first problem inherent in word learning is breaking the continuous speech stream into individual words. For instance, when a child is presented with a sentence such as “Bring me the chromium plate”, where ‘chromium’ is a novel word, the child is faced with the complex task of identifying the new word by disentangling it from rest of the words in the speech stream (O’Grady, 2005). The second challenge involves choosing the correct ‘referent’ from a logically infinite number of possible referents. For instance, when you say “Look, a dog!” the word ‘dog’ could refer to a number of
possibilities such as the speaker himself, all animals, only the eyes of the dog, or only the dog’s tail, just to name a few (Quine, 1960). Because children rarely make such errors, it seems evident that they have means to ensure that they make generally accurate word-referent mappings. Thus, while word learning seems to pose huge challenges, children fortunately have a number of resources that help them confront these challenges.

A number of remarkable abilities relevant to word learning have been identified in children, including specialized speech perception skills, based in part on sensitivity to transitional or statistical probabilities within language (Saffran, Aslin, & Newport, 1996). These assist in the development of phonological knowledge. In addition, infants and young children have been shown to be sensitive to cues present in their social environment, and these can be of assistance in making appropriate word-meaning mappings (e.g., Baldwin, 1993; Bloom, 2000). The fact that young children have specialized word learning skills is shown by the extensive literature that demonstrates that children have the ability to “fast map”—that is, apply a novel label to a novel referent following only a brief exposure (e.g., Carey & Bartlett, 1978; Dollaghan, 1985, 1987; Heibeck & Markman, 1987).

**Speech Representation in Children**

Unlike written language, where words are separated by spaces, spoken language has no clear boundaries to demarcate the individual words forming the speech stream. A part of this problem of identifying a novel word from a speech stream is solved by the ‘holistic’ nature of speech representation in young infants. That is, children are able to separate the words based on global cues, such as prosody, rather than specific cues, such as phonemes (Cooper & Aslin, 1989; Jusczyk, 1997). Prosody has been shown to be of interest to infants, in that they pay more attention to child-directed speech (‘Motherese’) rather than adult-directed speech (Cooper &
Aslin, 1990). These two speech styles differ on a number of parameters, but prosodic differences seem to be the most consistently present, cross-linguistically (Fernald, 1991). That infants do make use of prosodic cues has been established by presenting them with passages that are low-pass filtered. Despite this distortion, which removes most of the cues to segmental information, infants were able to discriminate between their native language and a nonnative language (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988). This ability of infants to discriminate between native and nonnative languages even when the segmental aspects of speech were filtered out suggests the role of the global suprasegmental cues present in intonation patterns in speech discrimination.

While word boundaries may be established in early learning based on holistic representation, infants still need to begin to represent the phonemic system of their language if they are to discriminate among different lexical items. Cross-linguistic investigations have shown that young infants can discriminate speech sounds. Children below the age of 6 months are equally sensitive to speech sounds in their native as well as nonnative languages. After the age of 6 months, as children become more tuned to their native language, owing to greater exposure, they become more sensitive to speech sounds within their native language relative to non-native languages. The ability to discriminate phonemes not present in the ambient language declines after this early period (e.g., Werker and Tees, 1984). Children are born with a universal readiness to learn any language, and so are able to discriminate between phonemes of any language, even ones they have not heard previously. As children grow older, they become finely tuned to the language(s) that they are exposed to, and they become poorer in their ability to discriminate between speech sounds of languages not present in their environment (see Bernthal & Bankson, 1998, for a review).
The process by which children learn their native phonemic contrasts would appear to take speech representation from the holistic level of prosody down to the segmental level. That is, it could be seen as a process in which children learn to look within words for the important details, and perhaps begin to neglect the suprasegmental cues they focused on in the earliest stages. Yet work on early word learning and speech representation by Jusczyk (1993) contradicts this notion. Holistic representations of words are important features of Jusczyk’s model of infant speech perceptual development, termed the Word Recognition And Phonetic Structure Acquisition (WRAPSA) model. This model theorizes the presence of innate auditory analyzers underlying the speech perception abilities of infants. According to this model, the auditory system in young infants provides a detailed (holistic) but transient analysis of the incoming speech and non-speech stimuli. With the emergence of words (8-12 months), this analysis undergoes refinement. The elements that are crucial for distinguishing between speech patterns are given prominence and irrelevant information is ignored. This refinement results in increased sensitivity to native contrasts in older children. The entire process is based on the storage of exemplars in the input, from which a featural representation of some sort is slowly extracted.

In summary, infants’ ability to break down the stream of speech into individual words can be partly attributed to the holistic nature of their speech representations. The first evidence for this comes from studies showing that infants pay more attention to global cues such as prosodic cues rather than phonemic cues to discriminate between various speech segments. The second evidence comes from young infants’ abilities to discriminate speech contrasts within native and non-native languages. There is reorganization in speech perception abilities of children with increased exposure to their native language. That is, children become more sensitive to the phonological features of their native language and hence their ability to
discriminate between speech sounds in both native and nonnative languages declines in children between 6 and 12 months of age. This language-specific reorganization is critical for word learning. A part of this reorganization can be attributed to children’s development of phonological knowledge,

**Development of Phonological Knowledge**

While children’s initial learning may be driven by exemplars represented holistically, the development of phonological knowledge is needed for achieving adult-like representations. Knowledge of phonological contrasts forms an integral aspect of word learning. To recognize when a word differs from another, a child must develop a number of abilities, including speech sound discrimination, phonotactic rule application, phonemic stress patterns (in stress-timed languages), and syllabic structures. Current theories of infant speech perception development emphasize the importance of infants’ ability to attend to statistical cues present in the input. These regularities are the cues that allow infants to begin to segment the speech stream into words, and ultimately form phonemic representations (Saffran, Aslin, & Newport, 1996).

Studies of speech discrimination abilities of children have shown that children as young as 1-4 months are able to discriminate between the vowels /a/, /i/, and /u/ and consonants differing in place and manner of articulation (Trehub, 1976; Jusczyk, 1997). Children in this age group were also able to discriminate between /a/ and /i/ when each vowel was produced with different intonation patterns (Kuhl, 1987). Children had difficulty in discriminating between the fricatives /sa/ vs. /za/, /fi/ vs. /θi/. and /fi/ vs. /θi/ (Eilers, 1977). They also had difficulty discriminating stops embedded within multisyllables. For example, they were poor at discriminating between /ataba/ vs. /atapa/ (Trehub, 1973). In sum, young children can discriminate between vowels and consonants differing in place and manner of articulation. They
however, have difficulty with finer consonantal discrimination, especially in multisyllabic contexts.

Exposure to the ambient language assists children in developing ever richer representations. Children between the ages of 6-12 months become increasingly sensitive to the phonological characteristics of their native language. At about 9 months, children become sensitive to the syllabic structure, phonotactic rules, and stress patterns of their native language (Friederici & Wessels, 1993; Jusczyk, Goodman, & Baumann, 1999). Detection of similarities between syllables serves as a precursor to the learning of phonotactic rules, the rules of speech sound combination, which is a significant element of word learning. These discriminatory abilities are important for word learning, because they assist in determining word boundaries and speed up processing of the input into a parsed representation. Learning phonotactic rules is not complete until children start generalizing the newly learned rules to new syllabic contexts. Chambers, Onishi, and Fisher (2003) found that 16.5 months-old infants could not only learn the pattern of distribution of speech sounds (phonotactic rules) but also generalize these newly learned rules to other new syllables. This ability of children to generalize phonotactic rules may be attributed to their increase in information processing skills at this age.

Another type of phonological knowledge closely related to phonotactic knowledge is children’s ability to detect regularities in the ambient language. Saffran et al. (1996) found that infants are sensitive to transitional probabilities within and between words. These transitional probabilities are the statistical likelihood of a particular phonological pattern occurring at a word boundary or a syllable boundary. For example, in the phrase ‘pretty baby’, ‘pretty’ and ‘baby’ are recognized as two different words but the child does not recognize ‘tyba’ (boundary between the two words) as a word. The child can make this decision based on statistical probabilities.
That is, there are only few syllables that can follow the prefix ‘pre;’ the probability of ‘ty’ following the syllable ‘pre’ is approximately 80%, and the probability of a syllable such as ‘ba’ following ‘ty’ is very low (about 0.03%). A child using this information could determine that ‘pretty’ (which has high inter-word probability) is a word and ‘tyba’ (which has a low inter-word probability) is not a word. The ability to identify words in the speech stream based on these statistical probabilities greatly simplifies the difficult problem of word recognition.

Learning stress patterns of a language is another type of phonological knowledge acquired during the first year of life. In languages such as English where stress is a significant feature, stress patterns are important for speech perception. Gerken (2004) showed that 9 month old children exposed to two artificial languages differing in 2 of the 4 stress pattern constraints were not only able to learn the stress patterns of these languages but were also able to generalize them to new patterns.

By 14 months, children start making associations between words and their referents. They however fail to make these associations when presented with words that are phonologically similar. For example, they are able to make word-referent associations for words such as ‘lif’ and ‘nim’ but fail to make such connections for minimal pairs such as ‘pin’ and ‘bin’. This is perplexing given that children between 8 and 14 months are able to differentiate between these words. Their inability to discriminate between these phonologically similar words is not due to their poor discriminatory abilities but due to the linguistic and cognitive demands of the task (children have to both perceptually discriminate and also make connections between words and objects). By 17 months children start making word-referent connections even for minimally contrastive word pairs. This overlaps with the vocabulary spurt of children, which occurs at around 18 months. This ability of children to associate minimally contrastive words with their
referents can be attributed to their increased metaphonological and cognitive skills (see Werker & Yeung, 2005 for a complete review).

*Phonological Knowledge in Preschool Children*

Phonological knowledge continues to develop during the preschool period. Nittrouer (1992) has shown that 3 to 7 year olds are poorer than adults in using formant transition cues to discriminate between syllables composed of fricatives and vowels. Researchers have consistently found that adults are better than pre-school children in word recognition when words are presented with degraded acoustic cues. That is, pre-school children required many more acoustic cues than adults and teenagers to recognize words (Elliot, Hammer, & Evan, 1987; Edwards, Fox, & Rogers, 2002).

Munson (2001) found that children between 3 and 8 years were less accurate than adults in repeating nonwords containing low frequency phoneme patterns. The repetition of nonwords containing high frequency phoneme patterns required children to rely on their lexical knowledge but repetition of low frequency nonwords required a much more fine grained phonemic representation, which improves with age and vocabulary growth (Metsala & Walley, 1998; Munson, Edwards, & Beckman, 2005).

In sum, children are born with a universal ability to discriminate phonemes of both their native and non-native languages. When infants are between 6 and 12 months, they become increasingly sensitive to phonemic contrasts within their native language alone. This increased sensitivity to native language patterns can be attributed to increased perceptual sensitivity and their ability to detect statistical regularities in their native language (Werker & Tees, 1984). At around 14 months, children begin to make word-object mappings, but it is not until 17 months that they become proficient. Word learning is a hierarchical process, where higher-level
linguistic units are built upon foundations laid by phonological knowledge (Werker & Yeung, 2005). As children grow older, their phonological knowledge improves, but they are still less mature than adults in terms of word recognition using acoustic cues, and repeating nonwords with infrequent phoneme substitutions (e.g., Nittrouer, 1992; Munson, 2001).

**Phonology and Lexical Development**

Work by Storkel & Rogers (2000) and Storkel (2001, 2004) has shown that phonological information plays a role in children’s ability to learn novel words. Words that have a higher phonotactic probability are learned faster. That is, children more readily learn words with likely sequences of phonemes. Unlikely sequences, that is, those with relatively low statistical frequency in the ambient language, are more difficult to learn. Thus as children develop knowledge of the phonological details of the language, they make use of that knowledge in the word learning process.

Storkel and Rogers (2000) and Storkel (2001) examined the effects of phonotactic probability in novel word learning of children between the ages of 3 and 13 years. Children in these studies were exposed to both high and low probability nonwords and their referents. The studies showed superior word learning performance for high probability nonwords when compared to low probability nonwords. Storkel (2001) has suggested that since word learning is constrained by limited set of cognitive resources, learning nonwords with high phonotactic probability is much easier because it involves the use of less cognitive resources relative to learning low probability nonwords which is taxing and utilizes more cognitive resources.

The process of lexical acquisition is also influenced by a different but related variable called ‘neighborhood density’. It refers to the number of words that are phonologically similar to a given word. For example, “pill” has a high neighborhood density with 32 phonologically
similar words. On the other hand, “choice” has a low neighborhood density with only 3 phonologically similar words (Munson, Swenson, & Manthei, 2005). Storkel (2004) found that phonologically dense words were the earliest to be acquired (low age of acquisition) and had shorter word lengths when compared to words in sparse neighborhoods. Maekawa and Storkel (2006) examined the role of phonotactic probability, neighborhood density, word frequency and word length in predicting expressive vocabulary development. A backward regression analysis revealed that word length was the only consistent significant predictor of future expressive vocabulary. Although phonotactic probability, neighborhood density, and word frequency were significant predictors of expressive vocabulary, they varied across different children. These individual variations in factors predicting expressive vocabulary of children were attributed to developmental differences between children. In sum, investigations by Strokel and Rogers (2000), Storkel (2001, 2004), and Maekawa and Storkel (2006) clearly indicate that words with high phonotactic probability and high neighborhood density are easier to acquire compared to words with low phonotactic probability and low neighborhood density.

Other Factors in Word Learning

Phonological knowledge may help children to identify words and differentiate among them, but there are several other abilities, including socio-pragmatic, syntactic, semantic, prosodic, perceptual, and cognitive, that are essential for word learning. Word learning rests on cognitive, perceptual, and affective resources, including such key factors as motivation to attend to and decode the input, ability to perceive phonological information, and general cognitive processes such as attention and memory. Social-pragmatic theories of word learning emphasize the importance of social cues for word learning. Studies in this area emphasize social aspects of learning, and have shown that children are able to select the correct referent upon hearing a novel
word based on certain pragmatic cues such as eye gaze (Baldwin, 1993), deictic pointing (Kalagher & Yu, 2000), inferring the intentions of other speakers (Bloom, 2000), discourse novelty (Akhtar, Carpenter, & Tomasello, 1996), and prosodic cues (Bloom, 2000; Yu & Ballard, 2004). Word learning in children and adults is also facilitated by grammatical knowledge. While learning concrete nouns such as ‘cat’ and ‘dog’ may be facilitated by making word-referent mappings using the real world context, learning grammatical morphemes such as determiners and conjunctions requires development and processing of syntactic knowledge, including attending to the syntactic frames in which they occur. Moreover, word-to-world mappings are not sufficient for learning verbs, because verbs may be spoken when the actual actions pertaining to the spoken verbs are not performed. A child who has mastered key facts of English grammar can deduce basic information about verbs based on syntactic structures in which they occur. For example, when a child hears a two-argument verb such as ‘hit’, which connects the noun (the hitter) with an object (the object hit by the noun), the child can deduce that the verb ‘hit’ occurs only in transitive structures such as ‘John hits the ball’. On the other hand, based on listening to a one-argument verb such as ‘laughs’, the child can deduce that ‘laughs’ occurs in intransitive sentences such as ‘John laughs’ (Gleitman & Gleitman, 1992). Finally, essential global cognitive resources and abilities are necessary to word learning, including basic motivation to attend to the input, intact perceptual ability, sufficient ability to direct and maintain attention to the linguistic and non-linguistic context, and to manipulate information in working memory (including at a minimum phonological, syntactic, and semantic information), and then to transfer sufficient information from working memory to long term storage to begin to form a lexical entry. While the present work focuses on phonological issues in word learning, it is acknowledged that all these factors interact in lexical development.
Incidental Word Learning

Incidental word learning is a well-known phenomenon, in which a child makes a connection between a novel word and its referent with minimal exposure and no direct instruction. The child may be exposed to a word “incidentally,” that is, in the course of everyday life, and retain some information about a novel label despite brief exposure. The process by which incidental word learning takes place has been investigated using the fast mapping paradigm. In such research, novel (usually nonce) words and their novel referents are presented to children along with familiar names and their referents. Children are tested at a later time to determine whether the word is recalled. Fast mapping is conceptualized as a process or skill by which incidental word learning takes place. A word that has been recently “fast-mapped” is essentially a bare-bones representation, a sparse lexical-semantic storage. Thousands of words are learned in this manner over the course of acquisition, after only a few exposures to words and their referents. These incomplete initial representations are later elaborated and refined during the extended phase of lexical acquisition (Bloom, 2000).

In 1978, Carey and Bartlett conducted the first investigation of fast mapping. Children at three years of age were tested by giving them the instruction “Bring me the chromium plate, not the blue one, the chromium one.” The label “chromium” was a novel one. It was found that children were not only able to readily fast map the novel label onto the novel object, but also were able to recollect the word’s meaning after a one week delay.

Dollaghan (1985) extended the fast mapping task introduced by Carey and Bartlett (1978) to examine the abilities of 2 to 5 year-old children to fast map the novel word ‘koob’ with a white, oddly shaped ring (referent). The study consisted of five tasks: exposure, comprehension, production, recognition, and location. The exposure task consisted of a hiding game where
children were asked to hide the pen, fork, and ‘koob’ in three different locations. In the comprehension task, children were asked to give the pen, fork, and the ‘koob’ from a set of two familiar objects (pen, fork), two unfamiliar objects and the target (koob). In the production task, children were asked to name the target (koob) and in the recognition task children were shown the koob and asked if it was a ‘koob’, ‘soob’, or ‘teed’. Finally, in the location task children were asked about the location in which the koob was hidden. The results of this investigation revealed that children in all age groups could easily fast map a novel label with a novel object. Most children were better on comprehension and location tasks than production tasks.

The reason for the relative ease of comprehension versus production is speculated to be that initial representation of a fast mapped label is incomplete. The phonological representation (the word form) may be incomplete, given the brief exposure. The details of the semantic representation must practically of necessity be incomplete, given that the item has only been seen in one context. The child’s representation will be limited to the particular socio-linguistic context in which the novel label and its referent were introduced. This sparse initial representation is sufficient for the child to identify the referent when the novel label is named by the experimenter, because it need only be detailed enough to differentiate the lexical item from competitors. On the other hand, the incomplete knowledge encoded in the child’s lexicon is insufficient for the child to form an expressive template from which a label for the novel object could be constructed.

In sum, the findings of controlled studies have shown that children can readily fast map novel names with their novel referents, even after a single exposure. This brief exposure may be sufficient for performing well on comprehension tasks (identifying a novel object from an array) but is insufficient for performing well on word production tasks. This suggests that a sparse
lexical-semantic storage may be sufficient for word comprehension tasks (Carey & Bartlett, 1978; Dollaghan, 1985, 1987). On the other hand, performing well on word production tasks necessitates more complete lexical representations, which may include knowledge about word meanings, the syntactic frames in which words occur, phonetic characteristics of words, and the non-linguistic contexts associated with words (Brown, 1957; Gleitman, 1990; Gillette, Gleitman, & Lederer, 1999; Gelman & Markman, 1986; Gelman & Wellman, 1991). Studies have also shown that phonological factors such as phonotactic probability, neighborhood density, and word frequency have an influence on vocabulary acquisition (example, Storkel, 2001, 2004).

Incidental word learning in natural contexts. A problem associated with controlled studies conducted in laboratory environments is poor ecological validity. Children in these studies are exposed to words in an environment quite different from that in which they normally learn words, in natural contexts. In order to understand how children learn words in real environments, the fast mapping literature has evolved over time, seeking ways to simulate a more natural word-learning context. Rice and Woodsmall (1988) tested 3 and 5-year-old children’s ability to learn novel words belonging to four classes (attribute, object, action, and affective) after exposure to them through television programs. The procedure for this study consisted of 3 sessions. In the first session, a normed test of vocabulary was given and a pre-test of comprehension of pictures taken from the TV program was administered. In the second session, children were exposed to 20 words in four different semantic categories, through a 6-minute TV program, and each novel word was repeated at least five times. In the last session, post-test comprehension (pictures taken from the TV program) was once again administered. The post-test comprehension revealed the following mean number of words learned (out of 5) from the different word classes: 2.49 for attribute, 2.38 for object, 1.62 for action, and 1.36 for
affective words. It also revealed an average gain of 4.87 words by 5-year-olds and an average gain of 1.56 words by 3-year-olds, when compared to their pre-test comprehension. This ability of children to fast-map novel words in a natural context was termed “Quick Incidental Learning (QUIL)” by Rice and Woodsmall (1988). Overall, the findings of this study indicate that children are able to learn novel words exposed through natural contexts such as television viewing. It also indicates that attribute and object words are easier to learn than action and affective words.

Rice, Buhr, and Nemeth (1990) replicated the Rice and Woodsmall (1988) study on 5-year-old language impaired children and two comparison groups, one matched for chronological age (CA) and the other matched for mean length of utterance (MLU-morphemes). The chronological age-matched typically developing children performed better than MLU-matched children, who in turn outperformed language-impaired children. The findings also showed that children in all age groups were superior in learning object labels, followed by attribute, action, and affective labels in descending order.

In summary, the findings of word learning studies in natural contexts indicate that children are able make initial partial representations of words and learn various aspects of novel words, after brief exposure to them through natural contexts such as stories, conversations, explicit definitions, and television viewing (Oetting, Rice, & Swank, 1995; Rice, Buhr, & Nemeth, 1990; Rice & Woodsmall, 1988). These children can also maintain these representations after a delay of 3 to 7 days. Studies on different semantic classes indicate that children learn object and attribute terms much faster than action and affective words. Finally, language impaired children are relatively poorer in fast-mapping of novel words in natural contexts. It is unknown what exact factors may contribute to this poorer performance, whether
cognitive, such as memory and attention, or linguistic, such as phonological, lexical, and/or grammatical knowledge.

*Role of Memory in Fast mapping*

One of the ways in which the relationship between verbal working memory and incidental word learning can be investigated is by studying children’s ability to retain fast-mapped labels. Dickinson (1984) investigated the retention of fast-mapped labels by measuring the performance of children on fast mapping after a delay of 3 to 7 days. Dickinson found that just after one exposure children of all age groups were familiar with the novel words (they could tell if they had heard the word before or not). Children could also tell the syntactic use of novel words after a single exposure. Finally, 10 and 11-year-olds could provide rudimentary definitions of novel words indicating that older children were able to grasp the semantic aspects of novel words even after a brief exposure. The children were able to perform equally well on these tasks even after a delay of 3 to 7 days. Overall, the findings by Dickinson (1984) indicate that children can form syntactic, semantic, and phonological representations of words and also maintain these representations in long-term memory, after even a brief exposure to these words in natural contexts.

Golinkoff, Hirsh-Pasek, Bailey, and Wenger (1992) examined the retention of fast mapped labels in children between 2.4 and 2.8 years old. Golinkoff et al. (1992) tested the extension of a recently fast-mapped label to its variant (another token of the recently fast-mapped referent) in the presence of a novel distracter and familiar objects. They also tested children’s ability to retain a fast-mapped label by asking children to select an object referring to a second novel label from an array consisting of a just-labeled referent, a second novel referent, and familiar objects. It was found that more than 60% of the children extended a recently fast-
mapped label to another token of the same kind and 80% of the children correctly selected a
second novel referent upon hearing a second novel label.

The selection of a variant of a recently fast-mapped label in the presence of a novel
distracter and familiar objects indicates that children are able to extend the just learned label to
another token of the same object. The selection of a second novel object in the presence of
recently fast mapped referent, a second novel object, and familiar objects when the second novel
label is named indicates that children have still retained the recently fast-mapped label and
understand that the second novel label refers to a second novel object and is not another label for
the recently fast-mapped label.

The study by Golinkoff and her colleagues (1992) used procedures that were highly
facilitative. That is, all the trials occurred immediately following the exposure to a novel word
investigated fast mapping in children in a context that simulated some of the challenges faced by
children during the process of word learning. They tested fast mapping abilities of children when
certain information was missing or partially available.

Participants in this study were conditioned to respond to the name of an object when the
original referent was missing by touching a black square, which represented the missing object.
They examined children’s understanding that a newly learned label does not extend to an
available novel picture (second novel distracter) in the absence of the original newly learned
referent. This is referred to as ‘referent mismatch’ condition. This is similar to the analogy of a
child hearing the word ‘zebra’ (recently fast mapped label) in the absence of the animal ‘zebra’
and in the presence of ‘polar bear’. This study also examined children’s understanding that a
novel label, which had never been heard before, should not be affixed to the object that the child
was exposed to recently (original fast-map referent). This is referred to as ‘label mismatch’ condition. This is similar to the analogy of a child hearing the word ‘panda’ in the presence of the animal ‘zebra’ (recently fast mapped referent).

The results of this investigation showed that 69% of the children responded accurately to the referent mismatch task and 46% of the children responded accurately to the label mismatch task. In other words, 54% of the children in label mismatch task incorrectly selected the just-labeled object when a second novel label was named. The findings here suggest that children more readily accept a second label for a just-labeled object (label mismatch) rather than extending a novel label to an available novel distracter in the absence of original novel referent (referent mismatch). In sum, the findings by Dickinson (1984), Golinkoff et al (1992), Wilkinson and Mazzitelli (2003) suggest that phonological memory for novel labels is encoded and retained for long periods. This phonological memory is important for the formation of long-term memory representations of these words. Any problems in the formation and maintenance of phonological memory may lead to poor retention of fast-mapped labels.

*Components of incidental word learning.* The process of incidental word learning encompasses phonological processing, memory for a novel lexical item, and choosing the correct referent. Studies have shown that children choose the correct referent, and make a connection between the novel lexical item and the appropriate referent following brief exposure to a word and its referent (for example, Carey & Bartlett, 1978; Dollaghan, 1985, 1987). There have been some studies that have investigated the role of working memory in novel word learning (Gathercole, Hitch, Service, & Martin, 1997; Hansson, Forsberg, Lofqvist, Maki-Torkko, & Sahlen, 2004). Gathercole et al. (1997) used a paired-associate learning procedure as a measure of novel word learning. Hansson et al. (2004) used a controlled fast mapping procedure similar
to those used by Carey and Bartlett (1978) and Dollaghan (1985, 1987). Neither of these studies employed a naturalistic incidental word-learning task, such as those employed by Rice et al. (1990). There have been no studies that have investigated the complex interaction of both phonological processing abilities and working memory capacity in children’s abilities to make a stable initial representation of novel lexical items in the process of incidental word learning in naturalistic word learning contexts.

Working Memory

Memory for phonological forms of novel lexical items is an important component of word learning. In the current paper, the main focus will be on a particular aspect of memory, usually called working memory. The term working memory has evolved from its ancestor term, short-term memory, which refers to the passive storage of information such as storing a list of names or digits. This store, as the name implies, has been conceptualized as a temporary register of incoming information. The more modern concept of working memory expands the early idea of short term memory beyond a passive register of information. The label “working” has been applied to highlight the current belief that active processing of information takes place in this temporary store. Working memory performs the function of temporary storage of incoming information, holding it long enough so that it can be processed in long term memory can come into play. This capability is required for language comprehension and production, problem solving, executive functioning, reasoning, and other complex cognitive functions (Andrade, 2001).

Working memory has been proposed to play an important role in incidental word learning by storing and processing the phonological information for a novel lexical item. The “Functional working memory” model by Just and Carpenter (1992) and the “phonological loop”
model by Baddeley and Hitch (1974) are the two most prominent models of working memory. Each will be explored in turn below, with information about hypothesized contributions of the model to language development overall and lexical development in particular, as well as what is known about working memory and language impairment, according to the research completed in the two paradigms.

**Functional Working Memory**

The functional working memory (FWM) model developed by Just and Carpenter (1992) is an integrated model of working memory, which views working memory as a storage-limited system involved in the processing and storage of linguistic information. The processing system computes lexical, phonological, semantic and morphosyntactic representations of the incoming linguistic input. The storage system is responsible for the temporary storage of linguistic information that has been processed. The processing and storage components of this working memory system are constrained by common cognitive processes; whenever storage or processing demands of a task exceed the available cognitive resources, a trade-off between the two systems occurs. For example, if the linguistic input is grammatically complex, then all the cognitive resources maintaining old information will be devoted to processing, resulting in diminished storage and thereby, “forgetting” of some of the previously stored information. The reverse might also occur, if resources were devoted primarily to storage, processing efficiency might be adversely affected.

*Assessment of functional working memory (FWM).* FWM has been assessed by three kinds of measures: listening span tasks (Daneman & Carpenter, 1983), the competing language processing task (CPLT, Gaulin & Campbell, 1994), and the modified CLPT, or dual task processing task (Montgomery, 2000a, 2000b). In the listening span tasks (Daneman & Carpenter,
1983), undergraduates were required to read or listen to sets of unrelated sentences of varying length (processing component) while at the same time recalling all of words in the sentence final positions (storage component). In the competing language processing task (CLPT) (Gaulin & Campbell, 1994), which is a modified version of listening span tasks, children are presented with a set of sentences. After the presentation of each sentence, they are required to judge if the sentences are true or false by saying ‘yes’ or ‘no’ (processing component), and after the presentation of the entire set of sentences children are required to recall the sentence final words (storage component). Finally, the dual task processing (Montgomery, 2000a, 2000b) consists of no-load, single-load and dual-load processing conditions. In the no-load condition, children were required to recall a list of 3 to 7 words. In the single-load condition, children were required to recall a list of words according to their physical size. For example, children were given a list of words (cow, shoe, thumb) and they had to recall this list according to their physical size from smallest to largest (thumb, shoe, cow). So, in the single-load condition, children had to both store and process (perform one mental operation) at the same time. In the dual-load condition, children were required to recall a list of words according to both semantic category and physical size. For example, children were given a list of words (cow, tree, mouse, seed, cat) and they had to group them according to semantic category (cow, mouse, cat, seed) and then group them “beginning with the smallest and ending with the largest” (seed, mouse, cat, cow). The tasks described here, which help in the assessment of both storage and processing aspects of individuals’ FWM, have been used to explore the FWM capacity in typically developing children and children with language disorders (e.g., Gaulin & Campbell, 1994; Eliis Weismer, 1996; Montgomery, 2003).
**FWM and vocabulary.** Gaulin and Campbell (1994) used the competing language-processing task (CLPT) to measure FWM in children between 6 and 12 years of age. Gaulin and Campbell (1994) found that the FWM capacity increases up to 10 years of age, and also found a high correlation between FWM capacity and receptive vocabulary. Receptive vocabulary involves the dual functions of storing a word and understanding its meaning. So, children with low FWM (who have reduced ability for simultaneous processing) had a problem in receptive vocabulary, which requires simultaneous processing and storage of information.

Ellis Weismer (1996) and Ellis Weismer and Hesketh (1996) found that faster rate of presentation of novel words had a significant negative impact on novel word production, but not on novel word comprehension, in both SLI and typically developing children aged between 4 and 7 years. Children with SLI, were significantly worse than typically developing children in the production of novel words. An error analysis revealed that, when compared with normal children, children with SLI had more word substitutions (substituting real words for novel words), vowel errors and problems in making a connection between the novel name and its referent. This shows that children with SLI not only had a problem in storage of phonological information, but also had problems in other aspects of lexical learning, such as making an association between the word and its referent.

In sum, findings by Ellis Weismer (1996) and Ellis Weismer, and Hesketh (1996) show that children with SLI had problems in producing the phonological forms of novel words, but not in their comprehension. In addition, children with SLI had problems in making an association between the word and its referent. These findings fit well within the FWM model by Just and Carpenter (1992). Applying this model to children with impairments, one may hypothesize a problem in the simultaneous processing and storage of information. That is, the breakdown...
occurs because of general cognitive demands, with competition occurring between storage and processing components of FWM. Moreover, the findings by Gaulin and Campbell (1994), which show a high correlation between FWM and vocabulary in children between 6 and 12 years of age, could be taken to indicate that children with low FWM capacity have a problem in the simultaneous processing and storage of information. That is, learning a novel word involves storing the phonological form of a novel word and processing its meaning. Whenever the processing demands are high (e.g. processing the meaning of abstract words or morphologically complex words), the storage of the novel phonological information is affected, leading to poor word learning capacity (trade off between processing and storage components of FWM).

**Phonological Loop Model**

According to the “phonological loop” model by Baddeley and Hitch (1974), working memory is a multi-component system consisting of the central executive, the visuo-spatial sketchpad, and the phonological loop. The phonological loop will be the main focus of the current paper and is discussed in detail below. The visuo-spatial sketchpad is responsible for storage and processing of visual information. The central executive, which is the least documented component of this model, is responsible for the processing, storage, regulation, and retrieval of linguistic information. In the phonological loop model, the central executive allocates resources to processing, and is in a sense similar to Just and Carpenter’s FWM in that it is involved in the storage and processing of information required for complex cognitive tasks such as reasoning, problem solving and executive functions. The important distinction is that the FWM model does not propose the existence of sub-domains of working memory devoted to particular tasks, instead placing all processing and storage within a single layer. The term “fractionated” is applied to the phonological loop model, referring to their proposal that
dedicated modules exist within working memory, specific to the processing of visual and phonological information.

*The Phonological Loop*

The phonological loop, which is the most well documented component of the system, is involved in the active storage and rehearsal of verbal information (see Andrade, 2001, for a summary). The phonological loop consists of two components, a phonological store and an articulatory control process.

*Phonological store.* The phonological store is involved in the temporary storage of verbal information. This storage is constrained by time and space. That is, the storage of verbal information in the phonological store is for a short period of time and only a limited amount of information can be stored at a given point of time. If this stored information is not rehearsed in the articulatory control process, then it will be completely lost. On the other hand, if the verbal information exceeds the space in the phonological store, the information will be transferred to the central executive for further processing.

Evidence for the existence of the phonological store comes from the ‘phonological similarity effect’ and ‘irrelevant speech.’ The phonological similarity effect refers to poorer recall of phonologically similar verbal stimuli when compared to phonologically dissimilar stimuli. Phonologically similar stimuli are less distinct when compared to phonologically dissimilar stimuli. This leads to superior recall of less similar-sounding items (distinct representation) relative to more similar-sounding items (Conrad & Hull, 1964). The poorer recall of similar-sounding words is held to result from the overlapping (confusion) of phonological codes in the phonological store. These findings are held to support the phonological loop model,
because they suggest that information is stored at a sub-lexical (phonological) level rather than at a lexical level in the phonological store.

‘Irrelevant speech’ is the second source of evidence for the existence of a phonological store. It refers to reduced performance on recall of verbal stimuli when presented with irrelevant speech stimuli in the background. Colle and Welsh (1976) found that the recall of visually presented digits (in English) was affected by presence of German language in the listener’s background. Salame and Baddeley (1982) found that the presentation of digits (1, 2) and phonemes that sound similar to digits (tun, woo) contributed equally in interfering with the recall of digits. Salame and Baddeley (1982) found that phonemes that sound similar to the target stimuli cause more interference in their recall when compared to phonemes sounding dissimilar to the target items. The findings by Colle and Welsh (1976) and Salame and Baddeley (1982) once again suggest that information is stored at a sub-lexical (phonological) level rather than at a lexical level in the phonological store.

Overall, Baddeley and colleagues claim that the findings from the phonological similarity effect and irrelevant speech show that information is stored at a sublexical level. According to them, this is strong evidence for the existence of a phonological short-term store because, unlike long-term memory, which stores information as lexical items including both semantic and phonological information, the phonological loop stores verbal information as phonological codes and processes the phonological information separately from other lexical information. In the long-term memory, a lexical similarity effect rather than a phonological similarity effect should be seen because it stores semantic and other relevant information in addition to phonological. That is, once long-term memory is accessed, listeners have the opportunity to make use of all
information about the word, whereas at the instant that the phonological loop is employed to
process incoming information, access to long-term storage is impossible.

While phonological similarity and irrelevant speech effects have been argued to support
the existence of a temporary phonological store, other interpretations of these data are possible.
Copeland and Radvansky (2001) found that although their subjects showed a phonological
similarity effect in a word span task, the reverse effect was seen in a task where subjects were
asked to recall the last words from a list of sentences. That is, in the sentence task, subjects were
able to recall similar words better than dissimilar words in sentence final positions. These
contradictory findings suggest that similar-sounding words (rhymes) may act as cues in
remembering words at the sentence level. The different findings by Conrad and Hull (1964) and
Copeland and Radvansky (2001), can be explained by using a FWM model. In the Conrad and
Hull (1964) study, when children were asked to recall a list of words, they had to perceive the
phonological forms of words, discriminate the speech sounds, process the meaning of words, and
retrieve the words. The superior recall of words containing similar sounding words when
compared to dissimilar sounding words (phonological similarity effect) in this study has been
interpreted by Baddeley and colleagues as an evidence for sub-lexical (that is, purely
phonological) representation of information in the phonological loop. In the FWM model,
phonological forms of words are not processed separately from their content or meaning. This
model can account for the similarity effect in terms for greater need for cognitive resources.
Specifically, the recall of similar sounding words requires finer discrimination than dissimilar
words (because fewer features differentiate them), and hence is cognitively more demanding
than recalling words that sound dissimilar. Different factors come into play for the Copeland and
Radvansky study, because children had to recall words presented at the level of sentences. This
increased the cognitive processing load, requiring participants to both process sentences and store words, in addition to phonological and semantic processing of words. This increased cognitive demand could have led children to adopt a strategy of remembering words based on their phonological similarities (rhymes). With the help of this strategy, children would have been better at remembering words that sounded similar than dissimilar sounding words presented at sentence final positions.

*Controlled articulatory process.* As mentioned earlier, if the verbal information stored in the phonological store is not rehearsed, then it would lead to decay of that information. This rehearsal of auditory verbal information occurs in the controlled articulatory process. The evidence for the existence of a controlled articulatory process comes from the word-length effect and articulatory suppression (Andrade, 2001).

The word-length effect refers to better recall of shorter words when compared to longer words. The better short-term memory for shorter words is attributed to the shorter articulation time required for these words (shorter rehearsal time) when compared to longer words. The shorter rehearsal time (for shorter words) means less decay and better recall of verbal information (Baddeley, Thomson, & Buchanan, 1975).

Articulatory suppression refers to reduced recall of verbal material when a subject is asked to say an irrelevant word such as “the” repeatedly during the presentation or recall of verbal information. Articulatory suppression eliminates the word-length effect in both auditory and visual modalities. That is, better memory for shorter words when compared to longer words (presented in auditory or visual modality) is not seen when the person is asked to repeatedly produce an irrelevant word. This suggests that articulatory suppression prevents active rehearsal required for both verbal information and visually presented verbal material. Articulatory
suppression eliminates phonological similarity effect of visually presented verbal material only. That is, recall of words that sound similar is not different from recall of words that are dissimilar (only when these words are presented visually). This indicates that articulatory suppression prevents the conversion of visually presented information to phonological codes required for verbal rehearsal (Baddeley, 1986).

**Phonological Working Memory (PWM) and Vocabulary Development**

Gathercole and Baddeley (1990b) have argued that phonological working memory drives vocabulary development. They have used the ‘nonword repetition’ task to test the functioning of phonological working memory. Nonword repetition, unlike repetition of real words, involves the activation of different phonological processes such as encoding, storage, and retrieval, which are independent of lexical knowledge. Gathercole and her colleagues suggest that verbal STM tasks such as digit span, which are lexically mediated, can be useful measures of the phonological loop. However they prefer nonword repetition, suggesting, “non lexical tasks such as nonword repetition may provide purer assessment of the capacity of the loop” (Gathercole et al., 1997).

Gathercole (2006) has suggested that there is a high correlation between nonword repetition and novel word learning because both are constrained by the phonological store. That is, children’s ability to repeat an unfamiliar sequence of phonemes can determine their ability to store and learn a sequence of phonemes pertaining to a novel word in question. Since every word is a novel word when it is first introduced to the child, both nonword repetition and vocabulary acquisition may have shared cognitive and neural mechanisms (Gupta & MacWhinney, 1997). There is some evidence showing association between nonword repetition and learning word-nonword pairs in an adult patient with short-term memory deficits (Papagno & Vallar, 1992). Some studies have also shown strong correlations between nonword repetition and novel word
learning in typically developing children and children with language impairment (e.g., Gathercole & Baddeley, 1989a; Gathercole & Baddeley, 1990b). The proponents of the phonological loop model have claimed that storage of phonological information in the phonological loop is critical for learning words (Gathercole et al., 1997; Gathercole & Baddeley, 1990b). Gathercole (2006) also proposes:

Although this is not the only route by which new phonological structures can be acquired (lexically mediated learning is one alternative), it is a primitive learning mechanism that is particularly important in the early stages of acquiring a language.

(p. 251).

Thus the theory currently emphasizes the role of the phonological loop as crucial to early lexical development.

Snowling, Chiat, and Hulme (1991) have argued that nonword repetition involves other phonological processes, such as phoneme segmentation and assembly of articulatory instructions, in addition to phonological memory. In response to this, Gathercole et al. (1991b) acknowledge that such phonological processes are involved in nonword repetition. They also agree that these phonological processes may contribute to the link between nonword repetition and vocabulary knowledge. However, they claim that nonword repetition is a significant contributor to children’s subsequent vocabulary development, and that the phonological processes offer little in predicting future vocabulary size.

Evidence from research in typically developing children. Gathercole and Baddeley (1989a) found a high correlation between phonological short-term memory (measured by digit span) and vocabulary knowledge in 4 and 5 year old typically developing children. The researchers also found that phonological memory measures taken when children were 4 years old
could predict their vocabulary knowledge one year later (when they were 5 years old).

Gathercole and Baddeley (1990a) investigated the causal relationship between phonological memory and vocabulary acquisition by comparing the abilities of children between the ages of 5 and 6 years, with high and low nonword repetition scores to learn proper names of familiar and unfamiliar toys. The children were asked to repeat the names of a set of toys, half of which were familiar names such as Michael, and half nonce words used as names. Following the repetition of names, children were asked to name the toys in response to the question ‘What’s this one called?’ The speed of learning was measured by calculating the number of trials taken by children to accurately say the names of all the toys. After a 24-hour delay, children were tested on retention of the names by asking them to produce the names in response to ‘What’s this one called?’ and comprehend the names of toys by placing all 4 toys on the table and asking them ‘Which one is Michael?’.

The children with high non-word repetition scores were found to be faster in learning unfamiliar names (non-names) when compared to children with low nonword repetition scores. However, no differences were seen between the two groups in learning familiar toy names. The difference between the two groups on vocabulary and reading skills could have contributed to the difference in performance of the two groups on learning non-names. However, in a regression analysis, when non-verbal intelligence (measured by Raven’s progressive matrices) was factored in, vocabulary and reading skills did not significantly contribute to variation in speed of learning non-names, suggesting a causal link between phonological working memory and vocabulary learning. The authors argue that their results indicate that the short-term memory measured by nonword repetition is important for forming short-term representations of phonological forms of novel lexical items, which in turn are necessary for long-term phonological representations of these items. Poorer performance of the low nonword
repetition group on a delayed retention task suggests the negative impact of poor short-term memory representations on formation of stable long-term representations, which are necessary for learning words. It should be noted that this study differed from other lexical research, in that it used proper names, which differ in syntactic, semantic, and pragmatic properties from regular nouns. While the exact implications of this choice are not clear, it does make comparison of this study to other word-learning studies somewhat difficult. The abilities demonstrated in this work also differ from those in lexical research using fast-mapping techniques, because the children were required to provide expressive labels to criterion. This does not occur in incidental learning research paradigms. More importantly, elicitation of repetition of labels occurs only in a minority of natural word learning scenarios. Thus the word learning abilities tapped in the Gathercole and Baddeley task differed from those that would be in evidence in real-world word learning.

*Evidence from adult research.* Papagno and Vallar (1992) explored the impact of phonological similarity and word length effects on word learning by using a paired associate word-learning paradigm. In the paired associate word-learning task, subjects were presented with real word pairs and word-nonword pairs. Following the presentation of these pairs, the subjects were presented with the first word from the pair and they were required to say the second word or nonword associated with that particular word. It was found that phonological similarity and word length effects had a negative impact on paired associate learning of word-nonword pairs but not word pairs. This suggests that word length and phonological similarity affects the phonological storage, which in turn affects people’s ability to store novel phonological forms required for learning word-nonword pairs (Gathercole, 2006).

*Evidence from research in neurologically impaired populations.* The evidence for a direct relationship between phonological working memory and vocabulary in neurologically impaired
patient comes from an investigation by Vallar and Papagno (1993) on an Italian left hemisphere stroke patient named PV. PV could consistently repeat monosyllabic and disyllabic nonwords and also could repeat trisyllabic non-words 80% of the times. However, she could not repeat 4 and 5 syllabic non-words at all. On a paired associate task, PV could learn Italian-Italian word associates but had problems learning Italian-Russian word associates. Thus, with her limited phonological working memory she was able to learn word associate pairs of her native language (Italian) but failed to learn word associate pairs containing a familiar (Italian) and an unfamiliar (Russian) word. These findings suggest an association between phonological STM (measured by non-word repetition) and word learning (paired associate learning).

Laws (1998) investigated the potential advantages of using nonword repetition as a measure of phonological working memory in individuals with Down syndrome. This investigation revealed a strong correlation between nonword repetition and digit span, when controlled for age, non-verbal ability and word repetition skills. There was also a significant relationship between nonword repetition and vocabulary, and a weaker relationship between digit span and vocabulary. Finally, nonword repetition had a strong correlation with reading and grammar comprehension and conversely, digit span had a weak correlation with reading and grammar comprehension.

In sum, evidence from typically developing children, normal adults and neurologically impaired populations suggests a direct relationship between nonword repetition and some types of word-learning abilities. This indicates that repetition of nonwords and learning word-nonword pairs, and novel names and words may be constrained by a common underlying short-term phonological storage capacity (conceptualized as the phonological loop by Gathercole and Baddeley). Neurological impairments that damage this storage would affect the ability to encode
phonological forms and therefore repeat nonwords and learn novel phonological forms (Gathercole, 2006).

Evidence contradicting the role of phonological working memory in vocabulary development. A longitudinal study by Gathercole et al. (1992) to explore the relationship between phonological working memory and vocabulary in typically developing children consisted of four stages. Children were given tests of non-verbal intelligence, vocabulary, and phonological short-term memory at each stage. The findings of this study revealed that nonword repetition at age 4 predicted vocabulary at age 5, but vocabulary at age 4 did not predict non-word repetition at age 5. In children between the ages of 5 and 6 years, and 6 and 8 years vocabulary knowledge was a strong predictor of subsequent nonword repetition performance. On the other hand, nonword repetition was not a good predictor of subsequent vocabulary development in children between the ages of 5 and 6, and 6 and 8 years of age. Gathercole et al. (1992) have hypothesized that children’s use of existing vocabulary knowledge as analogies to build new vocabulary, their reliance on conceptual skills to learn new vocabulary, and their reading skills may overshadow the role of phonological short-term memory in children beyond age 5.

Laws and Gunn (2004) investigated the role of phonological working memory in later language development of children with Down syndrome. The findings here were similar to that of Gathercole et al’s (1992) findings in typically developing children in that phonological working memory (measured by nonword repetition) was a predictor of later vocabulary acquisition only in younger Down syndrome children. In older Down syndrome individuals or Down syndrome individuals with higher levels of vocabulary, vocabulary was a predictor of later phonological memory performance, which is the reverse of what is seen in younger children. The
researchers here hypothesized that the relationship between earlier vocabulary and later measured nonword repetition skills was due to better reading skills (better decoding skills) developed by Down syndrome participants of this study.

Baddeley and his colleagues (1991a 1991b, 1997) have argued for several years that there is a clear link between phonological working memory and subsequent vocabulary acquisition. Some findings fail to show this link. For example, Gathercole et al. (1992) did not find a link between phonological working memory and subsequent vocabulary acquisition in typically developing children older than 5 years. Rather, vocabulary knowledge predicted their performance on nonword repetition. Laws and Gunn (2004) failed to find a significant relationship between phonological short-term memory and subsequent vocabulary acquisition in older Down syndrome children or Down syndrome children with higher receptive vocabulary. Gathercole (1995) found that when autoregression effects were controlled, repetition of both less wordlike nonwords and wordlike nonwords at age 4 failed to predict composite vocabulary scores obtained at age 5. However, when autoregression effects were controlled, vocabulary scores obtained at age 4 predicted repetition of more wordlike nonwords at age 5. Overall, these findings weaken the claims by Gathercole and her colleagues for the existence of a direct link between phonological working memory and subsequent vocabulary acquisition. The findings of these studies, which have explored the relationship between phonological working memory and lexical abilities, have been summarized in Table 1.
TABLE 1

*Summary of Findings on the Relationship between Phonological Working Memory and Lexical Abilities*

<table>
<thead>
<tr>
<th>Study</th>
<th>Measure of PWM</th>
<th>Lexical ability tested</th>
<th>Participants</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathercole &amp; Baddeley</td>
<td>Digit span</td>
<td>Vocabulary size</td>
<td>Typically developing children 4 &amp; 5 year olds</td>
<td>High correlation between digit span and vocabulary size in both 4 &amp; 5 year olds. Phonological memory measure taken when children were 4 years could predict their vocabulary at age 5.</td>
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<td>(1989a)</td>
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<tr>
<td>Gathercole &amp; Baddeley</td>
<td>Nonword Repetition</td>
<td>Speed of word learning of novel toy names</td>
<td>Typically developing children between 5 &amp; 6 years</td>
<td>Children who obtained low scores on Nonword Repetition were also slow on word learning when compared to children who obtained high nonword repetition scores</td>
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<td>(1990a)</td>
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<tr>
<td>Study</td>
<td>Measure 1</td>
<td>Measure 2</td>
<td>Sample Description</td>
<td>Findings</td>
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<tr>
<td>Vallar &amp; Papgno (1993)</td>
<td>Nonword Repetition</td>
<td>Paired associate</td>
<td>Italian left hemisphere stroke patient</td>
<td>High correlation between Nonword Repetition and learning word-nonword pairs but not word-word pairs</td>
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<td>word learning</td>
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<td></td>
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<td>Digit span</td>
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<tr>
<td>Gathercole et al. (1992)</td>
<td>NWR</td>
<td>Vocabulary</td>
<td>Typically developing children between 4 &amp; 8 years</td>
<td>Nonword Repetition was a good predictor of vocabulary in children between 4 &amp; 5 years.</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Vocabulary was a good predictor of Nonword Repetition in children between 5 &amp; 8 years.</td>
</tr>
</tbody>
</table>
Lexical Restructuring Model

The findings by Gathercole et al. (1992), which show that nonword repetition was not a good predictor of future vocabulary development and that vocabulary knowledge was a better predictor of nonword repetition in children beyond the age of 5 years can be explained to some extent with the help of the lexical restructuring model. The lexical restructuring model theorizes that vocabulary development leads to reorganization of the mental lexicon from holistic to a more segmental representation (Metsala, 1999). As a consequence of segmental representation, there is an increase in children’s phonological knowledge of a language. This increase in phonological knowledge in turn leads to superior performance on nonword repetition, phonological sensitivity, and other tasks that require phonological knowledge (Snowling et al., 1991). Since children with higher vocabulary have better segmental representation, vocabulary knowledge of children beyond the age of 5 years should predict subsequent nonword repetition or performance on tasks tapping phonological sensitivity (Metsala & Walley, 1998; Metsala, 1999).

Another claim of this hypothesis is that nonword repetition does not solely measure phonological memory. It is a combination of phonological memory and general phonological processing. Similarly, a phonological sensitivity task such as phoneme identity measures both phonological memory and a general phonological processing capacity. In other words, the lexical restructuring model theorizes that the tasks used to measure phonological working memory (nonword repetition task) and the phonological sensitivity tasks share a common set of processes such as speech perception, phonological representation, phoneme memory, and retrieval of the phonological representation from the phonological memory (Bowey, 2001). Thus, nonword repetition is not a “purer” measure of phonological working memory and it is not necessarily the
best predictor of subsequent vocabulary size. In fact, skill at nonword repetition and other phonological sensitivity tasks emerges from one’s knowledge about the lexical structure of a language (Metsala & Walley, 1998; Bowey, 2001).
Figure 1. A conceptual framework of the Lexical Restructuring Model
Evidence Supporting the Lexical Restructuring Hypothesis

Gathercole, Willis, and Baddeley (1991a) found that when age and Raven’s progressive matrices (a measure of IQ) variables were controlled, nonword repetition was highly correlated with vocabulary at 4 and 5 years but a phonological sensitivity task such as rhyme oddity did not contribute to variation in vocabulary for 4 and 5 year old children. Evidence contradicting Gathercole et al.’s (1991a) findings was reported by Bowey (1996). Bowey (1996) found that when age and IQ (measured by Block design) were controlled, both nonword repetition and phoneme identity accounted for 9-10% variance in receptive vocabulary and when age and block design were controlled, phoneme identity and digit forwards contributed to 5% variation in receptive grammar. These findings suggest that both nonword repetition and phoneme identity tasks can predict vocabulary development, and that phonological memory measured by nonword repetition, has no unique contribution to vocabulary development.

Bowey (1996) also found that when phonological sensitivity was controlled, digit span and not nonword repetition contributed to variation in vocabulary. Also, phoneme identity contributed to 3% of the variance in receptive vocabulary when phonological memory (measured by nonword repetition) was controlled but on the contrary when phonological sensitivity was controlled, phonological working memory (nonword repetition) was not a significant contributor to vocabulary. These findings once again bolster the claim that nonword repetition is not the only predictor of subsequent vocabulary, and phonological sensitivity tasks such as phoneme identity have a much stronger correlation with future vocabulary growth. Metsala (1999) found that when phonological awareness and age were controlled, phonological working memory (measured by nonword repetition) did not contribute to any significant variation in receptive vocabulary but
when phonological working memory was controlled, phonological awareness contributed to a significant variance in receptive vocabulary.

A longitudinal study by Bowey (2001) examined the relationship between phonological working memory (using nonword repetition) and vocabulary in young children. The correlational data of this study showed that when effects of IQ (measured by block design) were co-varied, nonword repetition contributed to 6-7% of additional variance in vocabulary age. However, a significant correlation (10%) was seen even between phoneme identity and vocabulary when effects of IQ (measured by block design) were controlled, thus ruling out any unique contribution of nonword repetition to vocabulary development.

Bowey (2001) found that when nonword repetition effects were controlled, phoneme identity accounted for 5-6% of the variation in vocabulary, but on the contrary when block design and phoneme identity effects were controlled, nonword repetition did not contribute to any significant variation (only 1-2%) in vocabulary. Predictive data of this study revealed that when autoregression and block design were controlled, verbal abilities of session 1 (PPVT-R, nonword repetition, rime identity task, grammatical understanding subtest of TOLD-P) predicted receptive vocabulary of session 2. It was also found that when autoregression and block design effects were controlled, both nonword repetition and phoneme identity accounted for variance in subsequent vocabulary but only leniently scored nonword repetition accounted for a significant variation in vocabulary and phoneme identity did not account for a significant variation in vocabulary. The fact that only leniently scored nonword repetition scores contributed to variance in receptive vocabulary is suggestive of a small contribution of phonological memory to vocabulary and the use of nonword repetition as the sole measure of phonological memory should be done with great caution.
Bowey (2001) also found that when autoregression and block design were controlled, session 1 vocabulary predicted session 2 nonword repetition. This finding is congruent with previous work by Gathercole et al. (1992), which showed that for children above 5 years, receptive vocabulary significantly contributed to nonword repetition. The findings by Bowey (2001) and Gathercole et al. (1992) support the lexical restructuring hypothesis, which states that development of vocabulary leads to phonemic restructuring or reorganization, which in turn leads to better segmental representation, which is required for nonword repetition.

Bowey (2001) has suggested that children with reading problems also have deficits in speech perception, nonword repetition, verbal working memory, phonological sensitivity, articulation, and pseudoword decoding. These deficits in multiple areas can be attributed to “latent phonological processing” problems. The claim that problems in phonological memory cause SLI is weakened by the findings which show that deficits in nonword repetition persist even after language deficits are resolved in individuals with SLI (Bishop, North, and Donlan, 1996).

De Jong, Seveke and van Veen (2000) investigated the relationship between phonological short term memory (nonword repetition), phonological sensitivity, and paired associate word learning in Dutch speaking 5-year-old children. They found a significant contribution of phonological sensitivity and a weak contribution of phonological short-term memory in paired associate word learning tasks. A second study investigating the effect of training in phonological sensitivity on paired associate word learning revealed a performance improvement in word learning following a short 2 weeks training. The findings support the lexical restructuring model by suggesting that enhanced phonological sensitivity (a richer phonemic representation) leads to enhancement in word learning skills.
Beyond the Lexical Restructuring Model

The lexical restructuring model theorizes that nonword repetition is not a “purer” measure of phonological working memory as suggested by Gathercole et al. (1997). Further, other factors in addition to performance on nonword repetition tasks are important in accounting for vocabulary development. Investigations by Bowey (1996, 2001) and Metsala (1999) have shown that when effects of age and IQ were controlled, both nonword repetition and phoneme sensitivity contributed significantly to vocabulary size, thus ruling out nonword repetition as a unique contributor. A second important finding of these investigations is that when effects of phoneme sensitivity were controlled, nonword repetition failed to show any independent significant contributions to vocabulary. On the other hand, when effects of nonword repetition were controlled, phonological sensitivity still showed significant contribution to vocabulary in both 4 and 5 year-olds (Metsala, 1999).

The significant contributions of both nonword repetition and phonological sensitivity can be accounted for under the lexical restructuring model, which theorizes that both these tasks are products of latent general phonological processing skills (Metsala & Walley, 1998; Metsala, 1999). The findings that show a failure of nonword repetition in predicting subsequent vocabulary development are not well explained by the lexical restructuring model (Metsala, 1999). A more complex model of general phonological processing similar to the functional working memory model proposed by Just and Carpenter (1992), which considers both processing and memory aspects of a linguistic task, can explain this relationship better.

Nonword repetition is relatively a less complex measure of phonological processing when compared to more metaphonological tasks such as phoneme identity, rhyming, phoneme deletion, etc (Hansson et al., 2004). Nonword repetition is a simpler task, with a decreased
metaphonological component, requiring speech perception, phonological representation, retrieval of phonological representation, and articulatory instructions (Bowey, 2001). On the other hand, phonological sensitivity tasks, such as phoneme identity (for example, asking a child to match the target ‘sun’ with another word from the word choices which begin with the ‘s’ sound) require speech perception, phonological representation, isolating the initial sound of target words and word choices, matching the target word with a word beginning with the same sound as the target from the given word choices, and articulatory instructions. Although nonword repetition and phonological sensitivity tasks share a similar set of cognitive and linguistic processes, the latter is a more complex task requiring conscious manipulation of structural components of words, and therefore may require cognitive processes that are not required for nonword repetition (Munson, 2001; Munson et al., 2005). Word learning is a complex process requiring a number of abilities, including attention, phonological processing, phonological working memory, and sensitivity to statistical, semantic, syntactic, and socio-pragmatic cues. Phonological sensitivity tasks are metaphonological in nature, requiring higher level phonological knowledge. For instance, to match two words beginning with the /s/ sound, the child needs to have word segmentation knowledge, and also knowledge about the different word combinations and positions in which /s/ can occur. For example, the child must know that /s/ can occur in words such as sun, ask, and has (Munson et al., 2005). The child should possess this higher level phonological knowledge in addition to some of the basic phonological processing skills such as speech perception, phonological representation, and articulatory instructions (Bowey, 2001). The significant contribution of phonological sensitivity in predicting vocabulary could be attributed to the complex cognitive and linguistic processes shared by word learning and metaphonological tasks such as phoneme identity.
The utility of complex working memory in word learning has been investigated by a number of researchers (Hansson et al., 2004; Hayiou-Thomas, Bishop, & Plunkett, 2004; Marton & Schwartz, 2003). Hansson et al. (2004) have examined the potential utility of a complex working memory task in predicting word learning in children with hearing impairment (HI) and specific language impairment (SLI). Participants were given a word learning task, a nonword repetition task, and a complex working memory task (Competing Language Processing Tasks or CLPT by Gaulin & Campbell, 1994). In the CLPT task, children were required to listen to sentences and judge if they were semantically acceptable or not (processing part of working memory). They were also required to recall the last word of all the sentences (storage part of working memory). The findings revealed that the complex working memory (CLPT task), which taps both processing and storage aspects of working memory, was a better predictor of word learning than nonword repetition in children with HI and children with SLI.

Marton and Schwartz (2003) examined the role of the phonological loop and central executive components of the phonological loop model by Baddeley & Hitch (1974) in children with SLI and typically developing children. The two groups were presented with nonwords in a variety of tasks. These included nonword repetition, nonword discrimination, modified listening tasks (where children had to listen to sentences of different length and complexity with embedded nonwords and then respond to questions related to the sentence), and list recall tasks (where children had to listen to a set of sentences and then recall the sentence-final nonwords of all the sentences in the set). The results indicated qualitative rather than quantitative differences between the two groups. Although both groups had difficulty in repeating nonwords of greater length and syntactic complexity, children with SLI performed more poorly than typically developing children. This decrease in performance in children with SLI was attributed to the
inability of these children to simultaneously process linguistic information rather than encode and analyze the components of nonwords, because these children performed as well as typically developing children on nonword discrimination. It is also important to note that syntactic complexity rather than syntactic length had a greater impact on accuracy of nonword repetition, thus strengthening the significant role of complex working memory in nonword repetition.

Hayiou-Thomas et al. (2004) were able to simulate the language characteristics of a specific type of SLI in typically developing children by compressing the speech signal and increasing their memory load. Archibald and Gathercole (2006) found that children with SLI were better in nonword repetition compared to nonword recall. They also found that these children with SLI performed poorly on verbal working memory tasks requiring both storage and processing. Archibald and Gathercole (2005b) found that nonword repetition in children with SLI was superior when compared to serial recall of a sequence of phonemes, which were matched with nonwords in terms of length and complexity. All these data put together indicate that a model based on specific impairment in the phonological loop is inadequate in explaining word learning and language deficits seen in children with SLI and HI. A complex working memory model, which theorizes the simultaneous processing of linguistic information and a breakdown in language due to increased cognitive load, can explain this relationship much better.

In sum, the lexical restructuring model theorizes that vocabulary development leads to restructuring of a child’s lexicon, which in turn leads to a segmental phonemic representation. This segmental representation aids the child in tasks requiring general phonological processing such as nonword repetition and phonological sensitivity tasks (Metsala, 1999). Investigations by Metsala (1999) and Bowey (1999, 2001) have led to two main conclusions. First, nonword
repetition is not the only predictor of subsequent vocabulary size. Second, hierarchical regression analyses have shown that when effects of nonword repetition were controlled, phonological sensitivity contributed to significant variance in vocabulary but when phonological sensitivity effects were controlled, nonword repetition failed to show a significant variance in predicting vocabulary. The latter findings can be attributed to the more metaphonological nature of phonological sensitivity tasks relative to nonword repetition. There is some evidence showing that a functionally complex working memory task was a better predictor of word learning than nonword repetition (Hansson et al., 2004; Hayiou-Thomas, Bishop, & Plunkett, 2004; Marton & Schwartz, 2003). These investigations suggest the significant role of skill at metalinguistic tasks, such as those involving as the ability to manage competing language stimuli, and metaphonological ability, in predicting subsequent vocabulary development and word learning.
Purpose of the Study

Vocabulary acquisition is a complex process requiring attention, phonological working memory, phonological sensitivity, and the ability to process and store statistical regularities of recurring patterns in the linguistic input. All this must take place while the word learner is attending to the socio-pragmatic and other cues available in the linguistic environment (Werker & Yeung, 2005). Gathercole and Baddeley (1990a) have claimed that nonword repetition is a significant predictor contributing to vocabulary acquisition. Since nonword repetition involves formation of phonological representations independent of lexical knowledge, it is considered as a purer measure of phonological store relative to tasks such as serial recall or digit span for instance which are lexically mediated (Gathercole, 2006; Gathercole et al., 1997). Because the process of vocabulary acquisition is complex, it is important to develop and test models that are reflective of that complexity.

There is some evidence to show that there are other measures besides nonword repetition that can significantly predict vocabulary acquisition (Metsala, 1999; Bowey, 1996, 2001). Also, when multiple regression analysis was used and effects of phonological sensitivity were controlled, nonword repetition was not a significant predictor of word learning as measured by formal tests of receptive vocabulary (Metsala, 1999; Bowey, 2001). Incidental word learning, which refers to word learning with minimum exposure and indirect instructions, is an important ability facilitating lexical acquisition (Bloom, 2000). If the lexical restructuring hypothesis is valid, it should apply to all types of vocabulary acquisition phenomena, including incidental word learning. To date, most explorations of the relationship between phonological sensitivity and lexical acquisition have focused on vocabulary size, as measured by formal tests. Incidental word learning includes partial phonological and semantic representation of a novel lexical item.
following a brief exposure to the novel word and its referent. These initial incomplete representations are later elaborated and refined during the extended phase of vocabulary acquisition. The process of incidental word learning entails phonological processing, short-term memory storage of the lexical item, and transfer of some phonological and semantic information to long-term memory. On the other hand, the process of fully acquiring a lexical item entails sufficient exposure to multiple exemplars to enable a phonological representation of the item sufficient for both expressive and receptive use, coupled with a semantic representation containing a wide variety of pragmatic detail.

Studies of incidental word learning have focused on children’s ability to choose the correct referent, and making connections between the novel lexical item and the appropriate referent (for example, Rice & Woodsmall, 1988; Rice et al, 1990). There is one study on Dutch speaking children, which has investigated the role of phonological working memory and phonological sensitivity on a controlled word learning task (de Jong et al., 2000). There have been no studies to date that have investigated the interaction between phonological knowledge and phonological memory in the process of a naturalistic word learning task such as Quick Incidental Word Learning (Brackenbury & Fey, 2003). The purpose of this study was to determine the interaction between phonological memory and phonological sensitivity at the initial stages of new word learning.

Research Questions

1. Does performance on nonword repetition have any unique contribution in predicting performance on an incidental word-learning task?
2. Does performance on phonological sensitivity tasks have any unique contribution in predicting performance on an incidental word-learning task?

3. Does a measure of performance on both nonword repetition and phonological sensitivity tasks contribute significantly and independently to an incidental word learning task?

Predictions

If nonword repetition emerges as a unique contributor in predicting incidental word learning, then it would lend support to the phonological loop model, which theorizes that nonword repetition (a measure of the phonological loop or store) ability will be an important independent predictor of novel word learning, because both nonword repetition and novel word learning are constrained by phonological store. That is, the phonological store required for repeating nonwords also helps in learning phonological forms of novel words (Gathercole et al., 1997; Gathercole, 2006). If both phonological sensitivity and nonword repetition tasks have significant and independent contributions to incidental word learning, then the results would provide backing to the lexical restructuring hypothesis, which posits that both nonword repetition and phonological sensitivity tasks are subserved by a common general phonological processing capacity (Bowey, 1996, 2001; Metsala, 1999). Finally, if phonological sensitivity tasks alone have unique contributions to incidental word learning, then it would indicate that metalinguistic phonological ability, requiring complex storage and processing of linguistic information, plays a substantial role in incidental word learning (Munson et al., 2005).
CHAPTER 3

METHOD

Participants

Forty typically developing children (22 males, 18 females) in the age range of 48 to 60 months (M = 55 months) and who were native speakers of English participated in this study. Four year-olds were selected for this study because at age 5, nonword repetition is influenced by children’s lexical knowledge and phonotactic knowledge. Nonword repetition becomes a less sensitive measure beyond age 5, and some studies have shown that nonword repetition is not a significant predictor of vocabulary at this age (Gathercole et al, 1992; Laws & Gunn, 2004). In order to rule out any confounding factors, such as children’s lexical knowledge, on nonword repetition, which could happen at age 5, only 4 year olds were selected for this study. Children with hearing impairment and history of speech, language, sensory or cognitive impairments were not included in the study. Hearing screening tests using a portable audiometer were done on all participants at 20 dB HL, to rule out hearing impairment. The Fluharty Preschool Speech and Language Screening Test-2 (Fluharty, 2001) was administered to all participants to help rule out any language impairments. Children who failed any of these tests were not allowed to participate in this study.

Phonological Working Memory

Nonword repetition. The nonword repetition stimuli developed by Dollaghan and Campbell (1998) were used to measure the phonological working memory of the participants of this study. The nonword repetition stimuli consisted of 16 nonwords of varying lengths (one, two, three, and four syllables). All nonwords began and ended with a consonant. The main rationale for choosing the nonword repetition stimuli developed by Dollaghan and Campbell
(1998) was that the syllables (CV or CVC) in these nonwords have no correspondences with any real English words. That is, the nonwords developed by Dollaghan and Campbell (1998) are not “word-like” and so the child does not have an opportunity to make use of his/her lexical knowledge to repeat these nonwords. Children have to encode, store and retrieve nonwords independent of their lexical knowledge. This would help in tapping phonological memory independent of any influences by children’s lexical knowledge.

Procedure. The administration and scoring procedures used for nonword repetition was similar to the nonword repetition procedures used in the Dollaghan and Campbell (1998) study. The participants were given audiotaped instructions (pre-recorded by a native speaker of English) “Now I will say some made up words. Say them after me exactly the way I say them”. Following the instructions, the participants were presented with nonwords via headphones at comfortable listening levels. Children’s responses were picked up by the microphone placed in close proximity to their mouths. The responses picked up by the microphone were recorded for analysis. The responses were analyzed for percentage of correct phonemes. Phoneme substitutions and omissions were counted as incorrect; distortions and additions were not counted as errors.

Reliability. The investigator, a non-native speaker of English, and a native speaker of Kannada (a Dravidian language spoken in South India) scored the data. The investigator has been in the United States for over 6 years, and English has been his medium of instruction throughout his entire education. To establish reliability of scoring, recordings of 20% of children were randomly selected and analyzed by a second trained clinician, who was a native speaker of English. The inter-rater reliability between the investigator and the second trained clinician (a native English speaker) was calculated by counting the total number of phonemes...
that were transcribed identically by both the raters and then dividing the result by the total number of phonemes (which was 96 phonemes). An inter-rater reliability of 91-99% was considered reliable in both conditions.

*Quick Incidental Learning (QUIL)*

A modified QUIL procedure based on that used by Brackenbury and Fey (2003) was adopted for the current study. The aim was to obtain a measure of incidental word learning that was more naturalistic than that of fast mapping. The modified QUIL procedure used here not only examined children’s initial ability to make a connection between the novel word and the novel referent, but also the stability of retention of the newly learned word. This stability was tested in two generalization procedures, the “generalization item-label mismatch” and the “generalization item-referent mismatch”. In the “generalization item-label mismatch”, children were asked to match a novel unfamiliar label with a picture from a choice of the target picture, two familiar pictures, and a blank comparison. In the “generalization item-referent mismatch”, children were asked to match the target label with a picture from a choice of two unfamiliar pictures, a familiar picture, and a blank comparison (see example in figure 1). The stability of newly learned label was determined by testing children’s ability to reject associations between a novel label (which the child has never heard before) and the target picture (label mismatch) and between the target label and a novel object, which the child has never been exposed to (referent mismatch). If children are able to perform at above chance levels on the generalization-items (if they select the black-comparison on label-mismatch and referent mismatch trials), then it would strengthen the interpretation of children’s responses on identification trials. Specifically, it lends supports to the interpretation that children’s selection of correct referent and rejection of black-comparison response on the identification trials was not because of a response bias, but in fact
children had learned the association between the target words and the target referents presented via the stories.

Procedure. The QUIL procedure consisted of three stages: Training and testing on Blank Comparison, Exposure phase, and Post-exposure comprehension testing.

Training and testing on blank-comparison. On the Blank-Comparison method, children were conditioned to respond to a missing picture (when that picture is named) by selecting a black square. The black square represented the response “the correct picture is hidden behind this black square or none of the above”. The Match to Sample Program (Version 11.0.1; Dube & Hiris, 1997) was used to train children on the Blank-Comparison method. In this program, children were presented with three familiar pictures and one of the three familiar pictures was named by the experimenter. At the beginning of the trials, a small black square partially covered one of the familiar pictures and with the progress of trials; the size of the black square increased and eventually covered the entire picture. The children were asked to either select the picture hidden behind the black square (the picture name is missing from the screen) or select one of the uncovered pictures.

Target word selection. The following six target words were selected: *dap, gid, shan, zik, paz, puk*. These words were chosen because they were all monosyllabic and had similar phonotactic probabilities and neighborhood densities. The target stimuli, and the information regarding their phonotactic probability and neighborhood densities, were established by Gupta, Lipinski, Abbs, Lin, Aktunc, Ludden, Martin, & Newman (2004) and were taken from Psychonomic Society Archive of Norms, Stimuli and Data.

Exposure phase. The participants in this phase were exposed to two stories presented in the form of cartoon slide shows with pre-recorded audio narrative to go with them. The two
stories had three target words each (see Appendix D and Appendix E). The children had five exposures to each of these target words. During the exposure phase, the participants were instructed that they would be listening to a story, which had some new words in it. They were asked to pay attention to the new words and try to learn them if possible.

*Post-exposure comprehension testing.* Following the exposure to each story, children were asked to complete post-exposure comprehension testing for the three novel words presented to them in that story. The order of presentation of novel words in the comprehension testing was the same as the order of presentation of words in the story. The post-exposure comprehension testing for each novel picture consisted of four trials (two identification trials, one label mismatch trial and one referent mismatch trial). The identification trials required children to select the just-labeled novel picture from a field that included a familiar picture, the target novel picture, an unfamiliar picture and a blank comparison. The two identification trials were identical except for the location of different pictures on the screen. In the label mismatch trials, a new novel label (one not heard before during the exposure phase) was requested from a field that included a just-labeled picture (original referent from the exposure phase), two familiar pictures and a blank comparison. The purpose of this trial was to examine the child’s ability to prevent making an association between a novel label, which the child had never heard before, and the just-labeled referent, which the child was introduced to during the exposure phase via a cartoon story. The child’s ability to reject this association would strengthen the case that his or her responses on the identification trials truly indicated that the child had learned the label for an object that was introduced in the story. If the child made a mapping between any novel label and the target object (from the exposure phase), it would undermine the case for word learning having taken place. The referent mismatch required children to select one of the target objects
from a field that did not include a picture of its referent (instead showing two unfamiliar pictures, a familiar picture, and a blank comparison). This trial was included to examine the child’s ability to prevent making an association between a novel object, which the child had never seen before and the novel label for a target object introduced to the child during the exposure phase. The ability of the child to reject this association would once again strengthen the child’s responses on the identification trials by suggesting that they had correctly learned the association between the novel label and the novel object introduced in the cartoon stories. If the child was making associations between a label which was introduced to him or her during the exposure phase and an unfamiliar novel object never seen before, then it would suggest that the child’s representation of the newly learned word was unstable. The four comprehension trials continued for all the three target labels selected for each story. That is, there were four comprehension trials for the six target labels from two different stories (three target labels for each story).

Scoring: Children were given a score of 1 only if they consistently identified the correct referent on both the identification trials for each target word.
Figure 2. Examples of the four trials on the post-exposure comprehension testing (for the word “dap”).

1. Generalization item-Label mismatch

   “Where is chiv”?

<table>
<thead>
<tr>
<th>Target picture “dap”</th>
<th>Familiar picture “apple”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar picture “table”</td>
<td>Blank comparison</td>
</tr>
</tbody>
</table>

2. Identification item: Target “dap”

   “Show me dap”

<table>
<thead>
<tr>
<th>Blank comparison</th>
<th>Target picture (“dap”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfamiliar picture 1</td>
<td>Familiar picture (“table”)</td>
</tr>
</tbody>
</table>

3. Generalization item-Referent mismatch

   “Find dap”

<table>
<thead>
<tr>
<th>Unfamiliar picture 1</th>
<th>Familiar picture (“table”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank comparison</td>
<td>Unfamiliar picture 2</td>
</tr>
</tbody>
</table>

4. Identification item

   “Point to dap”

<table>
<thead>
<tr>
<th>Familiar picture (“table”)</th>
<th>Blank comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target “dap”</td>
<td>Unfamiliar picture 1</td>
</tr>
</tbody>
</table>
Phonological Sensitivity

The phonological sensitivity tasks were based on the tasks used by Burt, Holm, and Dodd (1999)

Alliteration Awareness Task

Materials. Colored pictures of leaf, light, lake, and dog.

Procedure. The experimenter and the child sat facing each other across a table. The experimenter then introduced the task by asking the child’s name and telling the child 3 names that start with the same sound. The child was shown pictures of a leaf, a light, a lake, and a dog and explained how leaf, light, and lake were similar because they started with the same sound “l,” and how the word “dog” was different because it started with the sound “d”.

Practice. The child was given a practice trial with feedback on the words head, house, bird, and hat. The practice trial was done without any pictures.

Testing: The testing phase consisted of 12 trials and no feedback was given to the child during this phase. No pictures were used and one repetition was allowed.

Scoring: A score of 1 was given for correctly identifying the odd-one-out.

Rhyme Awareness Task


Procedure. The nursery rhyme of Humpty Dumpty was recited by the experimenter and the child’s attention was drawn towards the rhyming words wall and fall in the nursery rhyme. The experimenter explained that wall and fall sound alike because both end with the sound –all.

Practice. The experimenter pointed to and named the pictures of wall, fall, ball, and cat. The experimenter then asked the child to point to the picture that sounded different. Feedback
regarding why wall, fall, and ball sound similar and why cat sounds different was given to the child. The same procedure was repeated with the pictures feet-meat-seat-key. After these two trials, the child was asked to pick out the word, which “does not belong”, or “sounds different “by just listening to those words and without any pictures. The words sun-one-hat-gun, was presented to the child during these trials.

**Testing.** The testing phase consisted of 12 trials and no feedback was given to the child during this phase. No pictures were used and one repetition was allowed.

**Scoring.** A score of 1 was given for correctly identifying the odd-one-out.

---

**Data Analysis**

An interaction between phonological working memory, phonological sensitivity, and incidental word learning was measured by calculating the bivariate correlations between the different variables. In order to measure the relative contribution to the variance in word learning of nonword repetition and phonological sensitivity (rhyming and alliteration), a multiple regression analysis was used. The purpose of using multiple regression analysis was two-fold. First, it gives the proportion of variance (amount of contribution) of each of the independent variables (nonword repetition, phonological sensitivity) to incidental word learning (through a measure of R2). Second, it tells how significant each of the independent variables is in predicting the dependent variable (which is done by comparing beta weights). This analysis can help us explain the contributions of nonword repetition and phonological sensitivity in predicting incidental word learning.
CHAPTER 4

Results

The current study was done with the purpose of answering the following research questions:

1. Does performance on nonword repetition have any unique contribution in predicting performance on an incidental word-learning task?

2. Does performance on phonological sensitivity tasks have any unique contribution in predicting performance on an incidental word-learning task?

3. Do both nonword repetition and phonological sensitivity tasks contribute significantly and independently to an incidental word learning task?

In order to answer these questions, a bivariate correlation between the different variables of the study and a series of hierarchical multiple regression analyses were carried out. Since the purpose of the study was to determine the unique variance of nonword repetition and phonological sensitivity tasks in incidental word learning, a hierarchical multiple regression analysis where the experimenter determines the number of variables and the order in which variables are entered would be the best approach. A regression analysis in which the researcher can control the entry of variables into the equation is more preferable than analysis methods such as simultaneous regression where variables are entered based on their statistical properties (Cohen & Cohen, 1983). In hierarchical multiple regression analysis, the predictor variables were entered into the equation in a specific order. As each new predictor variable was entered into the equation, its additional contribution in predicting the dependent variable was assessed by controlling the effects of the independent variable already entered. The independent variables in this study were nonword repetition (a measure of phonological working memory), rhyming, and
alliteration (measures of phonological sensitivity). A phonological sensitivity composite (combined scores on rhyming and alliteration) was also calculated. The dependent variable was consistent word identification (a measure of incidental word learning).

Before carrying out the correlation and hierarchical regression analysis, children’s stability of newly learned target words was measured by calculating the percentage of correct responses on label-mismatch and referent-mismatch generalization items. The ability of children to generalize the newly learned labels to other referents can be evaluated only if children were able to consistently identify the correct referent in response to the target name. Therefore, generalization responses from children who obtained at least 50% or more correct response on consistent identification (correctly identified at least 3 target words or more) were analyzed (Brackenbury & Fey, 2003). Twenty-nine children met this criterion and the analysis revealed that on the label mismatch generalization-item, these children chose the correct response, which was the black-comparison response, 68% of the time. On the referent mismatch generalization-item, children chose the correct response (black-comparison), 98% of the time. These results support the conclusion that children who performed well on the tasks were actually recognizing the previously reported words and not just pointing to unfamiliar objects when they heard novel labels.

Results of Correlation between the Variables

The results of the bivariate correlation between the different variables are presented in Table 3. As can be seen in Table 3, the incidental word learning task is significantly correlated with rhyming ($r = 0.400, p < 0.05$), alliteration ($r = 0.462, p < 0.01$), and phonological sensitivity composite ($r = 0.475, p < 0.01$). There was, however, no significant correlation seen between incidental word learning and nonword repetition ($r = 0.080, p > 0.05$). As can be seen in Table 3,
there was also a significant correlation seen between the different variables of phonological sensitivity measures but there was no correlation between the different phonological sensitivity measures and nonword repetition.

Results of Hierarchical Regression Analysis

As can be seen in regression 1 of Table 4, when hierarchical multiple regression analysis was conducted with nonword repetition entered as step 1 of the regression equation, it accounted for 0.6% of variance in incidental word learning, which was not statistically significant (R square change = 0.006, p = 0.624). In the second step, when alliteration was added into the equation and nonword repetition effects were controlled, it accounted for 20.7% of additional variance in incidental word learning, which was statistically significant (R square change = 0.207, p = 0.004).

As it can be seen in regression 1a of Table 4, when hierarchical multiple regression analysis was conducted with alliteration entered into the regression equation as step 1, it accounted for 21.3% of variance in incidental word learning, which was statistically significant (R square change = 0.213, p = 0.003). When nonword repetition was added into the equation as step 2 and effects of alliteration were controlled, it did not account for any additional variance in incidental word learning (R square change = 0.000, p = 0.910).

Regression 2 of Table 4 shows that when nonword repetition was entered into the equation as step 1, it contributed to 0.6% of variance in incidental word learning, which was not statistically significant (R square change = 0.006, p = 0.624). When effects of nonword repetition effects were controlled, and rhyming was entered into the regression equation as step 2, it accounted for 15.4% of additional variance in incidental word learning, which was statistically significant (R square change = 0.160, p = 0.013).
As it can be seen in regression 2a of table 4, rhyming resulted in a significant variance of 16% when entered into the equation as step 1 (R square change = 0.160, p = 0.011). When effects of rhyming were controlled, and nonword repetition was added into the equation as step 2, it did not contribute to any additional variance in incidental word learning (R square change = 0.000, p = 0.896).

As shown in regression 3 of table 4, a hierarchical multiple regression analysis with nonword repetition as step 1 of the regression equation resulted in 0.6% of variance in incidental word learning, which was not statistically significant (R square change = 0.006, p = 0.624). When phonological sensitivity composite (combined scores on alliteration and rhyming) was added into the equation as step 2 by controlling the effects of nonword, it accounted for a significant additional variance of 22% in incidental word learning (R square change = 0.220, p = 0.003).

Finally, as indicated in regression 3a of table 4, phonological sensitivity composite, when entered as step 1 of the regression equation contributed to 22.6% of variance in incidental word learning, which was statistically significant (R square change = 0.226, p = 0.002). Nonword repetition when added into the equation as step 2 by controlling phonological sensitivity composite effects once again failed to add any additional variance in incidental word learning (R square change = 0.000, p = 0.966).
TABLE 2

Means and standard deviations for incidental word learning, nonword repetition, alliteration and rhyming

<table>
<thead>
<tr>
<th>Task</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>3.45 (max = 6)</td>
<td>1.43</td>
<td>40</td>
</tr>
<tr>
<td>NWR</td>
<td>84.79 (max = 100)</td>
<td>11.85</td>
<td>40</td>
</tr>
<tr>
<td>ALI</td>
<td>6.08 (max = 12)</td>
<td>3.09</td>
<td>40</td>
</tr>
<tr>
<td>RHY</td>
<td>7.95 (max = 12)</td>
<td>2.01</td>
<td>40</td>
</tr>
<tr>
<td>PS compo</td>
<td>14.03 (max = 24)</td>
<td>4.69</td>
<td>40</td>
</tr>
</tbody>
</table>

CI = Consistent Identification (a measure of incidental word learning)

NWR = Nonword Repetition

ALI = Alliteration

PS compo = Phonological sensitivity composite (combined scores on alliteration and rhyming)
TABLE 3

*Bivariate correlations between the different variables of the study*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Incidental Word Learning</th>
<th>Rhyming</th>
<th>Alliteration</th>
<th>Phonological Sensitivity Composite</th>
<th>Nonword Repetition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidental Word Learning</td>
<td></td>
<td>0.400</td>
<td>0.462</td>
<td>0.475</td>
<td>0.80</td>
</tr>
<tr>
<td>Rhyming</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alliteration</td>
<td></td>
<td></td>
<td>0.677</td>
<td>0.874</td>
<td>0.151</td>
</tr>
<tr>
<td>Phonological Sensitivity Composite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonword Repetition</td>
<td>0.080</td>
<td>0.151</td>
<td>0.138</td>
<td>0.155</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05 (2-tailed)

** p < 0.01 (2-tailed)
TABLE 4

Hierarchical regressions predicting incidental word learning from nonword repetition and phonological sensitivity tasks

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable entered</th>
<th>R² change</th>
<th>F change</th>
<th>Level of significance</th>
<th>$f^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression 1 (N =40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonword repetition $^a$</td>
<td>0.006</td>
<td>0.245</td>
<td>0.624</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>Alliteration $^b$</td>
<td>0.207</td>
<td>9.730</td>
<td>0.004 **</td>
<td>0.261</td>
</tr>
<tr>
<td>Regression 1 a (N = 40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alliteration $^a$</td>
<td>0.213</td>
<td>10.285</td>
<td>0.003 **</td>
<td>0.271</td>
</tr>
<tr>
<td></td>
<td>Nonword repetition $^b$</td>
<td>0.000</td>
<td>0.013</td>
<td>0.910</td>
<td>0.000</td>
</tr>
<tr>
<td>Regression 2 (N = 40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonword repetition $^a$</td>
<td>0.006</td>
<td>0.245</td>
<td>0.624</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>Rhyming $^b$</td>
<td>0.154</td>
<td>6.776</td>
<td>0.013 *</td>
<td>0.182</td>
</tr>
<tr>
<td>Regression 2a (N =40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rhyming $^a$</td>
<td>0.160</td>
<td>7.227</td>
<td>0.011 *</td>
<td>0.191</td>
</tr>
<tr>
<td></td>
<td>Nonword repetition $^b$</td>
<td>0.000</td>
<td>0.017</td>
<td>0.896</td>
<td>0.000</td>
</tr>
<tr>
<td>Regression 3 (N =40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonword repetition $^a$</td>
<td>0.006</td>
<td>0.245</td>
<td>0.624</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>PS comp $^b$</td>
<td>0.220</td>
<td>10.502</td>
<td>0.003 **</td>
<td>0.282</td>
</tr>
<tr>
<td>Regression 3a (N =40)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PS comp $^a$</td>
<td>0.226</td>
<td>11.097</td>
<td>0.002 **</td>
<td>0.292</td>
</tr>
<tr>
<td></td>
<td>Nonword repetition $^b$</td>
<td>0.000</td>
<td>0.002</td>
<td>0.966</td>
<td>0.000</td>
</tr>
</tbody>
</table>

$^a$ = Variable forced into the equation as step 1 of the regression
b = Variable forced into the equation as step 2 of the regression

* p < 0.05

** p < 0.005

PS comp = Phonological sensitivity

f² = Effect size
Summary of Findings

A bivariate correlation between the different variables revealed a significant correlation between incidental word learning and the different phonological sensitivity variables but there was no significant correlation between incidental word learning and nonword repetition. A significant correlation was also found between the different measures of phonological sensitivity but no significant correlation was found between phonological sensitivity measures and nonword repetition.

A hierarchical multiple regression analysis revealed that nonword repetition contributed to only 0.6% of variance in incidental word learning (which was not statistically significant) when entered as step 1 of the regression analysis. When the effects of alliteration, rhyming, and phonological sensitivity composite were controlled (each of these variables were entered one at a time as step 1 of the equation), nonword repetition did not contribute to any significant additional variance (the R square change for nonword repetition was 0.00 when entered as step 2 of the equation). On the other hand, when alliteration, rhyming, and phonological sensitivity composite scores were entered separately as step 1 of the regression equation, they contributed to 21.3%, 16%, and 22.6% of variance respectively in predicting incidental word learning. When effects of nonword repetition were controlled (entered as step 1 of equation), and alliteration, rhyming, and phonological sensitivity composite measures were entered separately as step 2 of the regression equation, they each contributed to 20.7%, 15.4%, and 22% of significant additional variance respectively in predicting incidental word learning. In sum, nonword repetition did not contribute to any significant variance in incidental word learning, when entered as step 1 of the regression equation and when effects of phonological sensitivity measures were controlled, nonword repetition did not contribute to any additional variance in incidental word learning. On
the contrary, each measure of phonological sensitivity (alliteration, rhyming, phonological sensitivity composite) contributed to significant variance in predicting incidental word learning when entered as step 1 of regression equation and when effects of nonword repetition were controlled, each measure of phonological sensitivity contributed to significant additional variance in predicting incidental word learning. The effect sizes for the contribution of nonword repetition in incidental word learning were extremely small. The effect sizes for the contribution of phonological sensitivity tasks in incidental word learning were between moderate and high ranges (Cohen & Cohen, 1983).
CHAPTER 5

Discussion

This study was done with the purpose of exploring the role of phonological working memory and phonological sensitivity in incidental word learning by 4-year-old typically developing children. It evaluated two competing models, the phonological loop model by Baddeley and Hitch (1974) and the lexical restructuring model by Metsala (1999). It was predicted that if nonword repetition (a measure of phonological working memory) resulted as a unique contributor in predicting incidental word learning, then it would lend support to the phonological loop model (Baddeley, 1998). If both phonological sensitivity and nonword repetition tasks had significant and independent contributions to incidental word learning, then the results would provide backing to the lexical restructuring hypothesis (Bowey, 1996, 2001; Metsala, 1999). Finally, if phonological sensitivity tasks alone had unique contributions to incidental word learning, then it would provide support for a theory in which phonological knowledge requiring complex storage and processing of linguistic information plays a substantial role in incidental word learning (Munson et al., 2005).

Forty 4 year-old children were administered a test of nonword repetition (to investigate phonological working memory), rhyming and alliteration tasks (to investigate phonological sensitivity), and an incidental word learning task, via a computer-based presentation of a cartoon story. On the incidental word learning task, children’s stability of newly learned labels was tested by measuring their ability to prevent making associations between novel label, which was never heard before and the just-labeled object from the exposure phase (label-mismatch), and between the newly learned label from the exposure phase and an object which the child had never seen before (referent-mismatch). (The results revealed that children who were able to consistently
identify at least 3 target words or more, were also able to correctly reject a novel label never heard before for a just fast mapped referent (label mismatch), 68% of the time and were able to correctly reject a novel referent not seen in the cartoon story for a just-learned label (referent mismatch) 98% of the time. The high percentage of correct responses on the generalization-items (selecting the black-comparison response) indicates that children were selecting the correct referent and rejecting the black-comparison response on the identification trials because of their ability to correctly fast map the target word with the target referent. This enhanced the validity of children’s responses on identification trials. The high percentage of correct responses in the referent mismatch items when compared to label mismatch items suggests that children more readily accept a novel label for a newly learned referent rather than accepting a novel referent for the newly learned label. These findings are consistent with the quick incidental word learning studies by Golinkoff et al. (1992) and Brackenbury and Fey (2003).

A hierarchical multiple regression analysis revealed that nonword repetition did not contribute to any significant variance in incidental word learning, when entered as step 1 of the regression equation and, when effects of phonological sensitivity measures were controlled, nonword repetition did not contribute to any additional variance in incidental word learning. On the other hand, each measure of phonological sensitivity (alliteration, rhyming, phonological sensitivity composite) contributed to significant variance in predicting incidental word learning when entered as step 1 of the regression equation. The phonological sensitivity measures contributed to significant additional variance in predicting incidental word learning, even after effects of nonword repetition were controlled and the effect size for this variance was in the moderate to high range (Cohen & Cohen, 1983). These findings lend support to a model of incidental word learning where phonological knowledge plays an important role.
Examination of the Role of the Phonological Loop Model in Incidental Word Learning

The phonological loop model of working memory is a modular account of how memory is stored and processed for psycholinguistic and cognitive functions such as syntax, semantics, morphology, verbal reasoning, problem solving, etc. Gathercole (2006) has argued that since both nonword repetition and novel word learning are constrained by the phonological loop (which stores phonological information), a clear link exists between the two in the different populations studied. That is, both word learning and nonword repetition tasks require short-term storage and processing of novel phonological forms in the phonological loop and these short-term phonological representations are required for adult-like long-term phonological representations of lexical items. Any factors affecting the phonological loop can hamper both word learning and nonword repetition. There is some evidence showing a direct correlation between nonword repetition and word learning (for example, Gathercole & Baddeley, 1990a; Gathercole et al., 1997). The findings of the current study, however, do not support the phonological loop model. The nonsignificant contribution of nonword repetition in predicting incidental word learning in the current study can be attributed to a number of reasons. Research in the past showing significant association between nonword repetition and novel word learning could be attributed to the common phonological memory shared between them (Gathercole, 2006). The word learning tasks used in previous research by Baddeley and colleagues have failed to capture the true essence of word learning. These studies have either used paired associate word learning (for example, Papagno & Vallar, 1992) or controlled word learning procedures (Gathercole & Baddeley, 1990a). In the paired associate word learning task, subjects were exposed to word-word and word-nonword pairs. Following the exposure, they were presented with the first word from the pair and subjects were required to say the second word/nonword
associated with the word. A failure to say the nonwords in response to a word was considered as a failure to learn novel words. This task was more of a word recognition task rather than word learning, because it involved storing words and nonwords in the memory and then matching the spoken word with the stored set of nonwords and then repeating the nonword that exactly matched with the target word. This task did not capture the complexity involved in learning novel words. For example, it did not involve making associations between a word and its referent, which is one of the most important aspects of learning a new word.

The controlled word learning task used by Gathercole and Baddeley (1990a) involved making association between a novel toy and a nonword. This task was more representative of word learning than the paired-associate task but lacked the complexity of word learning. In this controlled word learning task, children had to learn names of both familiar and unfamiliar toy names. The child had to repeat the name of each toy presented by the experimenter and this repetition continued until the child accurately repeated a toy’s name. This exposure phase was followed by a learning trial where the child had to name each toy, which was presented in the exposure phase. Speed of learning was measured by calculating the time taken by a child to reach this learning criterion. These children were tested for comprehension and production of these toy names after a 24-hour delay. Learning new names by children in a natural setting rarely involves direct exposure to objects and requests to repeat their names. It is a complex process requiring abilities such as attention, phonological processing, phonological working memory, and sensitivity to statistical and socio-pragmatic cues. Both the word learning paradigms adopted by Baddeley and his colleagues were unsuccessful in capturing these complex elements of word learning.
Nonword repetition, on the other hand, shares several cognitive and linguistic processes with paired associate and controlled word learning tasks used by Baddeley and colleagues. The relationship between nonword repetition and word learning in these studies cannot be generalized to incidental word learning procedures adopted by Rice et al. (1990) and Brackenbury and Fey (2003). In the modified QUIL procedure used in the current study (based on the procedure used by Brackenbury & Fey, 2003), children were indirectly exposed to novel names and their referents through cartoon stories presented via a computer. This not only enhanced the naturalness and semantic richness of the word learning environment, it also examined children’s initial ability to make a connection between the novel word and the novel referent, along with the stability of retention of the newly learned word. Another important difference between the study by Gathercole & Baddeley (1990a) and the current study is in the method of scoring. The study by Gathercole & Baddeley (1990a) used rate of word learning, which was a measure of the time taken by children to repeat the novel names accurately. The current study used consistent identification, which was a measure of correct response on both the identification trials of the post-exposure comprehension testing. The rate of word learning is a measure of how fast a child can form a phonological template of a novel lexical item and produce it in response to visual presentation of that item. The consistent identification is a measure of how well the child can map a novel name onto a novel object without multiple and direct exposures to words and their referents and elaborate socio-pragmatic cues. In addition, Gathercole & Baddeley used explicit elicitation of labels to criterion, which differs from typical word learning situations, and from the naturalistic imitation of typical word learning environments used in this study. While it is unclear what the precise effect would be, it is also notable that they used proper names rather than ordinary lexical items in their study. Finally,
children between the ages of 5 and 6 years participated in the study by Gathercole & Baddeley (1990a) and the participants of the current study were between the ages of 4 and 5 years. The linguistic, cognitive, and developmental differences between the two age groups of these two investigations are potential factors contributing to the differences in findings between the two studies.

The word learning procedure used in this study was selected in order to attempt to incorporate some of the complexity of the word learning that occurs in the child’s natural environment. Although nonword repetition is a fairly complex task, which shares certain linguistic and cognitive processes with word learning, it is less metalinguistic in nature and may not be complex enough to predict performance on a complex word learning paradigm used in this study. In sum, the results of the current study, which did not find a significant contribution of nonword repetition in incidental word learning task, do not support to the phonological loop model, which argues for the presence of a strong relationship between nonword repetition and word learning.

**Examination of the Role of the Lexical Restructuring Model in Incidental Word Learning**

The findings of the current study showed significant and independent contributions of all measures of phonological sensitivity (rhyming, alliteration, and the phonological sensitivity composite, which was the combined scores on rhyming and alliteration) in predicting performance on incidental word learning. These findings are consonant with the findings by Metsala (1999), Bowey (2001), and de Jong et al. (2000), who found significant contributions of phonological sensitivity in predicting vocabulary acquisition and laboratory word learning experiments (the paired associate word learning task used by de Jong et al., 2000).
The current findings, however, differed from the studies by Metsala (1999) and Bowey (2001) in important ways. Unlike the findings by Metsala (1999) and Bowey (1996, 2001), nonword repetition scores of the present study failed to predict word learning before controlling for phonological sensitivity effects. This could be attributed to the differences in the nature of lexical knowledge tested in these studies. Metsala (1999) and Bowey (1996, 2001) used vocabulary acquisition (measured by PPVT-R) and the current study utilized a word learning task where children had to learn novel words presented through cartoon stories with pre-recorded narratives. The incidental word learning task used in the current study and vocabulary acquisition (measured via a static standardized test) are two different constructs (Metsala, 1999). Incidental word learning used in this study was a measure of whether a child could make an initial mapping between a novel word and its referent following a brief exposure to them via cartoon stories. This learning entails partial phonological and semantic representation of the novel lexical item following the brief exposure. The vocabulary knowledge measured by the PPVT-R in Metsala’s and Bowey’s studies represents an estimate of the size of child’s lexicon relative to age peers. It involves recognition of previously learned vocabulary, and thus is somewhat similar to the incidental word learning task in that partially recognized words could be correctly identified. But the test is intended to tap into words that have been more or less successfully learned. In theory, at least, the PPVT measures representations that are more stable, intending to estimate the general size of the lexicon at a given point in time. Such long-term lexical knowledge is achieved as a result of exposure to multiple exemplars of words and their referents (Bloom, 2000). Although nonword repetition is independent of children’s current lexical knowledge, they might make use of this long-term linguistic knowledge in repeating nonwords (Snowling, Chiat, & Hulme, 1991). Any overlap between facility with nonword
repetition and degree of children’s existing lexical knowledge measured via a formal receptive vocabulary test can partly explain the significant contribution of nonword repetition and vocabulary knowledge in studies by Metsala and Bowey.

The incidental word learning task used in this study measures the ability of a child to form an association between a word and its referent following a brief exposure and in the absence of rich socio-pragmatic cues such as eye gaze (Baldwin, 1993), deictic pointing (Kalogher & Yu, 2000), inferring the intentions of other speakers (Bloom, 2000), discourse novelty (Akhtar, Carpenter, & Tomasello, 1996), and limited prosodic cues (Yu & Ballard, 2004). Vocabulary acquisition in real-world contexts occurs in the presence of such cues, and often with multiple exposures to words and their referents, which were unavailable to children learning words in the current study (Werker & Yeung, 2005). Therefore, children in this study were heavily dependent on phonological knowledge and the limited contextual cues available through picture sequences and pre-recorded narration to go with the stories. Children had to listen to the story and break the continuous speech stream into individual words by applying their phonological knowledge. They had to disentangle the novel word and connect it to the novel referent by paying attention to the syntactic frames in which these novel words occurred and also by making a connection between a novel word which the child has never heard before and a novel object never seen before. The findings of this study indicate that the initial word learning process is dependent on phonological knowledge, including metaphonological knowledge. The findings of a significant contribution of phonological sensitivity and a non-significant contribution of nonword repetition to word learning are in agreement with studies by de Jong et al. (2000), which show a strong contribution of phonological sensitivity and a weak contribution of nonword repetition in predicting word learning. It is possible that the skills underlying
competence at metaphonological tasks are related to, or somehow tap into, those needed for novel word acquisition. The links between metaphonological knowledge and word learning have yet to be articulated within a specific model, however.

**Limitations of the Lexical Restructuring Model**

The findings of the current study support one of the claims of the lexical restructuring model, which states that nonword repetition is not the only predictor of word learning. These findings are in consonance with findings reported by proponents of the lexical restructuring model (Metsala, 1999; Bowey, 1996, 2001), with its critique of nonword repetition as uniquely related to word learning abilities. As mentioned earlier, the current findings differ from studies by Metsala (1999) and Bowey (1996, 2001). Vocabulary acquisition used in studies by Metsala (1999) and Bowey (1996, 2001) is a different construct from incidental word learning used in this study and this difference in the nature of lexical knowledge tested could have led to different findings.

Gathercole (2006) has argued that phonological sensitivity is dependent on phonological memory and therefore, both phonological sensitivity and phonological memory tasks can predict vocabulary acquisition. For example, children between the ages of 4 and 5 years can store up to 3 words at a time (Pickering & Gathercole, 2001). When children are given a rhyme oddity task where they are given 3 words and asked to pick the one word that does not rhyme with the other two, they are faced with the challenge of storing 3 words for a sufficiently long time in order to perform well on this task. Given that these children have a storage capacity of only 3 words, any failure to respond accurately in this task can be attributed to inadequate phonological memory rather than poor phonological sensitivity. Gathercole (2006) claims that the problems that children with SLI face in repeating nonwords of greater length (Gathercole & Baddeley, 1990b)
are better explained by a phonological loop model, which relies on the role of phonological short
term memory store for word learning rather than a lexical restructuring model, which relies on
the role of phonological sensitivity in shaping the process of word learning. Finally, she also
claims that the phonological sensitivity account cannot explain the negative effects of
phonological similarity, stimulus length, and articulatory suppression on phonological sensitivity
and the negative impact of impaired phonological sensitivity on novel word learning. The
phonological loop model theorizes that factors such as phonological similarity, stimulus length,
and articulatory suppression have a negative impact on the ‘phonological store’ and ‘the
controlled articulatory process’ components of the phonological loop. The negative impact of
these factors on the phonological loop would hamper learning of novel words, which is held to
be dependent on the phonological loop component of the multicomponent working memory
model (Baddeley & Hitch, 1974).

Although the lexical restructuring model cannot sufficiently explain the stimulus length,
phonological similarity, and articulatory suppression effects on word learning, the significant
contributions of both nonword repetition and phonological sensitivity in vocabulary acquisition
can be accounted for under the lexical restructuring model, which theorizes that both these tasks
are products of latent general phonological processing skills (Metsala & Walley, 1998; Metsala,
1999). The findings of the current study and the studies by Metsala (1999) and Bowey (1996,
2001), which show a failure of nonword repetition in predicting subsequent vocabulary
development when phonological sensitivity effects were controlled, are not well explained by the
lexical restructuring model (Metsala, 1999). The phonological sensitivity account may not be
able to adequately explain these inconsistent findings. In addition, the criticisms raised by
Gathercole (2006) must be addressed. Gathercole points out that a phonological sensitivity
account fails to address the reliance of phonological sensitivity tasks such as rhyme oddity on phonological memory, the inability of children with SLI to repeat nonwords of increasing length, and the effects of factors such as phonological similarity, stimulus length, and articulatory suppression. In order to address these issues, we need to move beyond the lexical restructuring model and utilize a more complex model of general phonological processing similar to the functional working memory model proposed by Just and Carpenter (1992), which considers both processing and memory aspects of a linguistic task. In spite of these inconsistencies, the lexical restructuring model provides a useful starting point for a complex model, one which stresses the role of metaphonological abilities in word learning.

Examination of the Role of the Complex Working Memory Model in Incidental Word Learning

Just and Carpenter (1992) proposed a complex, integrated model of working memory, called the functional working memory, which views working memory as a storage-limited system involved in the storage and processing of linguistic information. The processing component of this working memory model is involved in the processing of syntactic, semantic, and morphosyntactic information. The processed information is later stored in the storage component of the working memory. According to this model, processing and storage eventuate simultaneously and whenever the storage or processing demands exceed the available cognitive resources, a trade-off between the two systems is seen. That is, an increase in the processing demands (for example, grammatically complex linguistic input) would lead to a reduction in the storage component of the working memory.

The findings of the current study are in agreement with the findings by Hansson et al. (2004), Marton & Schwartz (2003), Hayiou-Thomas et al. (2004), and Archibald and Gathercole (2005b, 2006) in that nonword repetition failed to contribute significantly in predicting word
learning, and phonological sensitivity tasks made a significant contribution in predicting incidental word learning. Although the phonological sensitivity tasks used in this study did not use a complex working memory task, they require complex storage and processing of verbal information, and are at least in some respects comparable in resource demands to a complex working memory task. For instance, the rhyme awareness task used in the current study (for example, the child had to pick the odd word amongst the words *feet, meat, seat, key*) requires speech perception, phonological representation, phonological memory, separating the onset (initial consonant or consonant blend of a word) from its rime (the vowel and any final consonants), matching words that have the same rime, picking the word that does not end with the same rime and articulatory instructions. Therefore, a failure to perform well on a phonological sensitivity task such as rhyme awareness could be a result of a breakdown in any of these above-mentioned processes. Although nonword repetition and phonological sensitivity tasks share a similar set of cognitive and linguistic processes, the former is relatively a less complex measure comprising of speech perception, phonological representation, retrieval of phonological representation, and articulatory instructions (Bowey, 2001; Hansson et al., 2004; Munson, 2001; Munson et al., 2005).

Finally, Baddeley and colleagues have argued for the existence of a phonological loop by their investigations of phonological similarity effects, irrelevant speech, word length effects and articulatory suppression. For example, according to the phonological loop model, failure of children with SLI to repeat longer nonwords is due poor rehearsal of phonological information required for repeating nonwords (Gathercole, 2006). On the other hand, proponents of the lexical restructuring model propose that poor repetition of longer nonwords is because of degraded representation of phonemes required for repeating them (Bowey, 2006). The phenomenon of
phonological similarity, irrelevant speech, and word length effects observed by Baddeley and colleagues can also be explained alternatively by using a complex working memory model. Difficulties that people encounter while remembering words that sound similar (phonological similarity), recalling verbal material in the presence of irrelevant background speech (irrelevant speech), recalling words of greater length (word length effect) and recalling words while repeating a word (articulatory suppression) may be evidence for the breakdown in general cognitive processing rather than evidence for the existence of an isolated component called the phonological loop, because these tasks require simultaneous processing and storage of information and are thus cognitively more challenging when compared to mere recall of verbal information (Marton & Schwartz, 2003; Hayiou-Thomas et al., 2004; Gathercole, 2006).

There is some overlap between the lexical restructuring model and the phonological loop model. The proponents of the lexical restructuring model agree with the claims made by Baddeley and colleagues of a common phonological memory constraining word learning and nonword repetition (Bowey, 2006). Bowey (2006) proposes that the cognitive factors that underlie nonword repetition depend on the individual. For example, repeating shorter nonwords with high phonotactic probability and familiar prosody would underlie more phonological memory and less of phonological processing for adults with mature language skills when compared to children with immature linguistic skills. According to a complex working memory model, repeating nonwords of shorter length, with high phonotactic probability and familiar prosody requires less cognitive resources and simpler storage and processing skills, which is easier for adults who have more mature cognitive skills than children.

In summary, Baddeley and colleagues articulate a model of working memory where phonological memory as measured by nonword repetition plays a significant role in word
learning (Gathercole, 2006). The findings of the current study do not support the phonological loop model and thus suggest that phonological memory is necessary but not sufficient in explaining the interaction between nonword repetition, phonological sensitivity and incidental word learning. The lexical restructuring model has given us a relatively complex model where general phonological processing capacity plays an important role in nonword repetition and vocabulary acquisition (Metsala, 1999; Bowey, 1996, 2001). The findings of the current study do not support this model and thus general phonological processing may also be inadequate in explaining the interaction between nonword repetition, phonological sensitivity and incidental word learning. The findings of this study do not refute the phonological loop model and lexical restructuring model in its entirety. The findings here are in agreement with the notion that phonological memory and phonological processing are necessary because they are by-products of general cognitive processing but are insufficient in explaining the relationship between nonword repetition, phonological sensitivity, and incidental word learning. The findings of this study, however, provide more credence to a model where tasks such as nonword repetition, phonological sensitivity, and incidental word learning are constrained by general cognitive resources requiring storage and processing. The tasks such as nonword repetition, however, require limited metalinguistic ability, are less dependent on phonological knowledge, and may not require complex storage and processing of information. On the other hand, phonological sensitivity and incidental word learning are dependent on a complex set of storage and processing mechanisms. Although nonword repetition, phonological sensitivity, and incidental word learning may draw resources from the same cognitive pool, phonological sensitivity and incidental word learning may share a similar set of complex cognitive mechanisms, which may differ from those needed for nonword repetition. This may have led to a significant contribution
of phonological sensitivity and non-significant contribution of nonword repetition in predicting incidental word learning in the present study. The notion of a general cognitive processing ability underlying nonword repetition, phonological sensitivity, and word learning is in line with the current thinking by several researchers (Gathercole, 2006; Gupta, 2006; Snowling, 2006). For example, Gathercole (2006), has conceded that nonword repetition and word learning are multiply determined and that phonological memory deficits alone are not sufficient in explaining language deficits in children. She agrees that one needs to combine phonological storage deficits with impairment in general cognitive processing while accounting for such deficits. Gupta (2006) has used computational models to resolve the debate between phonological sensitivity and phonological storage hypotheses. Based on his models, Gupta (2006) has proposed that both phonological store and phonological sensitivity are important for word learning. He echoes Gathercole’s (2006) proposal that multiple factors may underlie nonword repetition and word learning. Snowling (2006) has proposed a developmental contingency model for language learning disorders in which nonword repetition, new word learning, and phonological awareness share common cognitive and biological mechanisms (see Snowling, 2006, for a complete review of the model). Overall, the findings of the current study suggest a domain general cognitive processing for nonword repetition, phonological sensitivity, and incidental word learning.
Figure 3. A conceptual framework of the relationship between nonword repetition, phonological sensitivity, and incidental word learning.
Future Research

The current study investigated the interaction between phonological sensitivity, phonological working memory, and incidental word learning. The findings indicated that phonological sensitivity, which required phonological knowledge and complex storage and processing of linguistic information, was a much better predictor of incidental word learning when compared to phonological working memory. It thereby lends credence to the vital role played by phonological knowledge and complex working memory in incidental word learning. These findings bolster the idea of a domain general rather than a domain specific cognitive processing for incidental word learning. The present study was an improvement over previous research exploring the relationship between phonological memory, phonological sensitivity, and word learning because unlike the previous investigations which explored the role of phonological sensitivity and phonological memory in controlled word learning tasks (for example, de Jong et al., 2000), the current study used a more complex and relatively more natural word learning task, where children had to make a connection between the novel word and the novel referent by watching cartoon stories with pre-recorded narratives, which contained the novel words. The scope of the current study was however confined to phonological working memory, phonological sensitivity, and word learning in typically developing children. A variety of developmental studies can be done to gain a complete understanding of this relationship.

Cross-linguistic Studies

Cross linguistic investigations exploring the role of phonological sensitivity, phonological working memory and incidental word learning would be important to see whether the current findings can be replicated in other languages. Similar findings in other languages
would strengthen the idea of a domain general cognitive processing in word learning across various languages. That is, it would suggest a similar set of mental operations governing the process of word learning across different languages. Such findings suggest that the domain general cognitive processing underlying word learning is not language-specific and that it can be generalized to different language families (Bates, Devescovi, & D’Amico, 1999). There is already some evidence of this from studies in Swedish-speaking children with SLI and hearing impairment (Hansson et al., 2004), and Dutch-speaking typically developing children (de Jong et al., 2000), where a complex working memory task and phonological sensitivity respectively were significant predictors of word learning. These findings are consistent with the findings of the current study. More cross-linguistic studies, however, need to be done to generalize these findings, especially to languages of diverse families and typologies.

Studies on Children with Language Disorders

Gathercole (2006) has proposed that children with SLI have lesser accuracy in producing nonwords of increasing length because of impairment in their phonological loop. Hansson et al. (2004), Hayiou-Thomas, Bishop, and Plunkett (2004), and Marton and Schwartz (2003) have shown that a complex working memory model that considers both processing and storage rather than nonword repetition can better account for language deficits in children with SLI. There have been no prior studies investigating the interaction between nonword repetition, phonological sensitivity, and a complex word learning tasks similar to the one used in this study. Replications of the current findings in children with SLI and other types of language disorders would provide support to the vital roles played by phonological knowledge and complex working memory in word learning.
Clinical Utility of Phonological Sensitivity Training

De Jong et al. (2000) investigated the effect of training in phonological sensitivity on paired associate word learning revealed. They found an improvement in performance on paired associate word learning following a short 2 weeks training in phonological sensitivity. These findings suggest that an enhanced sensitivity to the segmental aspects of speech can lead to better word learning. This short training might have been sufficient to see improved performance on paired associate word learning but it is not certain that such training would benefit complex word learning tasks similar to the one used in this study. Future studies should focus on the effects of such training on word learning in both typically developing children and children with language deficits. A positive effect of phonological sensitivity on word learning tasks suggests the use of phonological sensitivity training as an effective therapeutic tool for children with word learning problems.

The Role of Complex Working Memory and Phonological Sensitivity in Word Learning

It has been suggested that the phonological sensitivity tasks used here required complex storage and processing of verbal information, and is therefore comparable to a complex working memory task. It would be important to determine the contributions of both complex working memory and phonological sensitivity in word learning, and future work that incorporates tasks designed specifically to test complex working memory is needed. A similar contribution of both these tasks in word learning would bolster the idea that phonological sensitivity and complex working memory tasks may be by-products of a complex set of cognitive processing and storage operations. This would strengthen the findings of the current study, which suggests the vital role played by the complex nature of phonological sensitivity in word learning.
CONCLUSIONS

Lexical acquisition forms an important aspect of language acquisition. Children’s vocabulary acquisition accelerates throughout childhood, and by young adulthood, a typical vocabulary numbers in the tens of thousands of words. This rapid acquisition of words can be attributed to the ability to make initial mappings--sparse lexical-semantic representations of thousands of words--in the process known as fast mapping or incidental word learning (Bloom, 2000). The process of incidental word learning entails phonological processing, memory for a novel lexical item, choosing the correct referent, and making a connection between a word and its referent. Some studies have explored how children choose the referent pertaining to the novel word (for example, Carey & Bartlett, 1978; Dollaghan, 1985, 1987), the relationship between phonological memory, complex working memory and word learning (for example, Hansson et al., 2004), and the role of phonological sensitivity and phonological memory in paired-associate word learning (de Jong et al., 2000). This study filled a gap in the literature by also investigating the roles of phonological processing, memory, and knowledge in the process of incidental word learning.

The memory for a novel lexical item, which is required for vocabulary acquisition, has been investigated with models of working memory. Working memory is involved in the active storage and processing of information required for cognitive and linguistic processing. Functional working memory is an integrated model of working memory posits simultaneous storage and processing of information. Its chief competitor is the fractionated model of working memory that posits a separate phonological loop for word processing. Because FWM is an interdependent system (Just & Carpenter, 1992), an increase in processing load would lead to a breakdown. In the fractionated model, by contrast, the phonological loop is hypothesized to
operate independently of general cognitive processing (Baddeley & Hitch, 1974).

Baddeley and his colleagues (1990, 1997) have argued for the existence of a direct relationship between phonological working memory and subsequent vocabulary size, using a nonword repetition task to test phonological working memory. On the other hand, the lexical restructuring model theorizes that phonological knowledge itself influences word learning. The proponents of this model (Metsala & Walley, 1998) have suggested that nonword repetition tasks used to measure phonological working memory, and phonological sensitivity tasks are by-products of a common set of processes, which include speech perception, phonological representation, phoneme memory, and retrieval of the phonological representation from memory. Children are able to procure a greater knowledge of these processes when they move from holistic to a more segmental representation of speech, which occurs with an increase in children’s vocabulary size.

The study included a relatively small number of participants (n =40), and looked at just one age group. The findings are however, important because they throw light on some crucial aspects of word learning. Results of this study support a view of word learning as a complex process requiring a range of cognitive abilities and attainments, including attention, phonological knowledge, phonological processing, and sensitivity to statistical and socio-pragmatic cues. The word learning procedure used in this study was designed to mimic the relatively complex word learning that occurs in the child’s natural environment. Although nonword repetition is a fairly complex task, which shares certain linguistic and cognitive processes with word learning, it appears not to be sufficient to assess the type of phonological knowledge needed to succeed at real-world word learning tasks. Phonological sensitivity tasks, in contrast, entail some similar abilities, but also require other skills and knowledge, including metacognitive processing, and
thus entail both processing and memory aspects. It may be for this reason that they emerged as predictors of incidental word learning, when nonword repetition did not. Finally, the findings of the current study weaken support for a domain-specific, modular model of phonological and lexical processing. These results suggest that domain general cognitive processes underlie incidental word learning abilities.
REFERENCES


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Hello, My name is Vijay and I am a graduate student working on my Ph.D. in Communication Disorders at Bowling Green State University (in Ohio). I’m investigating word learning in young children. I’m working on this project with my advisor, Dr. Lynne Hewitt, who is on faculty in the Department here.

The age range of children who would be eligible for participation in my study is between 4 and 5 years. Does your school have children in this age range?

Could you please tell me the procedure that your school [center] uses for approving research projects? What I am looking for is to have letters handed out to parents of children in your school that explain my study and invite their participation.

[If receptive to idea]: That’s great, thank you very much. I can send you a completed Human Subjects application that I have on file with my university that explains the study in detail.

We are hoping to be able to test children at their schools. Would it be possible to test children at your facility? I would need a small, relatively quiet room where children could be tested.

We would do a speech and language screening and also a hearing screening. After the screenings are done, the study involves asking the children to repeat words and numbers, identify sounds in words, and also to identify words they have been taught.

In addition to Dr. Hewitt and myself, we will also be getting assistance to complete the speech and hearing screenings from graduate student clinicians in speech pathology.
APPENDIX B

Parental Consent Form

We are researchers at Bowling Green State University studying how people learn words. Our names are Vijayachandra (Vijay) A. Ramachandra and Lynne Hewitt. Vijay is a Ph.D. student and Lynne Hewitt is on faculty in the department. We also have some graduate students in speech pathology helping us with the study.

What is the study about?
We are studying how children learn words. Our findings may help someday to improve language teaching for children with problems in learning words.

What happens in the study?
Children who take part in our study will be asked to do several things: first, we will ask them if it’s OK with them to be in the study. If the answer is yes, we will do a brief screening test of speech and language, and also a hearing screening. Next, children in the study will repeat nonsense words and lists of numbers, and then do picture matching to test their ability to pick out different speech sounds in words. After this, we will ask the children to listen to a story regarding a picture presented on the computer screen, and then ask them to point to some pictures on a computer screen to see what they remember from the pictures they saw before.

How long will it take?
The entire study will take about one and a half hours to finish. If needed, some tests can be done on one day, and the rest on another day.

Can I get the results of my child’s tests?
If your child does not pass the speech, language, or hearing screening, we will contact you with information on how you can get further testing. Children who fail any of these screenings will be excused from doing the remaining part of the study.

Are there any risks?
We know of no risks to you or your child for taking part in this study.

Is this study required?
Taking part in this study is voluntary. That means you or your child may choose not to be in the study, or if you and your child decide to be in it, either of you can change your mind any time and withdraw from the study.

What do people in the study get for taking part?
Your child gets a free speech, language, and hearing screening.
Who gets to see information about people in the study?

All information collected about your child during this study will be kept private. No information that identifies your child personally will be given to anyone other than the researchers and their assistants. The only other people who might see your child’s records would be people who work for agencies whose job it is to check up on researchers, including members of the Bowling Green State University Human Subjects Review Board, and federal agencies.

Who can answer questions about this study?

If you have any questions, you may contact Vijay at (419) 378-1683. You may also contact the Chair, Human Subjects Review Board, Bowling Green State University, (419) 372-7716, (hsrb@bgnet.bgsu.edu), if you have any problems or questions about your and your child’s rights as a research participant.

What does it mean to sign this form?

If you sign below, it means that you have read this entire letter, and have had all your questions answered, and that you agree to have your child participate in the study. You will be given a copy of this consent form.

________________________________________     __________
Signature of Parent or Guardian of Study Participant       Date

________________________________________     __________
Printed Name of Parent or Guardian of Study Participant       Date

Principal Researcher: Vijayachandra A. R., Department of Communication Disorders, BGSU
Co-Researcher: Dr. Lynne Hewitt, Department of Communication Disorders, BGSU
To Be Read to Children Participating in the Study:

Dear [Name of child]:
My name is [Name of Researcher or Assistant]. I am learning about how children learn to talk.

I’d like to have you listen to some words, say some words, point to some pictures on cards and also some pictures on a computer.

Do you have any questions?
[WAIT FOR CHILD TO ANSWER]

Is that OK with you?
YES  NO

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Witness          Date

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Second witness   Date

PARTICIPANT NUMBER: _________________________
One morning John was getting ready to go to school. His mother reminded him to take his dap to school.

John’s school bus arrived and he was in a hurry to get into the bus. He grabbed his bag and forgot to take his dap.
When John reached school he saw Ted playing with the **dap**. John realized that he had forgotten his **dap** at home and began to cry.

John’s teacher saw this and asked him why he was crying. John told his teacher that he had forgotten his **dap** at home.
The teacher told him not to cry and asked him to go and play on the other side of the playground. John went there and saw gid swimming in the pond.

He then tried catching the gid. He tried and tried but could not catch the gid.

He then saw gid crawling up to the land. John was very happy to watch the gid dig for food.
At this point John felt hungry and saw a shan hanging from the branch of a tree.

He tried to jump and get the shan but he could not!
He slowly climbed the tree. He then started shaking the branch that had the shan.

The shan fell on the ground. John was happy and ran down to pick up the shan. He ate it and happily returned home.
One morning a lion went to the river to drink some water. The lion noticed a zik near a big tree.

The lion started drinking water from the river and suddenly he heard a loud noise. The lion turned back and saw the zik move towards him.
The lion got angry and chased the zik away.

The zik ran up the branch of a tree. The branch broke and the zik fell into the river.

The lion laughed at this and started walking back home. While walking he accidentally stepped on a puk and hurt his foot.
A monkey saw the lion in pain and asked him what had happened. The lion told the monkey that he had stepped on a **puk** and hurt his foot.

The lion asked the monkey to pull the **puk** from his foot. The monkey did as he was told and threw the **puk** in the river. The lion was happy that the **puk** was gone.
The monkey then took a paz from his bag. The lion kept looking at the paz for a long time.

The monkey rubbed the paz on the lion’s foot. The lion felt better and returned the paz to the monkey.
The monkey told the lion to keep the paz with him as he might need it in the future. The lion put it in his pocket and happily returned home.