

Winter 12-2011

# The Role of Verbal Working Memory in New Word Learning in Toddlers 24 to 30 Months Old

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THE ROLE OF VERBAL WORKING MEMORY IN NEW WORD LEARNING  
IN TODDLERS 24 TO 30 MONTHS OLD

A dissertation submitted

by

FRANCE WEILL

in partial fulfillment  
of the requirement  
for the degree of

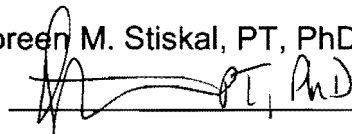
DOCTOR OF PHILOSOPHY

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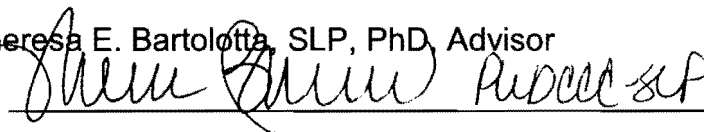
Health Sciences

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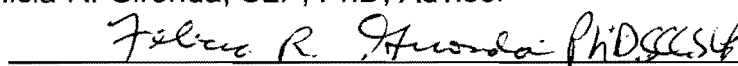
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## Acknowledgments

I am deeply grateful to

My Dissertation Committee

Dr Doreen Stiskal, as committee chair and as my mentor. Thank you for your wisdom, for your confidence, for your warmth, and for your expertise of research methodology. Thank you for having nurtured my passion for research. Thank you for all your help, the help that I am aware of, and the help about which I can only guess. You taught me to focus on my goal and elegantly set aside the obstacles. What a beautiful gift!

Dr. Theresa Bartolotta and Dr. Felicia Gironda. I am very grateful that you accepted my request to guide me through this process by sharing your clinical expertise with me.

Dr. Phillip Schneider. When I met you at a turning point in my undergraduate studies, you inspired me to passionately embrace our profession. You taught me that human beings have an infinite and God-given potential for change. I know now that you are right. Thank you for having become a lifelong friend for me and for my family.

Ron Grunfeld, my “red angel.” Ron, you seemed to magically appear each time I needed reassurance. You knew how to listen to me; you artfully chose encouraging words and made me believe that my goal was actually reachable. Thank you for your warm smile and for your unwavering support.

My colleagues from Touro College. Thank you for having allowed me to become part of your wonderful team.

My dear parents Dr. Claude and Dr. Claudine Bollack. *Maman*, throughout your accomplished career as an engineer and while raising us as a devoted mother, you taught me to question conventions. *Papa*, of blessed memory, you were a brilliant and caring physician and a loving father. From you, I have learned the harmony of science and humanity. Merci.

My wonderful family. Thank you for your enthusiasm. Thank you for being “on my team.”

My friends. You helped me stay sane and balanced through these years; thank you for being there. Always.

All the children and their families who participated to this study. Thank you for allowing me to briefly become briefly part of your life. You made this study possible. You contributed to a project that will hopefully serve the higher goal of helping the children who need us the most.

Each one of you, who were infants and toddlers when I worked with you during those past 20 years. Each one of you has triggered my curiosity. Each one of you taught me something about therapy, about hope and determination, about myself, and most importantly, about the fact that we all have a mission to accomplish. Thank you.

## Dedication

*“and God formed Man of dust from the earth and He blew into his nostrils the soul of life; and Man became a living being” (Genesis 2, 7)*

Onkelos, commentator and translator of the Bible into Aramaic in the second Century C.E. notes the apparent redundancy between “soul of life” and “living being”. He interprets that Man became a living being once God granted him with *the gift of speech*

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## ABSTRACT

**Introduction.** The ability of children to develop language harmoniously rests in large part on their capability to learn new words at a very fast pace and with minimal exposure. This capacity develops during their second year of life and depends on working memory and on existing word knowledge. According to the model of working memory proposed by Baddeley and Hitch (1974, 2000) as a framework to examine the acquisition of new words, one of the sub-systems of working memory, the phonological loop is responsible for processing and storing new verbal material. As such, the phonological loop plays a central role in the acquisition of unfamiliar sound sequences such as new words. The relationship between the role of the phonological loop and the role of existing word knowledge in word learning develops over time. Research has shown that the capacity of the phonological loop plays a central role in vocabulary acquisition. Although vocabulary acquisition is extremely rapid in children two years of age, the vast majority of studies have examined this relationship in children beyond the age of four. The purpose of this study this study was to evaluate the relative contribution of phonological loop capacity and of existing word knowledge to the ability of children 24-30 months to learn new words.

**Subjects.** A total of thirty-one typically developing monolingual English speaking toddlers, 24-30 months of age, were recruited for this study. Prior to data collection, the main investigator screened each subject through three screening processes: review of a demographic form filled by the parents of each subject, scoring of the Mac Arthur Communicative Development Index (MCDI; Fenson et al., 1993) completed in by the parents of each subject, and results of a speech and language screening performed during play interaction with the subject. A total of 22 children met the inclusion criteria, and 19 children completed the study.

**Methods.** Children were tested at their home during the course of two sessions of about 45 minutes each. We took three measures for this study: a measure of the size of productive vocabulary using the Expressive Vocabulary Checklist of the Toddler's version of the MCDI (Fenson et al., 1993); a measure of phonological loop capacity using a non word repetition task and a measure of expressive (naming) and receptive (recognition) fast mapping. We randomized both the measure of phonological loop capacity and the measure of word learning. The three measures performed were used to compute three statistics. A correlation between the phonological loop capacity and the size of the child's productive vocabulary indicated the strength of the relationship between those two variables. Multiple linear regressions computed the predictive value of phonological loop capacity and

of the size of productive vocabulary to expressive fast mapping and to receptive fast-mapping.

**Results.** Findings revealed a moderate to strong positive correlation between phonological loop capacity and the size of productive vocabulary ( $r=.71$ ,  $p<.01$ ). Together, the phonological loop capacity and the size of expressive vocabulary explained 20% of the results in expressive fast-mapping ( $R^2 = .20$ ) and 48% of the results in receptive fast-mapping ( $R^2 = .48$ ). Findings also indicated that phonological loop capacity is a better predictor of both expressive and receptive fast mapping ( $\beta_2 = .11$ ,  $p = .02$ ), than size of expressive vocabulary. Demographic findings indicated a moderate positive correlation between birth order and both size of productive vocabulary ( $r=.34$ ) and nonword repetition scores ( $r=.43$ ). Findings also showed a moderate positive correlation between maternal level of education and both size of productive vocabulary ( $\rho=.31$ ) and nonword repetition scores ( $\rho=.49$ ). Toddlers enrolled in care had a larger vocabulary size (Mean=358, SD=146) and lower non-word repetition scores (Mean=13.4, SD=5.7) than toddlers not enrolled. Females had larger vocabulary size (Mean=376, SD=168) and higher non-word repetition scores (Mean=16.2, SD=4.9) than males. Finally, age was not correlated with either of the independent variables.

**Discussion.** Typically developing toddlers 24 to 30 months old toddlers with large phonological loop capacity have a larger vocabulary size than toddlers

with small phonological loop capacity. Toddler's phonological loop capacity is a better predictor of their ability to produce new words than the size of their productive vocabulary. This is true especially for toddler's ability to remember new words. As word learning involves complex cognitive processes, a variety of factors might affect their ability to remember, to retrieve and to produce new words. It is noteworthy that social environment also plays a significant role in toddlers' ability to learn new words.

**Conclusion.** Findings of this study confirm the positive relationship between verbal working memory and the size of toddler's productive vocabulary. They also provide preliminary evidence that verbal working memory contributes significantly to the ability of toddlers to learn new words. Those findings are consistent with the hypothesis of verbal working memory serving as a language learning device for children four years and older but extend the model to younger children.

## Chapter I

### Introduction

#### Background

The development of language is a natural, but extremely complex process, by which each child, equipped with his or her specific predispositions, learn to use the environment to become a competent communicator. Most infants acquire their first words around the time of their first birthday, having acquired enough words to tell stories and make conversation by the end of their third year of life. The transition from a non-speaking child to a child using words characterizes the transition from infancy to toddlerhood (Bloom, 1991). After having acquired an initial lexicon of about 50 to 75 words, toddlers start learning new words at an exponential rate (Bates, Brethenton & Snyder, 1988; Bates et al., 2002). During this stage, known as vocabulary spurt, the rate of acquisition of new words increases from one new word every few weeks at the beginning of the second year of life, to 3 or 4 new words per day after 30 months of age (Bloom & Markson, 1998).

In this early stage of expansion of the lexicon, there are important variations in the rate of acquisition of words among typically developing



children (Fenson et al., 1994; Goldfield & Reznick, 1990). Some children acquire new words much faster than others. Thus by their second birthday, most toddlers start to systematically combine words into meaningful phrases and to use different grammatical forms to express distinct meanings (Bates, Dale & Thal, 1995; Marchman, Martínez-Sussmann, & Dale, 2004). By their third birthday, children are equipped with a vast and continuously expanding lexicon, and can produce complex and grammatically correct sentences (Bates & Goodman, 1997). The beginning of first grade, at the age of six, marks a major change in the dynamics of language acquisition for children. Instead of being mostly incidental, vocabulary acquisition and grammatical development becomes a formal school activity. During the first two years of school, children learn new words and concepts by learning to read and developing literacy. As they go through elementary school, robust vocabulary knowledge and efficient word learning skills are essential for learning language (Sternberg, 1987). In school, reading and writing take a central role for further development of literacy and acquisition of knowledge (Nagy, Herman & Anderson, 1985; Nagy, Anderson & Herman, 1987). Success at each stage of development is contingent on success at preceding stages. That is, children's ability to efficiently learn new words as toddlers will establish efficient foundations for language development in later years.

Word learning occurs along a continuum. It is a gradual process, taking place over repeated exposures to the new word label and its object-referent

(Carey & Bartlett, 1978). During this process, children establish a link between the new word label, the new word meaning and the object-referent. The acquisition of the sequence of phonemes is referred to as label or lexical learning and the acquisition of word meaning is known as semantic learning. According to Carey & Bartlett (1978), a single exposure to a new word allows children to retain “something about” that word, a process called fast mapping. During the fast-mapping phase, children are exposed to a new word for the first time, and must establish an initial link between the word label, the word meaning and the referent. They initially acquire an imperfect representation of the word by retaining an approximation of the sequence of phonemes that comprises the label, and associating it with an incomplete semantic representation or meaning of the word. Subsequent and repeated exposures to the new word then enrich the information stored in memory and the semantic representation gradually improves. A direct relationship exists between the increasingly comprehensive understanding of the word meaning provided by repeated and diverse exposures, and the acquisition of new words, measured by recognition and production tasks (Capone & McGregor, 2005). The richer a child’s semantic knowledge of a word, the more likely that word will be recalled for production, whereas weak semantic representations more often result in semantic naming errors (McGregor, Friedman, Reilly, & Newman, 2002).

Fast mapping skills develop after toddler's lexicon already contains a few dozen words, typically during the first half of the second year of life. Toddlers as young as 13 months demonstrate understanding of new words after only a limited number of exposures (Woodward, Markman & Fitzsimmons, 1994). Toddlers 16 to 20 months of age, whose lexicon contains less than 100 words, can spontaneously associate a new word to an object for which they do not yet have a label (Mervis & Bertrand, 1994). Fast mapping skills appear simultaneously with a sudden increase in rate of vocabulary growth, or vocabulary spurt (Bates, Bretherton & Snyder, 1988; Bates et al., 2002). The vocabulary spurt takes place "roughly after their productive lexicon have reached 50-100 words" (Dapretto & Bjork, 2000, p.636). Recent electrophysiological studies confirmed that typically developing 20-month-olds with large expressive vocabulary show fast mapping abilities, whereas children with small expressive vocabulary don't yet fast-map (Torkildsen et al., 2008). The relationship between vocabulary spurt and fast-mapping has been supported by research on clinical population. Children with language delay experience a similar relationship between vocabulary spurt and the onset of fast mapping, albeit chronologically later than typically developing children (Mervis & Bertrand, 1995; Lederberg, Prezbindowski, & Spencer, 2000).

Even though the development of fast-mapping typically occurs during the second year of life, it appears to be linked to a developmental stage,

rather than to chronological age. More specifically, the size of expressive vocabulary or vocabulary size is the pivotal criterion that marks the onset of fast-mapping capabilities (Bates, Bretherton & Snyder, 1988; Bates et al., 2002; Torkildsen et al., 2008). There are extremely large variations in vocabulary size among typically developing children. The average size of productive vocabulary is 64 words (range: 0 to 347) for 16 month old children, and 312 words (range: 7 to 668) for 24 month old (Fenson et al., 1994). The age of onset of fast-mapping thus varies greatly from one toddler to the other.

As toddlers acquire the ability to fast-map, they become capable of quickly forming hypotheses about the meaning of new words they encounter (Carey, 1978). They then rule out other potential meanings by using contextual information and a set of word learning constraints that limit the number of possible hypotheses that children will consider. Contextual information includes explicit linguistic information, formally taught to the child through the use of definitions, explanations, and gestures as well as implicit information that the child infers from the context (Heibeck and Markman, 1987). The innate predisposition of children to favor some hypotheses over others is called word learning constraints, or developmental lexical principles. This period of fast lexical development makes toddlers more vulnerable to naming errors when asked to retrieve a word previously learned (Gershkoff-Stowe and Smith, 1997; Gershkoff-Stowe, 2002). The second year of life is typically marked by an increasing efficiency in acquiring new words as

toddlers become more proficient in integrating information from various sources to support their learning.

The acquisition of new words requires contributions from a variety of sensory (visual and auditory), cognitive (memory and attention), and motor systems, which interact with each other (Repovs & Baddeley, 2006). One of those cognitive systems, working memory, plays a central role in word learning. The model commonly used to examine the acquisition of new words is the three-component model of working memory proposed by Baddeley and Hitch (1974). It comprises the central executive, the phonological loop and the visuospatial sketchpad. According to this model, a limited set of neural resources is available to process incoming information. The central executive recruits attention and distributes those limited resources between the two subsystems storing incoming auditory and visual information: the phonological loop (PL) and the visuospatial sketchpad (VSSP). The phonological loop is responsible for holding and rehearsing verbal material such as strings of phonemes. It plays a central role in the acquisition of unfamiliar sound sequences (Gathercole, Hitch, Service and Martin, 1997). The capacity of the phonological loop represents the amount of memory activation available to hold verbal material for short amounts of time until further processing. A fourth component, the episodic buffer, was hypothesized by Dr. Baddeley in 2000. It serves as a neural workspace recalls information from long-term memory and integrates it with verbal and

visual new information for meaningful processing and transferring into long-term memory for storage (Baddeley, 2000). In this model, we will only examine the role of the phonological loop, which carries a central role in acquisition of new words.

Learning a new word involves two independent processes: a phonological learning process, supported by the phonological loop, and a nonphonological learning process supported by existing word knowledge (Gathercole, Hitch, Service and Martin, 1997). The relative importance of each one has been examined. Word learning has a strong relationship with both phonological loop capacity and existing word knowledge, which is stored in long-term memory in the form of familiar word labels. There is a positive correlation between the capacity of the phonological loop and the child's word knowledge (Gathercole, Service, Hitch, Adams & Martin, 1999; Gathercole, Willis, Baddeley & Emslie, 1994; Gathercole, Willis, Emslie & Baddeley, 1992). A positive correlation also exists between the capacity of the phonological loop and the child's ability to learn new words (Gathercole & Baddeley, 1990; Gathercole Hitch Service Martin, 1997). In general, 4- to 6-year-old children with larger phonological loop capacity score significantly higher at learning new words, characterized by unfamiliar sequences of sounds (Gathercole and Baddeley, 1990). That is, children with larger phonological loop capacity tend to have larger vocabularies, and to learn new words more easily. Despite the fact that acquisition of new words is central to

language development in toddlers, all studies examining the role of the phonological loop in word learning were performed with children beyond the age of 4. Few studies have yet examined the role of working memory in word learning in toddlers.

Even though the relationship between existing word knowledge and phonological memory and their role in word learning evolves as the child matures, the constraints imposed by phonological loop capacity remain significant throughout childhood and teenage years (Gathercole, Willis, Emslie & Baddeley, 1992; Gathercole, Service, Hitch, Adams & Martin, 1999; Storkel & Morrisette, 2002). In fact, phonological loop capacity represents the main constraint on vocabulary development between 4 and 5 years of age, whereas existing word knowledge becomes the main constraint after the age of 5 (Gathercole, Willis, Emslie and Baddeley, 1992). If phonological memory represents the main constraint on vocabulary development in 4 year old children, it would be expected that phonological memory also represents the main constraint of new word learning in this age group. If existing word knowledge supports working memory by decreasing the amount of unfamiliar sound sequences the phonological loop needs to hold during learning; then the more words a child knows, the less s/he needs to rely on the phonological loop to learn new words. By contrast, the fewer words a child knows, the more s/he should have to rely on the phonological loop for learning new words. In this case, phonological loop capacity should be the constraining

factor in new word learning in toddlers. As toddlers' limited word knowledge likely forces them to rely mostly on their phonological loop capacity to learn new sequences of phonemes, their phonological loop capacity should be a better predictor of their ability to learn new words than their word knowledge.

It is unknown whether a methodology designed to measure phonological loop capacity in children 4 years and older, can be used in a population of toddlers. Toddlers tend to have a shorter attention span, and, as their sound repertoire is still developing, are often less intelligible and less consistent in their sound and word production than older children. To answer this question, a pilot study examined the applicability of a well controlled nonword repetition task to measure phonological loop capacity in children 24 to 48 months of age (Weill et al., 2008). Findings of the pilot study showed that both the methodology and the instrument developed were adequate for use with children as young as 24 months.

### **Problem statement**

The ability of children to develop language harmoniously and to become efficient learners at school rests in large part on their capability to learn new words at a very fast pace and with minimal exposure. This capacity typically develops during their second year of life, and depends on working memory and on existing word knowledge.



Most studies on the role of working memory in word learning examine the acquisition of new words in children beyond the age of 4. Reliance on existing word knowledge as a support for lexical and semantic learning develops as the child's lexicon grows. Children with limited lexicon, such as toddlers, may have to rely on the capacity of their phonological loop to acquire new words. In this age group, decreased capacity of the phonological loop would therefore impair toddlers in their capacity to learn new words quickly. This study is necessary to demonstrate the importance of phonological loop capacity on new word learning in toddlers.

### **Purpose**

The purpose of this study is to examine the relationship between toddlers' ability to learn new words, their phonological loop capacity, and the size of their productive vocabulary. The degree of learning will be examined with two measures: a word recognition task, for which semantic and phonological representation can be incomplete, and a word naming task, that requires better phonological knowledge as well as richer semantic representation of the word.

### **Research questions**

**Question 1.** What is the relationship between phonological loop capacity and size of productive vocabulary in post-vocabulary spurt toddlers?

**Question 2.** Is the size of productive vocabulary or is the capacity of the phonological loop a better predictor of expressive fast-mapping abilities in post vocabulary-spurt toddlers?

**Question 3.** Is the size of productive vocabulary or is the capacity of the phonological loop a better predictor of receptive fast-mapping abilities in post vocabulary-spurt toddlers?

### **Operational definitions**

Central executive: attentional cognitive component of working memory, whose purpose is to control attention and processing of new information (Baddeley and Hitch's, 1974).

Children: general term referring to humans from 0 to 12 years of age.

Constraint theory of word learning: hypothesis that explains how children infer the meaning of a new word by limiting the infinite possibility in connecting the new word label with the new word meaning.

Digit span: number of digits a person can remember and recall over a short period of time.

Early word learning: acquisition of the first hundred words, typically during the second year of life.

Episodic buffer: hypothetic cognitive workspace of working memory, used to integrate information from the visuospatial sketchpad and from the phonological loop, together with information from long-term memory (Baddeley, 2000).

Fast mapping: first association made between a new word and its referent, after a brief exposure, leading to weak mental representation of the new word's label and of its meaning.

Infant: child at the youngest stage of life, before they can walk or talk, typically in their first year of life.

Large productive vocabulary: productive vocabulary higher than 75 words independent from the age of the child, that refers to a vocabulary size threshold at which most children are capable of fast-mapping (Torkildsen et al., 2008).

Lexical learning: acquisition of the phonological string that comprises the word label.

Lexicon: vocabulary of a language.

Long-term memory (LTM): cognitive system responsible for lasting and unconscious storage of information.

Low productive vocabulary: productive vocabulary lower than 75 words, independent from the age of the child, that refers to a vocabulary size at which most children are not yet capable to fast-map (Torkildsen et al., 2008).

Naming: providing a label for a stimulus when asked to do so, in response to such question as, "what is this?"

New word learning: acquisition of novel, previously unknown words.

Mapping: gradual acquisition of the new word with its referent.

Memory span: number of items usually words or numbers that a person can retain and recall.

Phoneme: speech sound, used to distinguish words in a language.

Phonological processes: predictable speech errors that children make when they learn to talk and that affect classes of sounds rather than single sounds.

Phonological loop (PL): component of Baddeley and Hitch's (1974) model of working memory, responsible for processing and storing verbal information in short-term memory.

Phonotactic probability: the frequency with which a phoneme and a sequence of phonemes occur in a given position in a word (Jusczyk, Luce & Charles-Luce, 1994).

Recency effect: the most recently presented items in a list of digits, of words or of nonwords, which are recalled best.

Receptive vocabulary: lexicon of words understood by an individual.

Recognition: identification of an object upon being provided its label.

Semantic features: components of meaning for a word.

Semantic learning: acquisition of word meaning as well as associations with other related words.

Semantic representation: comprehensive meaning of a word, which depends on the experience and understanding a toddler has with the word and its referent.

Short-term memory: cognitive system that holds information in conscious awareness.

Slow mapping: enrichment phase of word learning after a word has been fast mapped, and that is enriched by frequency of exposure and by quality of each experience.

Specific language impairment (SLI): developmental language disorder that has no known cause, and occurs in the absence of hearing impairment, traumatic brain injury, mental retardation, and other neurological or cognitive impairment.

Toddler: child whose developmental status is characterized by rapid language acquisition, typically between 18 and 36 months of age.

Typically developing: term referring to children whose speech, language; social and cognitive development is consistent with what most people would be perceived as normal, with no significant deviation from average norms.

Visuospatial sketchpad: component of Baddeley and Hitch's (1974) model of working memory that allows the temporary storage and manipulation of visual and spatial information.

Vocabulary acquisition: word learning, seen as a global process leading to a child's vocabulary or lexicon.

Vocabulary spurt: increase in the rate of acquisition of new words, which takes place after children have acquired their first 50 to 75 words and typically starts in the middle of the second year (Bates et al., 2002; Bates, Bretherton, & Snyder, 1988; Goldfield & Resnick, 1990).

Word learning: Mental operation by which a word previously unknown is integrated into a person's lexicon.

Word-length effect: a phenomenon whereby the number of words that can be held in short-term memory depends on how long it takes to say those words.

Word retrieval: ability to recall from memory the correct word.

Working memory: limited-capacity cognitive system allowing the temporary storage and manipulation of visual and verbal information, while a more central system manages all incoming sources of information including information from long-term memory (Baddeley, 2000; Baddeley & Hitch, 1974).

## Chapter II

### Literature Review

This chapter presents a review of pertinent literature on mechanisms involved in word learning in children. It consists of two sections. The first section provides an introduction and overview on the chronology and the dynamics of word learning. It introduces the methodologies and tools typically used to measure word learning and vocabulary growth. The second section presents the theoretical model of working memory that will constitute the framework of this research. It introduces the methodology and tools used to assess the capacity of the phonological loop.

#### Word Learning

Language development is a complex mechanism in which children engage spontaneously and instinctively. More specifically, word learning is a central aspect of language development in the first few years of life. Hall and Waxman (2004) describe word learning using a “weaving” metaphor:

children weave together many different strands of knowledge and skills. [They] do not intertwine these strands in a uniform fashion over



the course of infancy and childhood [...]. [children are] recruiting some abilities and understandings more heavily at some developmental points than at others. (p. XI)

### **Characteristics of word learning.**

***Milestones in vocabulary development.*** Infants typically acquire their first word close to the time of their first birthday. The first 50 to 75 words are acquired at the very slow pace of a few new words every month (Bloom & Markson, 1998; Fenson et al., 1994). Towards the end of the second year, the rate of acquisition of new words increases significantly (Bates, Brethenton, & Snyder, 1988; Bates et al., 2002) and is referred to as vocabulary spurt or naming explosion (Bloom, 1973; Goldfield & Reznick, 1990). By their second birthday, toddlers acquire new words at a pace of one to two per day (Fenson et al., 1993). They can produce hundreds of words and can actually understand much more than they can express (Bates, 1993). Bloom and Markson (1998) showed that after 30 months, children can acquire 3 or 4 new words per day.

Acquiring new words at a rapid pace is therefore essential for language learning. This complex "weaving" process takes place over time, and involves learning to associate a sequence of sounds to a meaning of a new word. In order to learn new words, children also need to store the sound-meaning association in memory and to retrieve from memory as needed.

***Semantic and lexical learning.*** Word learning requires both lexical learning and semantic learning. Lexical learning refers to the acquisition of the phonological string that comprises the word label. Semantic learning refers to the acquisition of word meaning as well as associations between the new words and other related words. For example, learning the word “cup” requires storing /k/, /ʌ/ and /p/ in sequence, remembering its physical shape, its functional features (one drinks from it) and the fact that a cup is part of a larger category of items, i.e., dishware. The new lexical information (/k/, /ʌ/, /p/) is linked to the new semantic information (physical shape and functional features). The new word (cup) is also linked to other related words (dishware). Semantic and lexical learning occur gradually over time. Links between the word label and the word meaning and links with other words are established over repeated exposures to the new word.

***Vocabulary acquisition and lexical constraints.*** Vocabulary acquisition is defined as the acquisition of all the words that will constitute the lexicon. Both external factors, such as maternal linguistic input or object perception, and internal factors such as lexical constraints, constrain vocabulary acquisition in infants and toddlers (Uchida & Imai, 1999). Word learning in children and more specifically in infants and toddlers is guided by developmental lexical principles (Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Imai, 1999).

According to this constraint theory of word learning, a child learning a new word is faced with an infinite number of possibilities to associate a new word with a meaning. The child has to choose the best fit among all possibilities, then move on to probe these hypotheses and extend the word to other referents. Golinkoff, Mervis, and Hirsh-Pasek (1994) suggest that children acquire six “lexical principles” in a developmental sequence. The first three principles (Reference, Extendibility and Object Scope as defined below) are necessary for the child to acquire the fundamentals of word learning. The principle of Reference states that the child maps new words onto his or her existing representation of the world. The principle of Extendibility suggests that the child will use the same word to label referents that share similarities. (e.g., extensions based on shape or taxonomy). Based on the principle of Object Scope, children have an innate assumption that words refer to whole objects, rather than to object parts or attributes. Those principles serve as a foundation for the acquisition of the next three principles.

The principle of Categorical Scope indicates that children extend the label of a word based on basic level category assignment. According to the Novel Name–Nameless Category principle, referred to in this research as fast-mapping ability, new words are mapped onto objects for which the child does not yet have a name. That is, a child capable of fast-mapping is able to map a new word simply when exposed to an unknown object a minimum number of times. There is no need for an explicit link between the word and

the object. This behavior is explained by two other rules: the principle of Mutual Exclusivity (Markman, 1989) stating that one object can have one name only, and the principle of Contrast (Clark, 1983), stating that two different names assume two different meanings. Golinkoff et al. (1992) have unequivocally confirmed the use of Novel Name–Nameless Category principle by typically developing 30-month-old toddlers. The sixth principle or principle of Conventionality accounts for the use of consistent phonological forms or words, conventionally shared by a linguistic community, to label a referent.

The coordination of those developmental lexical principles and adequate environmental input with all other linguistic and cognitive abilities, is essential to the development of word-learning capabilities, contributing to vocabulary growth. The present study will more specifically focus on the acquisition of the Novel Name–Nameless Category principle, which has been described as the fast-mapping ability and its developmental relationship to vocabulary spurt.

### **The process of word learning.**

Word learning takes place along a continuum of time. Carey and Barlett (1978) described two phases of word learning, fast mapping and slow mapping, which characterize the gradual nature of word learning (Swingley,

2010). The existence of progressive word learning has been demonstrated both in typically developing children and in clinical populations.

***Fast mapping: the initial and incomplete phase of word learning.***

*Definition.* When toddlers are exposed to a new word for the first time, they are often capable of recognizing and using this new word without fully understanding it and without remembering the exact sequence of sounds that comprises the label. Toddlers seem to make an educated guess, using all the contextual cues available to quickly incorporate this new word in their lexicon. In the process of word learning, fast mapping refers to the first association made between a new word and its referent, after a limited exposure. Toddlers form a weak mental representation of a new word's meaning and of its label.

*Explicit versus incidental learning.* Fast-mapping has mostly been examined in well-controlled studies, in which children were exposed to a limited number of new words and were probed for either comprehension or production of the new words. Most of those studies have examined fast-mapping in contexts where the child was taught the new word explicitly (Capone & McGregor, 2005; Dollaghan, 1985; Heibeck & Markman, 1987; Mervis & Bertrand, 1994). However, children beyond the age of 2 years start to learn new words through play interaction, or conversation related to the activity they are involved with at the moment (Clark & Wong, 2002).

Tomasello and Akhtar (1995) showed that 27-month-old toddlers use social-pragmatic cues to determine which object or action to associate to a new label. On another hand, Skolnik and Fernal (2003) showed that 28-month-old toddlers could learn new words taught incidentally, using only linguistic cues. The ability of children to learn new words incidentally through non-structured contexts that characterize real-life situations steadily increases from 2 to 5 years of age (Rice, Buhr, & Nemeth, 1990; Rice & Woodsmall, 1988).

*Fast mapping varies by word class.* Object labels are typically easier to fast map than other word classes, such as attribute, action, or affective states (Oetting, Rice, & Swank, 1995; Rice, Buhr, & Nemeth, 1990). Oetting et al. (1995) suggest that object learning requires fewer exposures because the referent is concrete. The extended exposure needed to learn other word classes may reflect the more abstract nature of those referents.

***Slow mapping: the enrichment phase of word learning.*** Slow mapping refers to a gradual process of repeated exposures that enriches the initial semantic and lexical representation of the new word provided by fast mapping. At each subsequent exposure, the child's understanding of the new word is enriched through a variety of new phonological, semantic, contextual, and gestural information. Slow mapping, also known as extended mapping, depends on the frequency of exposure to the new word, and on the quality and nature of these exposures. Gershkoff-Stowe (2002) looked at word

learning under different practice conditions, varying the exposure to semantic information via pictures. She found that word learning was improved by increased practice, and concluded that “practice is a general agent of lexical development” (p. 684). Capone and McGregor (2005) looked at word learning in controlled-frequency conditions, but exposing children to different qualities of experience. They showed that word learning was improved by enrichment of semantic information through gestural cueing. A higher number of exposures and a richer nature of exposures are expected to result in a more complete and comprehensive meaning of the new word for the child.

### **Fast-mapping.**

#### ***Fast mapping and vocabulary spurt.***

*Vocabulary spurt or sharp acceleration of word learning.* The concept of vocabulary spurt has been widely accepted as a linguistic and cognitive milestone. Experts associate the vocabulary spurt with the understanding that new words refer to new referents (Golinkoff, Hirsh-Pasek, Bailey & Wenger, 1992; Mervis & Bertrand, 1994), with the ability to learn words after minimal exposure (Gershkoff-Stowe, 2002; Mervis & Bertrand, 1994; Gershkoff-Stowe & Smith, 1997; Woodward, Markman & Fitzsimmons, 1994) and with the ability to categorize objects (Gopnik & Meltzoff, 1987). However, the shape and operational definition of the vocabulary spurt are still subjects of debate. While many children actually experience a sudden vocabulary spurt, other

children experience a gradual acceleration of word learning with no clear inflection point (Ganger & Brent, 2004; Mitchell & McMurray, 2009).

*The cause of the vocabulary spurt.* Even though the vocabulary spurt, defined as the significant acceleration of word learning ability, is considered a robust phenomenon leading to a rapid increase of the lexicon, the cause of this phenomenon is not known. Woodward, Markman and Fitzsimmons (1994) hypothesize that toddlers' increased motivation to communicate verbally, better articulatory control, and improved ability to retrieve words from memory might all contribute to the vocabulary spurt. Dapretto and Bjork (2000) suggest that the rapid increase in the size of the lexicon is linked to significant changes in children's word retrieval process by the end of the second year. These changes appear supported by neural reorganization as well as by the actual increase in the size of the lexicon. Mitchell and McMurray (2009) support the hypothesis that that the increase in the size of the lexicon it-self triggers leverage learning, or the fact that "knowledge of some words help with the learning of others" (p. 1503). Leverage learning does not generate the sudden acceleration in word learning, but can change its curve and its timing. In summary, toddlers' better control of their articulators and increased motivation to speak might contribute to the acceleration in vocabulary acquisition. But according to existing research, the main contributors appear to be toddlers' improved ability to retrieve words from memory and the efficient use of their expanding "reservoir" of words.



*Vocabulary spurt and fast mapping.* Woodward, Markman, and Fitzsimmons (1994) suggested that receptive fast mapping, as measured by recognition in a multiple-choice procedure, is available at the start of lexical acquisition. They documented fast mapping in infants as young as 13 months of age, when first words are emerging in their productive lexicon. Infants might actually be able to fast map sooner, since their average receptive vocabulary is about 120 words by that same time (Fenson et al., 1994). Other studies, by contrast, strongly support the hypothesis that fast mapping is not available at the start of lexical acquisition, but that it develops simultaneously with the vocabulary spurt. Mervis and Bertrand (1994) used a longitudinal study to identify the onset of fast mapping in typically developing 16- to 20-month-old toddlers. After exposing the child to new object-referent and its label, the researchers assessed comprehension by using a word recognition task. They showed that half of the toddlers could fast map for word recognition at the beginning of the study. They monitored those toddlers who had not yet demonstrated fast mapping abilities. As soon as each child attained a vocabulary spurt, as indicated by the ongoing filling of the Communicative Development Inventories (CDI) Words and Sentences (Fenson et al., 1993) by parents, Mervis and Bertrand reapplied the same procedures as in the first phase: exposure to a new word followed by a word recognition task. They showed that fast mapping and vocabulary spurt emerge at the same time. Those findings, concluded the researchers, could

not be attributed simply to chronological age or to cognitive development, but that there is a very strong relationship between vocabulary spurt and the onset of fast mapping abilities.

*Vocabulary spurt and fast mapping as a universal phenomenon.*

Researchers have also studied the characteristics of fast mapping in clinical populations. Mervis and Bertrand (1995) examined word learning in 28 to 39 month old toddlers with Down syndrome. Results indicated the existence of a similar relationship between vocabulary spurt and fast mapping, but toddlers with Down syndrome presented delays in both vocabulary spurt and fast-mapping capabilities. Lederberg, Prezbindowski, and Spencer (2000) studied word learning in deaf and hard-of-hearing children, and suggested that the relationship between vocabulary spurt and the onset of fast-mapping might be universal. The researchers used a longitudinal study to examine the development of fast-mapping in 3- to 6-year-old deaf and hard-of-hearing children who were severely delayed in their language development. Each child was exposed to two fast mapping tasks, the first one involving incidental learning, and the second one involving explicit learning of a new word. The researchers then used a word recognition task to test for word learning. They monitored the children who failed the tasks and reassessed their word learning skills over an 18-month period. At the onset of the study, some children could learn quickly in both implicit and explicit contexts, other children could learn quickly only if an explicit reference had been previously

established, and some children could not yet perform fast mapping. Over the course of the 18 months, all children eventually developed fast-mapping abilities in both implicit and explicit contexts. Using the vocabulary section of the CDI-Words and Sentences (Fenson et al., 1993) as an index of vocabulary size, Lederberg et al. (2000) showed that the development of fast mapping is also strongly connected to vocabulary development in deaf and hard-of-hearing children.

### ***Fast mapping and word retrieval.***

*Word retrieval.* Word retrieval refers to the ability to retrieve words from the mental lexicon, either following an internal motivation (i.e. desire to say something) or following an external stimulus (i.e. answer a question, name a picture, identify an object). There is a strong relationship between children's ability to retrieve a word from memory and their degree of semantic learning of this word (Capone and McGregor, 2005).

*Word retrieval as an index of semantic learning.* Word retrieval can serve as an index of semantic learning. Word learning can be thought of as a series of steps or degrees of learning (Capone and McGregor, 2005), leading to better word retrieval. Those degrees of learning depend on the quality of the semantic representation of a word. That is, a weak semantic representation is sufficient for recognizing a word, whereas a rich semantic representation is necessary to name the word. The initial representation of a

word acquired through fast mapping is a weak representation. Functional and physical properties of objects are the salient features that serve as basis for toddlers to remember those objects (McGregor, Friedman, Reilly, & Newman; 2002). The strength of the semantic representation of the object in the toddler's lexicon is directly dependent on how much he remembers about the object. The more knowledge a toddler has about an object, the easier it will be for him or her to retrieve the word from memory and recognize and name the object.

Weak word representations are fragile, and toddlers tend to make naming errors when retrieving newly acquired words. The origin of those errors is not always known; errors might stem from overgeneralization (Clark, 1973) or from other sources. Many naming errors might be retrieval errors due to either interferences with a previously activated word or from similarities with other words (Gershkoff-Stowe, 2002). Gershkoff-Stowe and Smith (1997) looked at the evolution of toddler's naming errors between 15 and 22 months of age. The researchers demonstrated an increase in naming errors of new words during the period of rapid vocabulary spurt, and concluded that this high rate of naming errors indicated that the new words are weakly represented initially.

Dollaghan (1985) exposed children to a new word and its referent a single time. She first probed comprehension and then production of this word.

A total of 81% of the normally developing 2- to 5-year olds identified an object after exposure to the word referent only once, yet less than half of them produced a word label. In a follow-up task, 62% of the subjects who did not attempt to produce the label successfully identified it. These studies all support the existence of a continuum between weak and rich representation. Furthermore, they demonstrate that word retrieval, or the ability to recall from memory the correct word and to name it, can be used as an index of word learning.

*Universality of the relationship between semantic learning and word retrieval.* Children with language disorders further demonstrate the universality of the relationship between semantic learning and word retrieval. Children with specific language impairment (SLI) are known, among other characteristics, to have a smaller lexicon than their peers. Those children also experience well-documented word-retrieval difficulties. McGregor, Newman, Reilly, and Capone (2002) further demonstrated the link between word retrieval as measured by naming errors and semantic representation of an object. They compared three different sources of expression: naming of the object, drawings of the object, and verbal definition of the object, and found that the frequent naming errors of SLI children often stemmed from limited semantic knowledge about an object. McGregor et al. concluded that the limited semantic representation of the objects contributed to the high rate of naming errors of children with SLI.

Few studies so far have looked at fast mapping of semantic information. Alt, Plante, and Creusere (2004) looked at both typically developing and children with SLI and confirmed the previous findings. They first exposed children to novel objects and actions (training phase), and then probed their semantic knowledge about those objects or actions (experimental phase). The researchers showed that children with SLI could identify fewer semantic features than their normally developing peers, and concluded that both lexical learning and semantic learning contribute to difficulties with receptive vocabulary. The relationships between object naming, object recognition, and knowledge of the semantic features of an object supports the existence of a strong relationship between the continuum of semantic learning and word retrieval.

### **Summary**

In summary, word-learning research shows that children acquire new words through two phases: fast mapping and slow mapping. Fast mapping, or the first association a child makes between a new word and its referent, involves some semantic learning. The child is then able to recognize the novel word, but this weak semantic representation is not sufficient to produce the word. Word production requires that a richer semantic representation be available to the child. The enrichment phase of word learning, or slow mapping, provides a gradually richer semantic representation of the word. As

the number of exposures increases and depending on the quality of those exposures, the child stores more information about the object. Word learning is therefore related to memory, and, in the early stages of word learning, to working memory more specifically.

### **Working Memory**

A general theory of human memory, described by Shiffrin and Atkinson (1969), hypothesize the existence of three components: a durable long-term memory, a limited capacity working memory and a sensory memory that allows visual or verbal information to be retained for 1 to 4 seconds after the stimulus has ceased. According to this model, sensory memory allows the gathering of information and working memory is responsible for rehearsing this information until it is transferred to long-term memory for durable storage. The Working Memory model first proposed by Baddeley and Hitch (1974), and updated by Baddeley (2000), stands a commonly employed model used to understand word learning (Gathercole & Baddeley, 1990; Gathercole, Hitch, Service, & Martin, 1997; Michas & Henry, 1994), and vocabulary development (Gathercole & Adams, 1993, 1994; Gathercole, Hitch, Service, Adams & Martin, 1999; Gathercole, Willis & Baddeley, 1991; Gathercole, Willis, Emslie, Baddeley, 1992). Working memory is a short-term memory system. It provides temporary storage to the information being processed. Baddeley and Hitch (1974) originally described three components of the

model: the central executive, the phonological loop and the visuospatial sketchpad. The function of the central executive is to guide attention, to allocate neural resources and to retrieve information from long-term memory in order to aid in the interpretation of new incoming information. There are limited amounts of neural resources available to process incoming information. Neural resources and attention are split between two workspaces: the phonological loop that processes verbal information, and the visuospatial sketchpad that processes visuo-spatial information. Baddeley (2000) expanded the model to include the episodic buffer. The episodic buffer is the workspace used to integrate information from the visuospatial sketchpad and from the phonological loop, together with information from long-term memory. For example, the episodic buffer allows the visualization of a cup to be verbally encoded (/k<sup>^</sup>p/).

***Relationship between working memory and long-term memory.***

There is a complex bidirectional relationship between working memory, which serves as the cognitive workspace for acquiring new words, and long-term memory, in which word knowledge is stored. Many studies have shown that working memory, and more specifically the phonological loop, plays a central role in word learning (Baddeley, Gathercole, & Papagno, 1998). However, “it is oversimplistic to claim that the phonological loop mediates long-term phonological learning in a unidirectional manner” (Baddeley et al., 1998, p. 161). Baddeley et al. propose that the primary function of the phonological



loop is to process new phonological form for permanent storage of the new words, while its secondary function is to use existing word knowledge to support the processing of these new phonological forms. In this view, long-term memory would therefore exert a direct influence on the capacity of working-memory to process new words.

### **Phonological loop: storing speech-based information.**

**Definition.** The phonological loop is a memory mechanism responsible for the processing and storage of verbal material, and as such, is an essential language-learning device (Baddeley et al., 1998). It is the most studied and best understood component of working memory (Baddeley, 2003). The phonological loop is comprised of two subsystems: the phonological store and the subvocal articulatory rehearsal process (Baddeley, 2000). The phonological store keeps new speech-based information in temporary storage. The articulatory rehearsal system refreshes this speech material in order to maintain its memory trace in storage for brief periods of time while other cognitive tasks such as auditory comprehension are taking place (Baddeley, Thomson, and Buchanan, 1975; Gathercole & Baddeley, 1993). Rehearsing capabilities seem to emerge between 4 and 5 years of age (Gathercole & Adams, 1994).

### ***Assessment of the phonological loop capacity.***

*Measurement tools.* The measure of the phonological loop's ability to store information is called the capacity of the phonological loop. The capacity of the phonological loop is typically measured by computing the number of digits (digit span repetition), the number of words (word span repetition) or the number of nonsense words (nonword repetition) the subject is able to remember after a single presentation. Even though all three methods have been widely used, often in conjunction with each other, some carry limitations inherent to the nature of the task. Actual words and digits are already stored in the subject's long-term memory. Therefore, a task involving repetition of actual words or digits might not reflect only the capacity of the phonological loop to process new information, but the ability to retrieve existing information from long-term memory as well. By opposition, a task involving repetition of nonsense sequences of syllables or nonwords is not subject to this confounding factor.

### ***Factors influencing the measurement of phonological loop capacity.***

The performance of the phonological loop varies with both internal factors and external factors. The most striking internal factor affecting its performance is the child's development. Children's ability to imitate sequences of nonwords significantly increases between the ages of 24 and 48 months (Weill, 2008). External factors include the length of the items presented (word-length effect),

the serial position of the items presented (primacy and recency effect) and the linguistic structure of the items presented (phonotactic probability).

The existence of a word-length effect has been hypothesized by Baddeley, Thomson, and Buchanan (1975), as part of their theory to support the existence of a limited capacity phonological loop. They showed that shorter words are significantly better recalled than longer words and that the number of words recalled was inversely proportional to word length. However, if the existence of word-length effect has been agreed upon, its interpretation as an indication of the phonological loop functioning has subject of debate. Consistent with Baddeley's theory, Jacquemot, Dupoux, & Bachoud-Lévi (2011) have shown that the subvocal articulatory rehearsal process accounts for word-length effect, and that the effect disappears if the subject is prevented from rehearsing the stimulus. The existence of a word-length effect has been attributed to other cognitive processes, such as the integration of auditory information during intervals between presentations or different properties of long and short words (Jalbert, Neath, Bireta, & Surprenant, 2011; Yuzawa, 2001).

The existence of a serial position effect has been hypothesized by Hebbinghaus, a German experimental psychologist, at the end of the 19<sup>th</sup> century (Plucker, 2003). When given a series of items to remember, subjects tend to better remember the first items of a series (primacy effect) as well as

the last items of a series (recency effect). The recency effect has been directly attributed to working memory capacity. In other words, subjects with better phonological loop capacity tend to remember more last items a series of stimuli (Sasaki, 2009).

For the purpose of this study, only nonword repetition stimuli will be used. This restriction will ensure that the task reflects the actual capacity of the working memory, and eliminates the confounding influence of long-term memory. Both the child's developmental level and the linguistic structure of the stimuli will be controlled.

*Nonword repetition tests.* Gathercole and Baddeley (Gathercole, Willis, Baddeley, & Emslie, 1994) developed the child's nonword repetition (CNRep) paradigm most widely used in research with children above the age of 4. It consists of 40 nonwords, 10 each containing 2, 3, 4 and 5 syllables, presented in a randomized sequence to the participant. It is a processing-based measure that isolates the phonological loop from long-term memory, because it does not rely on stored linguistic knowledge. Therefore, its results are not confounded by the child's linguistic knowledge (Gathercole & Baddeley, 1989). In order to perform this task, the child must accurately perceive and discriminate the auditory input, create a new motor program, and go through the phases of motor planning and execution (Adams & Gathercole, 2000). As the stimulus is not a word, there is no available lexical

or semantic representation to support the child's memory for imitation (Gathercole & Adams, 1994). The CNRep has been normed on a population of 600 children four to nine years of age; its relationship with vocabulary acquisition and vocabulary knowledge has been examined for those age groups (Gathercole, Willis, Baddeley, & Emslie, 1994). Dollaghan & Campbell (1998) developed a similar test, the nonword repetition test. It has been successfully used to predict whether children six to twelve years of age had been diagnosed with language impairment. The nonword repetition test has also been used successfully with children four years of age.

Tests used with children below the age of four. Some nonword repetition tests have been designed for children younger than four years of age, in an attempt to examine their phonological loop capacity. Gathercole and Adams (1993) designed a set of 15 nonwords made of 1, 2 or 3 syllables and used it in conjunction with a digit span repetition test and a word repetition test. The nonwords were controlled for phonological complexity and for sounds considered perceptually demanding. More recently, Roy and Chiat (2004) designed an 18 nonword-repetition task adapted for young children and used it together with a word repetition task. Each word and each nonword was composed of 1, 2 or 3 syllables, controlled for stress patterns, and words were phonologically matched to nonwords. In both studies, young children were able to perform the test and the authors considered that phonological loop capacities could be reliably assessed using repetition tasks.

Characteristics of nonword repetition tests. Nonword repetition tests have the advantage of being fast and simple and can be used in conjunction with standardized language assessment (Weismer et al., 2000). They represent a valid and reliable measure of the phonological loop capacity (Gathercole & Baddeley, 1990). They are independent from IQ (Weismer et al., 2000) and from cultural and gender influence (Dollaghan & Campbell, 1998). They have been considered a promising diagnostic tool in differentiating between children with and without language impairments (Botting & Conti-Ramsden, 2003; Dollaghan & Campbell, 1998; Gray, 2003; Weismer et al., 2000). Scoring is typically performed by counting the number of correct repetitions, but some provisions are made to either rule out errors due to immature articulation and phonological processes, or to ensure they do not affect the results.

Phonotactic probabilities. Phonotactic probability has been defined as "the frequency with which phonological segments and sequences of phonological segments occur in words in a given language" (p. 481, Vitevitch & Luce, 2004). Gathercole et al. (1991) showed that children repeated nonwords more accurately when those nonwords were linguistically close to real words (high wordlikeness) than when they were linguistically very different (low wordlikeness). They interpreted this close relationship between lexical knowledge and phonological loop by stating that the use of "long-term lexical knowledge... [relieves] the sole dependency on phonological working

memory for maintenance of the unfamiliar phonological sequence.” In other words, existing word knowledge, stored in the child’s long-term memory as a sequence of sounds, facilitates the repetition of nonwords and supports the capacity of the phonological loop.

Phonotactic probabilities also have a positive influence on word learning. Storkel (2001) exposed three to six year old children to two series of nonwords, one series containing common sound sequences and the other containing rare sound sequences. They measured word learning along a continuum of time. Correct responses were examined to determine the influence of phonotactic probability on the rate of word learning. Likewise, error responses were examined to determine the influence of phonotactic probability on the formation of semantic representation, lexical representation and the association between them. Storkel concluded that young children learn common sound sequences whose phonotactic probability is high faster than rare sound sequences. Furthermore, she concluded that phonotactic probability influences both the semantic representation of the referent and the association between semantic and lexical representation.

### ***Phonological loop as a word learning device.***

*Role of the phonological loop and of existing vocabulary in the acquisition of new words.* The phonological loop is an instrumental tool for children to learn words and build their vocabulary. The strong relationship

between phonological loop capacity, word learning skills and vocabulary knowledge has been established along a variety of measures of vocabulary size, vocabulary knowledge, expressive and receptive language skills and ability to acquire new words.

*Phonological loop and language skills.* There is a close relationship between phonological loop capacity and both receptive and expressive language skills. That is, children' ability to retain new phonological strings in working memory have a positive impact on their ability to understand people and to express themselves.

Studies have evidenced significant correlations between the phonological loop capacity and the size of receptive vocabulary as measured by the Short Form of the British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Pintillie, 1982), in children two to four years of age (Adams & Gathercole, 1995, 2000; Gathercole & Adams, 1993; Roy & Chiat, 2004). This relationship has also been evidenced with children's expressive language skills (Gathercole, Hitch, Service & Martin; 1997). Three years old children with a large phonological loop capacity tend to produce longer and more grammatically complex sentences and use a larger repertoire of words than younger children (Adam & Gathercole, 1995). Five year old children with a large phonological loop capacity are able to better recount a story, using longer sentences and recalling more information than other children (Adam &



Gathercole, 1996). Michas and Henry (1994) have shown that this correlation between phonological loop capacity and both receptive and expressive language skills also exists in children 5 to 6 years of age.

*Phonological loop and word learning.* The Baddeley model of working memory implies that the phonological loop is responsible for acquiring new phonological forms, therefore for learning new words. Even though a strong relationship has been established between various measure of vocabulary and phonological loop capacity; these relationships were correlational in nature and did not establish causality. That is, these studies did not examine the direct relationship between children's ability to learn new words and their phonological loop capacity.

In an early study, Gathercole and Baddeley (1990) considered two groups of 5 year old children: one group with high nonword repetition abilities, and a second group with low nonword repetition abilities. They exposed the children to new words, some labeled with phonologically familiar names, and others labeled with phonologically unfamiliar names. All children were able to learn the phonologically familiar names. However, children with high nonword repetition abilities were significantly better at remembering the phonologically unfamiliar names than children with low nonword repetition abilities. The researchers established a direct link between a child's phonological loop capacity and his or her ability to learn a new sequence of sounds. Michas and

Henry (1994) confirmed that the phonological loop capacity is a predictor of children's ability to learn new words, both receptively and expressively.

Gathercole, Hitch, Service and Martin (1997) demonstrated the relative contribution of phonological loop capacity and of existing vocabulary knowledge on children's ability to learn new words. In order to evaluate word learning, the researchers exposed children to pairs of word-word as well as to pairs of word-nonword. The three measures were the size of receptive vocabulary (Long Form of the British Picture Vocabulary Scale BPVS (Dunn et al., 1982)), the size of expressive vocabulary (Expressive One Word Picture Vocabulary Test Revised (Gardner, 1990)), and knowledge of word meaning (Oral Vocabulary component in the McCarthy Scales of Children's Abilities (McCarthy, 1972)). Findings indicated that learning pairs of familiar words was supported by existing vocabulary knowledge only. However, both phonological loop capacity and existing vocabulary knowledge support new word learning, when those words are made of unfamiliar sequences of sounds. Thus, learning new words, which are in essence new phonological forms, is supported primarily by the phonological loop.

*Phonological loop capacity as a marker for language impairment.* The relationship between word learning, phonological loop capacity and vocabulary knowledge has also been demonstrated in children with language impairment. Children with specific language impairment show depressed nonword repetition scores that correlate with depressed scores in traditional

language measures (Dollaghan & Campbell, 1998; Weismer et al., 2000), and with difficulties acquiring novel words (Oetting et al., 1995; Rice et al., 1990). In a review of series of studies, Montgomery (2003) highlighted strong relationships between working memory and receptive language abilities. More specifically, he found that diminished phonological loop capacity was responsible for poorer comprehension of long sentences (Montgomery, 1995). Other studies indicate that nonword repetition scores remain depressed even after the language difficulties seem to have resolved (Conti-Ramsden, Botting, & Faragher, 2001; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998).

These studies highlight the importance of examining the relationship between phonological loop functioning and the learning of new words in children as young as possible. If depressed phonological loop capacity is predictive of children' ability to learn new words and is predictive of language skills in school-age children, then early identification of children at risk for language impairment could be performed using nonword repetition tests, as a measure independent from gender, from IQ, from socio-economic status and from cultural influence.

*Development of the role of phonological loop on word learning.* The relative contribution of phonological loop capacity and of existing vocabulary seems to change as the child is growing up. Existing vocabulary knowledge

appears to play an increasing role in the acquisition of new words (Gathercole & Adams, 1994; Gathercole & Baddeley, 1989, 1990; Gathercole et al., 1992).

Gathercole et al. (1992) followed children longitudinally from four to eight years of age and showed that the relationship between phonological working memory and vocabulary development is not only more robust in younger children, but that there is a change in the direction of the influence. They used a cross-lagged design and inferred results from observing the differences in the strength of the correlations. They found a “shift in the causal underpinnings of the developmental association [between phonological memory and vocabulary knowledge] during the course of the longitudinal study” (p. 896). Before age five, receptive vocabulary development, as measured by the Short Form of the BPVS (Dunn et al., 1982) is directly dependent on phonological loop capacity measured the previous year. Between the ages of five and eight, vocabulary development is dependent more on existing vocabulary knowledge measured a year earlier than on phonological loop capacity measured a year earlier (Gathercole & al., 1992). This observation can be explained by the fact that children with larger repertoire of words stored in long-term memory are more likely to have stored sequences of sounds that are phonologically similar to the nonwords they are exposed to. Therefore, in order to learn new words, children rely increasingly on their existing repertoire of words as they grow and develop. By contrast,

younger children need to rely more on their phonological loop capacity to acquire new words, as their repertoire of stored words is still very limited. Even though the dynamics of word learning appears to change as children grow up, working memory and vocabulary knowledge both impose significant constraints on the acquisition of new words throughout the teenage years (Gathercole et al., 1999).

### **Summary.**

Working memory, and more specifically, the phonological loop, functions as an essential device for children to learn new words efficiently. It is therefore an essential tool for language development. Most studies that measure phonological loop capacity examine its relationship with vocabulary size. Few studies have examined the relationship between phonological loop and fast-mapping. Multiple studies have shown that the mechanisms involved in the acquisition of new words depend on the age of the child: the relationship between phonological memory, existing word knowledge, and word learning is dynamic and evolves as the child matures (Gathercole & Adams, 1993, 1994; Gathercole, Hitch, Service, & Martin, 1997; Gathercole, Willis, Emslie, & Baddeley, 1992). The relative impact of phonological loop and of vocabulary knowledge on vocabulary development changes between preschool and school age. The role of phonological loop capacity is stronger at five years of age than it is at eight years of age (Gathercole et al., 1992).

To this day, most studies have examined the role of the phonological loop in language development and in acquisition of new words for children beyond the age of four. Although acquisition of new words is the most essential aspect of language development in children during their second and third year of life, the role of phonological working memory in word learning in toddlers has been a little-explored area. Some preliminary studies have shown that nonword repetition tests could provide a realistic, valid, and reliable assessment of phonological loop capacity in two to four year old (Gathercole & Adams, 1993; Roy & Chiat, 2004). It is important to note however that within this age group, younger children have not only poorer scores at nonword repetition tasks, but also a much higher variability (Gathercole et al., 1994; Roy & Chiat, 2004).

### **Designing a Methodology**

To date, many studies of word learning have examined the acquisition of new words in pre-school and school age children (Nash & Donaldson, 2005; Gathercole, Hitch, Service & Martin, 1997; Gray, 2004; Michas & Henry, 1994). Yet, research has shown that mechanisms of fast mapping, central to young children's lexical development, develop at about the time as toddler's vocabulary spur (Gershkoff-Stowe, 2002; Mervis & Bertrand, 1994). As the onset of fast mapping is related to a developmental stage rather to a specific chronological age, this developmental milestone was therefore used

to define the population recruited for this study. Accordingly, the age range for this study was based on the data provided by Fenson et al. (1993), who estimated that, in average, 24-month-old children produce about 320 words and 30-month-old produce approximately 570 words. The children in this were ranging in age from 24 to 30 months of age. This age range reflects the need to target a young population, for which our knowledge regarding the functioning of its working memory is still very limited, as well as on the practical need to limit attrition.

### **Pilot study**

A copy of the abstract of the pilot study can be found in Appendix A. Twelve typically developing toddlers were enrolled in a pilot study that examined the ability of children 24 to 48 months to imitate sequences of nonwords. This preliminary study addressed three goals: first, an evaluation of the feasibility of the study with very young children, second, an assessment of an instrument designed to measure phonological loop capacity, and third, a determination of the sample size needed for the word-learning study.

In response to the first goal, results of the pilot study indicated that toddlers 24 to 30 months can be tested for the purpose of measuring their phonological loop capacity. Out of the 12 toddlers 24 to 48 month enrolled in the study, one did not complete the tasks. In the youngest group of toddlers (24 to 29 months), all three subjects completed the tasks. Older children

performed better in nonword repetition scores, and the variability of their performance decreased. This observation pertained to each of the three levels of syllable length, as well as to the total nonword repetition score. The average total scores were 15.33 nonwords (SD=11.59) for 24 to 29 months old, 23.17 nonwords (SD=7.81) for 30 to 39 months old, and 26.5 nonwords (SD=3.54) for 40 to 49 months old children. A Kruskal-Wallis test for comparison of medians indicated no significant difference in score distribution between the three age groups. The procedure used in the pilot study to measure phonological loop capacity could therefore be used in the word-learning study.

In order to address the second goal, an instrument was designed that takes into account specific challenges posed by testing the working memory of very young children. Behaviorally, toddlers often have shorter attention span, lower level of compliance and difficulties understanding directions, than older children, increasing the risk of attrition. Developmentally, their articulation and phonological systems are still maturing, and production errors during testing may be misinterpreted as memory limitation. Finally, as children's vocabulary rapidly expands during their toddler years, they might use stored linguistic knowledge to support the capacity of their phonological loop to retain new verbal material.

The instrument developed to test phonological loop capacity consisted of a list of 36 nonwords: 12 of 2 syllables, 12 of 3 syllables, and 12 of 4



syllables. In order to ensure validity of this measure in American English, those nonwords were run through the Phonotactic Probability Calculator, a web-based interface designed by Vitevitch and Luce (2004) to compute the phonotactic probability of words in U.S. English. The phonotactic probability is defined as the frequency with which a phoneme and a sequence of phonemes occur in a given position in a word (Jusczyk, Luce & Charles-Luce, 1994). Only the nonwords containing very low probability sequences of phonemes were retained as stimuli. These nonwords were the least likely to resemble an existing word in English and therefore the least likely to belong to the child's stored linguistic knowledge. The nonword repetition task consisted of asking the subject to imitate each nonword, one by one. Nonword sequences were scored by whole item accuracy.

Phonological development greatly varies between children (McLeod and Bleile, 2003). Furthermore, in the age group constituting the population of this research, the phonological system is still developing and children make many errors considered developmental. Those developmental errors therefore reflect production errors and not limitations in the capacity of the phonological loop. Consistent with existing research (Gathercole & Adams, 1993; Roy & Chiat, 1994), scoring of the nonword repetition task accounted for developmental errors, and children were given credit for typical articulation errors and developmental phonological processes identified in their speech.

Based on the pilot study, this instrument demonstrated good internal consistency reliability. A Cronbach's alpha analysis was run at each syllable length, as well as on the combination of the three syllable lengths in a single construct. Results indicated internal consistency reliability above 80% in each case. This result, even on a very small sample, signifies that this nonword repetition task would be effective for use with a similar population in a larger study. However, younger children showed a much higher variability than older children. This observation was consistent with the conclusion of Roy and Chiat (1994) regarding higher variability for younger children. The modified nonword repetition instrument addressed this problem in two ways. First, a reduction in the number of nonword stimuli reduced the length of the task. Second, sound combinations presenting a higher production difficulty, later-developing phonemes and nonwords starting with a vowel were eliminated from the stimuli. These measures were designed to better control for developmental status and therefore decrease the variability of the data.

Finally, based on the results of the pilot study, the power analysis recommended a conservative sample size of at least 75 subjects to detect a medium effect (Power= .8,  $\alpha$ = .1). However, the pilot study and the current study are very different in their nature and in the ages of the subjects sampled. The variability of the word-learning study was decreased by modifying the instrument and by increasing the homogeneity of sample with more stringent inclusion criteria. It was expected that better control of

inclusion criteria and of testing would affect the sample size needed to detect a medium effect.

## Chapter III

### **Methods**

This exploratory study used a correlational and predictive design to study the role of working memory on new word learning in toddlers 24 to 30 months of age. The Seton Hall University Institutional Review Board (IRB) and the Touro College's School of Health Science IRB approved the research. Copies of all letters of approval appear in Appendix B.

#### **Subjects**

Subjects for this study included 44 typically developing, monolingual English speaking toddlers ranging in age from 24 to 30 months. Toddlers were recruited from local communities through recruitment fliers (Appendix C) posted in daycare centers and businesses and through recruitment e-mails (Appendix D) posted on local list serves. All toddlers enrolled in the study were from New York City or from Bergen County, NJ.

#### **Enrollment schedule and screening**

The parents who responded and expressed interest in the study were contacted by phone or by e-mail and informed of the inclusion requirements, and of the procedures of data collection. If a toddler met the inclusion

requirements, parents were mailed an Informed Consent Form (Appendix E) and two questionnaires designed to serve as a preliminary screening prior to the first meeting. When the three documents were completed, signed and returned prior to starting the study, the principal investigator scheduled a direct screening session, performed during the first meeting. These screening procedures ensured that both inclusion and exclusion criteria were met prior to data collection.

*Preliminary screening.* The toddler's parent(s) completed and returned a demographic questionnaire (Appendix F) and a parent-report measure of early vocabulary, the MCDI-T (Fenson et al., 1993). The demographic questionnaire provided information about the subject and his or her family, including ethnicity, gender, birth order, parents' activity and level of education, languages spoken at home, developmental history, and day-care enrollment. The Vocabulary Checklist of the MCDI-T provided the size of the child's expressive vocabulary as reported by the parent(s). Based on the answers to the questionnaire and to the MCDI-T, all monolingual English toddlers reported to be typically developing, scoring above the 10<sup>th</sup> percentile on the MCDI, and whose size of productive vocabulary exceeded 90 words, enrolled in the study. Consistent with similar studies, toddlers whose parents reported no specific concern regarding hearing were also included in the study (Adam & Gathercole, 1995; Archibald & Gathercole, 2006; Roy & Chiat, 2004; Torkildsen, 2008). Following the preliminary screening, 13 toddlers did not

meet the inclusion criteria: 8 children were bilingual, 2 had a history of recurrent otitis media, and 3 were enrolled in speech-language therapy. Of the 44 parents who expressed interest, 31 parents (70%) enrolled their toddler in the study.

*Direct screening.* The direct screening was performed during the course of the first session. A spontaneous language sample and some elicited imitations were transcribed at the time of the interaction. This screening procedure provides ecologically valid results, as its sampling method and setting are representative of real-life situations for toddlers. Interactions were recorded by audiotape for 15 sessions. However, audiotape recordings were not used in data analysis and only the live transcription recorded at the time of the interaction served as the subjects record, as it is customary in most clinical contexts. There were two reasons for this decision, one linked to a production factor, and one linked to a perceptual factor. At a production level, toddler's speech was generally found to be only partially intelligible on the recording. Although words could be understood in known context, individual sounds and patterns were most often imprecise and required visual cues provided by looking at the child's mouth to be identified, which could be done only at the time the interaction took place. Therefore, the lack of precision of the recording and the absence of visual information made the use of recording invalid for our purpose. At the perceptual level, ongoing background noise linked both to the home setting and to the play activity did

not allow for the recording to be used to analyze speech sound production. In support of this decision, no studies to this date have compared the validity of audio tape analysis versus live transcription in assessing toddler's speech sound production.

The three inclusion criteria assessed in the direct screening included: 1) age-appropriate phonetic inventory of consonants (Robb & Bleile, 1994), 2) age appropriate phonological development (McLeod & Bleile, 2003), and 3) normal oral and speech motor structure and function evaluated by a oral-motor examination (Robbins & Klee, 1987). Toddlers whose phonological processes included weak syllable deletion and initial or final consonant deletion were tested for stimulability. Due to the nature of the task used in this study to measure working memory capacity, toddlers who were non-stimulable for those processes were excluded from the study. Toddlers who appeared to have comprehension difficulties during the direct screening were excluded from the study as well. Following the direct screening, 9 toddlers were excluded from the study, and their parent(s) were informed of the screening results. Of the 44 toddlers whose parent(s) expressed interest, 22 (50%) toddlers participated in the actual study.

### **Measure of vocabulary size**

Vocabulary size was assessed through the MCDI; Fenson et al., 1993), a parental questionnaire considered a valid and reliable instrument for measuring children's language development (Dale et al., 1989). The MCDI examines many aspects of early language development: use of gestures, play, acquisition of vocabulary, and development of syntax and of sentences. It provides separate receptive and expressive language scores. However, in the context of this research, only the Expressive Vocabulary Checklist of the Toddler's version of the MCDI (MCDI-T) was used for measuring vocabulary size. Researchers have examined the validity of the MCDI-T, in regard to the correspondence between reported language abilities through parental questionnaire and direct measurement of language functioning. Dale (1991) and Heilmann et al. (2005) found moderate to strong correlations between the MCDI-T and direct language measures. The MCDI-T is therefore considered to give an accurate account of size of vocabulary, as reported by the parents.

### **Measure of phonological loop capacity**

**Instrument.** The instrument was designed based on the findings from the pilot study (Weill et al., 2008). A list of 30 nonwords controlled for syllable length was developed to serve as stimuli: 10 2-syllable items, 10 3-syllable items, and 10 4-syllable items (Appendix G). The nonwords were also controlled for phonotactic probabilities: each nonword was run through the



phonotactic probability calculator (Vitevitch and Luce, 2004) to compute its phonotactic probability in American English. Stimuli included only nonwords containing phonological sequences with very low probability to exist in American English. All nonwords followed legal phonotactic rules in English. In order to control for phonological development, the nonwords did not include any late-developing consonants and consonant clusters. The presentation was randomized within each syllable length.

**Procedure.** The toddlers were tested individually, in their home. In order to control for fatigue, testing was performed over the course of two sessions: toddlers were exposed to the first 20 stimuli during the first session, following the direct screening. They were exposed to the last 10 stimuli at the beginning of the second session, just prior to the word learning task. A warm-up play period preceded each session, for the child to become familiar with the setting. Practice trials were performed before starting the actual test. The 10 2-syllable nonwords were preceded by two trials of nonwords of the same length; the procedure was identical for the 3- and 4-syllable length nonwords. If a toddler failed to respond to an item, he/she was given one more opportunity at the end of the test. The principal investigator transcribed the responses by hand immediately, and performed the scoring subsequently, after the end of the session.

**Scoring.** Consistent with existing research, nonword sequences were scored by whole item accuracy, and children were given credit for typical articulation errors and developmental phonological process identified in their speech (Dollaghan & Campbell, 1998; Roy & Chiat, 2004). The total number of nonwords produced accurately was computed.

### **Measure of fast-mapping**

**Stimuli.** The stimuli included two groups of objects, one comprised of six objects unknown to the children (new objects) and the other comprised of ten familiar objects known to the children (Appendix H). Three stimulus sets were created prior to each session. Each set comprised of 2 objects known to the child and 1 new object, unknown to the child. This assumption was verified with the parent prior to the onset of the task. A new label was created for each of the new objects. Each label used early-developing phonemes, identical articulatory complexity, and carried the phonological characteristics of American English (Gathercole et al., 1994). All the new labels were used previously in similar studies with this age group.

**Fast-mapping task.** This task of fast-mapping was meant to create a weak semantic representation of the new object (Capone & McGregor, 2005). The principal investigator presented a total of 3 stimulus sets to the child, each presented in succession. For each presentation, the child was allowed to play for 3 minutes with the 3 objects in the stimulus set. Each name was

introduced as the child manipulated the corresponding object. Each object was named a total of 4 times during the play interaction. Each new name was embedded in short sentences highlighting the new object, such as “Oh, look, a \_\_\_\_\_”, “give me the \_\_\_\_\_” or “the bunny wants to jump on the \_\_\_\_\_”. The sets selected and the orders of presentation were counterbalanced between subjects.

### **Measures.**

***Measuring the degrees of learning.*** The fast-mapping task consisted of exposing the child to the new word, and the following comprehension and naming probes assessed the degree of learning the new word. Both exposure and learning probe were all performed during the same session, so that the probe would be more sensitive to the child’s ability (Heibeck & Markman, 1987). The child was engaged in an unrelated activity for a few minutes, between the exposure to the words and the measure of learning. Two probes were used in this study, a comprehension probe followed by a naming probe (Heibeck and Markman, 1987; Michas and Henry, 1994; Dollaghan, 1985; Nash and Donaldson, 2005). In the comprehension probe, the child needed to recognize an object previously taught. Acquisition of incomplete phonological information and weak semantic representation of the object were sufficient to succeed in this task. The naming probe consisted of the production of a name

for an object previously taught. The child needed a more complete phonological knowledge to successfully retrieve the new word.

**Comprehension probe.** Each child was tested for word recognition after the fast-mapping task. The word recognition probe took place before the naming probe. Following the protocol used by Mervis and Bertrand (1994), each comprehension set was composed of four objects: 2 familiar objects, 1 new object (target) and 1 distractor (new object). The principal investigator praised the child following each response.

**Naming probe.** Each child was tested for naming following the word comprehension probe. The 3 objects comprising the original stimulus set were presented one by one. The 2 known objects were presented prior to the new object to serve as practice. The child was asked: "Do you remember what this is?" The child was praised following each response. If the child did not respond, he or she was encouraged to repeat the name of a known object: "This is a \_\_\_\_\_. Now it is your turn to say it." The child was then encouraged to name the new object. The procedure was repeated for each of the stimulus sets.

**Scoring.** The principal investigator transcribed the names produced live, at the time of testing. She scored the responses as right or wrong, both for the comprehension probe and the naming probe.

## **Statistical analysis**

Data analysis included both descriptive and inferential statistics. Descriptive statistics quantify the sample, and provide information about the distribution, the central tendency and the dispersion of each variable (Portney & Watkins, 2009). In this study, the mean and standard deviation were computed for data at the ratio level and rank for data at the ordinal level. As there were only few values for the variables, the distribution was presented using individual values.

Inferential statistics consisted of a correlation analysis and two multiple regressions analyses. A simple correlation study measured the strength of the relationship between phonological loop capacity of the working memory and productive vocabulary stored in long-term memory. The independent variable was the aggregate nonword repetition score. The dependent variable was the number of productive words, as reported on the MCDI. A Pearson product-moment coefficient of correlation (Pearson's  $r$ ) measured the strength of the relationship between those two variables (Portney & Watkins, 2009).

Multiple regression analyses computed the relative impact of working memory and long-term memory on the acquisition of new words, measured as the ability to first recognize, and then to retrieve and produce new words. More specifically, those statistics established the predictive relationship between the dependent variable, in this case word learning, and a set of

independent variable, in this case phonological loop capacity and size of productive vocabulary. The coefficient R square measured the association between the dependant variable and the set of independent variables. Here, R square represented the total variance of the word learning measure that can be explained by either the phonological loop capacity or the size of the productive vocabulary. The standardized regression coefficient  $\beta$  (Portney & Watkins, 2009) measured the relative weights of the phonological loop capacity and of the size of the productive vocabulary. In the first multiple regression study, the two independent variables were the number of productive words reported on MCDI and the aggregate nonword repetition scores, and the dependent variable was the number of words produced on the fast-mapping task. In the second multiple regression study, the two independent variables were the number of productive words reported on MCDI and the aggregate nonword repetition scores, and the dependant variable was the number of words comprehended on the fast-mapping task. All data were analyzed using the statistical package of Microsoft Excel 2007.

## Chapter IV

### Results

A total of 44 parents expressed interest for their children to enroll in the study. After the preliminary screening process, 13 toddlers were excused, either because they did not meet the inclusion criteria, or for practical reasons such as difficulties scheduling. 31 toddlers (70%) underwent the direct screening procedure, with 9 toddlers excused after failing the direct screening. Of the remaining 22 toddlers (50%) enrolled, 2 were non-compliant and 1 failed to understand directions to complete the study. A total of 19 toddlers (43%) completed the study and data analysis was performed on their complete data sets.

All children were Caucasian, living in New York City or Bergen County, NJ. The distribution of the population sampled is displayed in Table 1. The table does not include birth history, medical history and milestone, as all children enrolled in the study displayed typical results. Results of the demographics show that the ages of the toddlers ranged in age from 24 to 30 months ( $M = 26.3$ ,  $SD = 1.8$ ). The number of boys and of girls was equally distributed, so was the day-care enrollment status. Toddlers' birth orders were tanked from first-born to eighth-born, with more than half of the toddlers being

ranked third or more. There was one set of fraternal twins included in the group of second-born, and data for each twin was independently included in the total data set. Ninety percent of mothers held at least a Bachelor's degree.



Table 1. Distribution of the population sampled

		Number of children	% of total responses
<b>Age</b>	24 months	3	15.8
	25 months	4	21
	26 months	6	31.6
	27 months	2	10.5
	28 months	1	5.3
	29 months	1	5.3
	30 months	2	10.5
<b>Gender</b>	Males	10	52.6
	Females	9	47.4
<b>Enrollment in day-care</b>	Not enrolled	10	52.6
	Enrolled	9	47.4
<b>Birth order</b>	1 <sup>st</sup> born	7	36.9
	2 <sup>nd</sup> born, incl. 1 set of twins	4	21
	3 <sup>rd</sup> born	1	5.3
	4 <sup>th</sup> -born	4	21
	5 <sup>th</sup> -born	1	5.3
	6 <sup>th</sup> -born	1	5.3
	8 <sup>th</sup> -born	1	5.3
<b>Maternal level of education</b>	High school	1	5.3
	Associate degree	1	5.3
	Bachelor degree	9	47.4
	Masters degree	7	36.8
	Doctoral degree	1	5.3

The descriptive statistics of the sample are displayed in Table 2.

Table 2. Descriptive statistics of the sample

	Age (months)	Birth order (rank)	Maternal level of education (rank)*
Mean	26.3	-	-
Standard deviation	1.8	-	-
Median	26	2	2
Mode	26	1	2
Range	6	7	5

\*Ranked from 0 (high school) to 5 (doctorate)

Each toddler's scores for all four variables are presented in Table 3. Each variable was tested for skewness and kurtosis. Skewness describes the measure of asymmetry of the distribution around its mean. Kurtosis describes the level of "peakedness" of the distribution. All measures were within the range of -2 to +2. This indicates that the data are normally distributed. The size of productive vocabulary ranged from 144 to 619 words ( $M = 348$ ,  $SD = 146$ ). The total non-word repetition scores ranged from 3 to 24 nonwords ( $M = 14.9$ ,  $SD = 6.5$ ). The receptive fast-mapping scores ranged from 0 to 3 words ( $M = 2.1$ ,  $SD = 1.1$ ), and the expressive fast-mapping scores ranges from 0 to 2 ( $M = .7$ ,  $SD = .8$ ).

A Pearson correlation was used to measure the degree of linear relationship between phonological loop capacity and size of productive vocabulary. Results showed a statistically significant moderate to strong correlation ( $r = .71$ ,  $p < 0.01$ ) between the phonological loop capacity and the size of productive vocabulary. Visual inspection suggested that no outlier was present in this sample. The scatterplot of the relationship between the phonological loop capacity and the size of productive vocabulary is represented in Figure 1.

Table 3.  
Phonological loop capacity, size of productive vocabulary and fast mapping

<b>Age (months)</b>	<b>Gender</b>	<b>Total NW repetition (nonwords)</b>	<b>Size of productive vocabulary (words)</b>	<b>Receptive FW (words)</b>	<b>Expressive FM (words)</b>
24	Girl	12	357	2	2
24	Boy	19	336	3	0
24	Boy	22	384	3	1
25	Boy	6	166	0	0
25	Boy	13	195	2	1
25	Girl	13	211	3	0
25	Boy	15	362	2	1
26	Boy	4	206	2	0
26	Girl	8	144	0	0
26	Girl	17	433	3	0
26	Girl	18	251	3	2
26	Girl	23	619	3	1
26	Boy	26	453	2	2
27	Girl	18	608	3	2
27	Girl	24	547	3	0
28	Boy	3	253	0	0
29	Girl	15	312	1	0
30	Boy	14	276	3	0
30	Boy	14	499	2	1

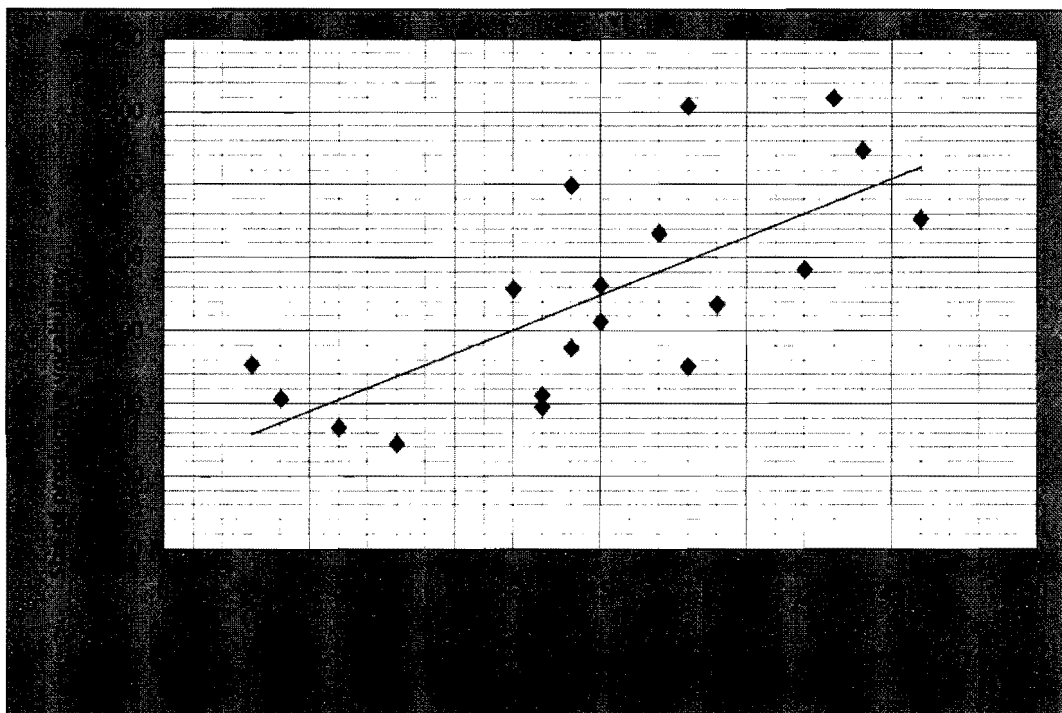


Figure 1.  
Correlation phonological loop capacity and the size of productive vocabulary

***Predictors of expressive fast-mapping.*** A multiple linear regression predicted the unique contribution of the phonological loop capacity and of the size of productive vocabulary on expressive fast-mapping. The regression equation accommodates both independent variables:

$$Y = -.24 + .001X_1 + .03X_2$$

The phonological loop capacity and the size of productive vocabulary explain 20% of the results in expressive fast-mapping ( $R^2 = 0.2$ ). The regression coefficient for each independent variable measures how much

each one is expected to increase when the dependant variable (fast-mapping) increases by one, holding the other independent variable constant. The regression coefficient  $\beta$  for each variable when controlling for the other one is positive, but small and non-statistically significant ( $\beta_1=.001$   $p=.52$ ,  $\beta_2=.03$   $p=.4$ ). However, data show that the main predictor of expressive fast-mapping is the phonological loop capacity ( $\beta_2 = .03$ ). Data also indicate that for both variables, the standard error (SE) is large compared to the coefficient. As the SE provides an estimate of the uncertainty of the representation of the population mean by the sample mean, a large SE suggests that those results might be due to random chance rather than to an actual effect of the vocabulary size and phonological loop capacity. The table of results of this multiple regression is represented on Table 4.

Table 4.  
Phonological loop capacity and size of productive vocabulary as predictors of expressive fast-mapping

	$\beta$	SE
Productive vocabulary	.001	.002
PL Capacity	.03	.04

$R^2=.20$

**Predictors of receptive fast-mapping.** A multiple linear regression was used to predict the unique contribution of the phonological loop capacity and of the size of productive vocabulary on receptive fast-mapping. The regression equation accommodates both independent variables:

$$Y = .3 + .0006 X1 + .11 X2$$

The phonological capacity and the size of productive vocabulary explain 48% of results in receptive fast-mapping ( $R^2 = 0.48$ ). There is a statistically significant relationship between phonological loop capacity and receptive fast-mapping, when controlling for the size of productive vocabulary. The better predictor of receptive fast-mapping is PL capacity ( $\beta_2 = .11$   $p = 0.02$ ). The standard error ( $SE=.04$ ) is much lower than the coefficient  $\beta_2$ , suggesting that the phonological loop capacity has a genuine effect on fast-mapping. The table of results of this multiple regression is represented in Table 5.

Table 5.  
Phonological loop capacity and size of productive vocabulary as predictors of receptive fast-mapping

	$\beta$	SE
Productive vocabulary	.00	.001
PL Capacity	.11	.04

$R^2=.48$ ,  $*p=.02$

***Influence of other demographic characteristics on the independent***

***variables.*** Pearson correlations were used to measure the degree of linear relationship between birth order, maternal level of education and day-care enrollment status on the independent variables. Findings indicated the presence of a moderate positive correlation between birth order and productive vocabulary ( $r=.34$ ) and between birth order and nonword repetition scores ( $r=.43$ ). That is, younger children of larger families tended to have a larger vocabulary and a larger phonological loop capacity than children with a lower birth order. The average size of their productive vocabulary was of 314 words for 1<sup>st</sup> and 2<sup>nd</sup>-born children ( $n=11$ ), and of 394 words for 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup> and 8<sup>th</sup>-born children ( $n=8$ ). Findings also showed a weak positive correlation between maternal level of education and nonword repetition scores ( $r=.35$ ), but no correlation with the size of productive vocabulary. Finally, day-care enrollment status was not correlated to either one of the independent variables.



## Chapter V

### **Discussion**

The current study examined the role of working memory, specifically of the phonological loop component of verbal working memory, in toddlers' ability to learn new words. Nineteen toddlers aged 24 to 30 months, completed the study. Three measures provided the data that was later analyzed for each toddler: the size of the toddler's productive vocabulary, the capacity of the toddler's verbal working memory and the ability of the toddler to learn new words with minimal exposure. Word learning was measured receptively and expressively to explore the relationship between comprehension and expression in word learning. Three hypotheses were examined and will be discussed in the three subsequent sections. Reconsideration of the overall theory of the role of working memory in word learning will then be addressed. Clinical implication and study limitations will be discussed in the last two sections.

#### **Phonological loop capacity and size of productive vocabulary**

The correlation study indicated a strong correlation between phonological loop capacity and size of the productive vocabulary. In other words, toddlers 24- to 30- months-old with a large phonological loop capacity

tend to have a larger vocabulary than toddlers with a small phonological loop capacity. As the phonological loop mediates word learning (Gathercole & Baddeley, 1990; Gathercole, Hitch, Service, & Martin, 1997; Michas & Henry, 1994), and vocabulary development (Gathercole & Adams, 1993, 1994; Gathercole, Hitch, Service, Adams & Martin, 1999; Gathercole, Willis & Baddeley, 1991; Gathercole, Willis, Emslie, Baddeley, 1992), our findings suggests that toddlers with better verbal working memory are more efficient in remembering words they have never heard before. Those toddlers can expand their lexicon faster than other toddlers. In previous studies on older children, researchers have examined the relationship between phonological loop capacity and size of productive vocabulary in 4 to 6 years old children. Findings have consistently indicated that, in this age group, children with large phonological loop capacity tend to have a larger vocabulary (Michas & Henry, 1994; Gathercole & Adams, 1994; Gathercole, Hitch, Service & Martin, 1997).

Our first hypothesis, based on the hypothesis that the same strong relationship should already exist in 2 year old children, has been supported by our findings. As the capacity of the phonological loop increases, so does the size of the productive vocabulary. Our findings approximate those of Stockes (2009), who also showed that the strongest predictor to vocabulary knowledge is phonological loop capacity in toddlers 24 to 30 months. Finally, examining toddlers younger than those in our study, Hoff, Core and Bridges

(2008) bring a longitudinal perspective to our hypothesis by showing that phonological loop capacity and vocabulary development are already closely related in 20 to 24 month old toddlers.

The instrument designed to measure phonological loop capacity requires from children to imitate sequences of sounds as accurately as possible. Looking at the dynamics of early vocabulary development, one of the most efficient strategies toddlers use to acquire new words is imitation of words they hear in their environment (Kymissis & Poulson, 1990). There are divergences among theories of language learning, with regard to the relative importance of imitation in the process of acquisition of new words. But whether imitation is regarded as a conditioned reflex, as an instinctive behavior or as a learned response, all schools of thought agree with the fact that it plays an important role in vocabulary acquisition (Kymissis & Poulson, 1990). The discovery of a mirror neurons system as a contributor to imitative behaviors in humans (Molenberghs, Cunnington, & Mattingley, 2009) further supports to the role of imitation in vocabulary development. In this learning context, the phonological loop, as a processing and storage device of new sequences of sounds, is the probable mediator allowing imitation to actually take place. An increase phonological loop capacity would increase the likelihood that new sequences of sounds can be imitated and that new words will be retained in the child's expressive vocabulary.

***A predictive relationship.*** Current research evidence support the existence of a strong relationship between measures of verbal working memory and a variety of language measures. The position of verbal working memory as a possible predictor for language measures is supported by its role in imitation, as explained in a previous section, and by other existing studies, in particular predictive studies and studies of clinical populations.

Some studies have examined the relationship between verbal working memory and second language learning. The ability to repeat nonwords is a strong predictor of the ability of 10- to 12- year old children to acquire English as a second language a few years later (Cheung, 1996; Service, 1992). These findings suggest that the phonological loop capacity is a significant constraint for acquisition of a second language.

More support for this strong relationship comes from the wealth of studies attempts to tease out the cause of specific language impairments (SLI). SLI is characterized by a delay in language development, not explained by any hearing, cognitive, social, motor, or other developmental delay. Children with SLI typically have difficulties acquiring grammar and have a smaller lexicon than typical language learners, and their expressive language skills are more impaired than their receptive language skills (Bishop, 1992). Studies of children with SLI indicate that poor phonological loop capacity correlates with depressed scores in receptive and expressive language

measures (Dollaghan & Campbell, 1998; Weismer & al., 2000). Examining other possible contributors to those language difficulties, Briscoe and Rankin (2009) ruled out the central executive component of working memory as an unequivocal cause of language difficulties, and supported the hypothesis that decreased phonological loop capacity was a more likely cause. The language difficulties encountered by children with SLI are typically addressed in the context of school and of therapy. However, depressed scores in measures of phonological loop capacity remain after language difficulties have been resolved (Bishop, North & Donlan, 1996; Conti-Ramsden, Botting & Faragher, 2001; Stothard, Snowling, Bishop, Chipchase & Kaplan, 1998). Bishop et al. (1996), comparing data from mono-zygotic and di-zygotic twins, suggest that poor verbal working memory might actually be an inherited marker of SLI, and a plausible contributor to the language problems found in this population. These researchers suggest that compensatory mechanisms developed by children as they grow allow them to overcome their language delay, even as their verbal working memory remains weak. If the disorder cannot be explained by any other hearing, cognitive, social, motor, or other developmental factor, if other possible sources such as functioning of central executive have been ruled out as main contributors and if the ability to remember new sequences of sounds is genetically determined, then limitation of phonological loop capacity is probably a strong contributor to the language delays characterizing SLI.

Probably the strongest indication of a predictive relationship between phonological loop capacity and vocabulary size is the landmark longitudinal study of Gathercole, Willis, Emslie and Baddeley (1992). They used a cross-lagged correlation analysis, in which the correlation between two variables is assumed to be stronger if the relationship is causal than non-causal. They found that verbal working memory at age 4 was the strongest predictor of receptive vocabulary knowledge at age 5. One should interpret their results with caution, as there is no absolute proof, in social and human sciences, that two variables are completely independent (Rogosa, 1980). However, Gathercole's findings, combined with findings of other studies, lend strong support to the idea that verbal working memory is the strongest predictor of vocabulary size and knowledge in pre-school and school-age children.

### **Phonological loop capacity as a predictor of fast-mapping**

Our second hypothesis has not been supported by our findings. Our results suggest a tendency of phonological loop capacity to be a better predictor of toddler's ability to produce new words. However, according to our findings, phonological loop capacity and existing word knowledge, even combined, explain only a small proportion of the results. Other factors therefore play an important role in toddlers' ability to retrieve and to produce new words.

Our third hypothesis has been supported by our findings. The capacity of phonological loop is the main predictor of toddlers' ability to remember new words. However, it is not the only predictor, and here again, other factors affect toddlers' ability to remember new words.

In order to understand more specifically the dynamics of word learning, the ability to understand a new word (receptive fast-mapping) and the ability to produce a new word (expressive fast-mapping) have been examined independently. The role of the phonological loop as a predictor of fast-mapping is statistically significant for receptive fast-mapping, but not for expressive fast-mapping. The results of this study indicate that the phonological loop is a better predictor of fast-mapping abilities than the size of productive vocabulary in 24 to 30 month old toddlers. The results also suggest that many other factors affect the ability to remember, to store, to retrieve and to produce new words. This section will address the variety of factors potentially affecting word learning. Overall, our findings support the hypothesis that verbal working memory plays a leading role in the acquisition of new words in toddlers.

The most compelling support for our results comes from Stokes' study (2009) that was published while this study was underway. Stokes examined the factors influencing vocabulary development in toddlers, ages 24 to 30 months. Her study is an important complement to our study, because its

findings increase the possibility to generalize our results to a wider population. Stokes looked at a population of British toddlers and we looked at a population of American toddlers from New York and New Jersey. In Stokes study, the sample was much larger ( $n=232$ ) than in this study. In both cases, toddlers were monolingual English; their vocabulary size was assessed through the toddler's version of the MCDI and testing took place during two meetings. Our inclusion criteria were more stringent, as toddlers with articulation and phonological difficulties were excluded from the study. Stokes tested the toddlers in the university lab and we tested them in their home. Stokes designed the fast-mapping tasks using explicit exposure to new words, in contrast to this study, where incidental exposure was used. The instrument used to measure the capacity of the phonological loop was made of 12 nonwords, controlled for length and development. In contrast, this study used 30 nonwords controlled for length, development, and phonotactic probability. Stokes showed that phonological loop capacity and fast mapping were both significantly correlated with expressive and receptive measures of vocabulary. Even more importantly, she found that the strongest predictor to vocabulary knowledge was phonological loop capacity.

Combined results from Hoff, Core and Bridges (2008), Stokes (2009) and the current study strongly support the hypothesis that phonological loop capacity is the strongest predictor of toddlers' ability to acquire new words.



***Receptive fast-mapping versus expressive fast-mapping.*** Findings of this study indicate that phonological loop capacity is a statistically significant predictor of receptive fast-mapping, whereas the result is not statistically significant for expressive fast-mapping. This difference should be examined further, in an attempt to explain the discrepancy in statistical significance.

Most studies examining young children's ability to learn new words use a receptive probe (Golinkoff, Hirsh-Pasek, Bailey & Wenger, 1992; Lederberg, Prezbindowski & Spencer, 2000; Mervis & Bertrand, 1994; Spiegel & Halberda, 2011; Woodward, Markman, and Fitzsimmons (1994). Very few also use an expressive probe (Dollaghan, 1985; Gray, 2005; Heibeck & Markman, 1987; Stokes, 2009). Looking at the ages sampled in those studies, it seems that for the most part, expressive fast mapping is examined in children beyond the age of 3. The studies using both expressive and receptive probes in children younger than 3 all report a much better ability of children to comprehend or identify words than produce them. Those studies support our findings, that the phonological loop, as a language learning device, is more closely related to the ability to recognize a new word than to the ability to produce it.

In an attempt to explain this discrepancy, one should examine the process of word learning. Learning a new word consists of encoding, storing,

retrieving and producing the word. It is a complex process, involving multiple cognitive and motor processes, such as attention, processing, comprehension, retention, motor planning and articulation. Errors can occur at any stage of the process. Production attempts can be affected by errors at any stage. However, comprehension would not be affected by errors at a later stage, once the word is well understood and stored. For example, a difficulty in processing or storing would affect both comprehension and production. In contrast, a difficulty in motor planning or articulation would not affect comprehension, but only production. Errors happening in the latest stages do not affect comprehension. Studies of children's errors attest to the high likelihood of production errors in young children, with a very sharp decline in the incidence of these errors between 14 and 30 months (Gershkoff-Stowe, 2002). These production errors are very different in nature from comprehension errors. They can range from faulty retrieval (Gershkoff-Stowe, 2002), to semantic interference (Gershkoff-Stowe, 2002), to articulatory simplification (Elsen, 1994).

When a child learns a new word, the probability that production will be affected by any of those processes is much higher than the probability of comprehension being affected. As the child matures, each one of these processes strengthens, thereby increasing the likelihood of producing the target word without error.

The discrepancy between comprehension and production measures, whether they are in word learning or of vocabulary knowledge, has been widely documented in the scientific literature. Bates, Dale and Thal (1995) reviewed existing literature on language development and showed that measures of cognitive development are more strongly correlated with comprehension than with production from birth to age two. They concluded that “studies of normal children provide robust evidence for a dissociation between comprehension and production” (p.11). Furthermore, ERP studies showed that comprehension and production are mediated by different neural systems: comprehension is mediated by bi-lateral mechanisms, whereas production is mediated by specialized left-hemisphere mechanisms (Mills, Coffey, Neville, 1993, 1997). Even though little is known about the specific dynamics of word learning, evidence suggests that physiological mechanisms, partially independent from each other, are implicated in the acquisition of new words.

***Phonological loop and vocabulary knowledge as predictors of fast-mapping.*** In our study, we examined the relative importance of the phonological loop and expressive word knowledge. We showed that phonological loop capacity and expressive word knowledge are strongly connected, and that phonological loop capacity is a stronger predictor of fast-mapping abilities than expressive word knowledge. These findings are consistent with Stokes findings (2009), that the correlation between

phonological loop capacity and fast-mapping is stronger than that of expressive vocabulary knowledge and fast-mapping. Our findings also support our original hypothesis, based on Gathercole, Willis, Emslie and Baddeley (1992). These authors showed that phonological loop capacity at age 4 was the strongest predictor of vocabulary knowledge at age 5, and that existing vocabulary became the strongest predictor after age 5. In other words, younger children rely on their verbal working memory to learn new words; whereas older children rely mostly on the lexicon they have already acquired to learn new words. Following this logic, our assumption was that the leading role of verbal working memory as a word learning device already existed prior to age 4. Our hypothesis has been fully supported by our findings.

### **Role of the social environment in word learning**

Our findings indicate that maternal level of education and family size both affect toddlers' vocabulary development. The positive influence of the maternal level of education is a well known factor, and numerous studies support this hypothesis (Baca, 2009; Cockcroft, 2008). Regarding family size, younger children of larger families tend to have a larger vocabulary and better fast-mapping skills than children from smaller families.

According to government data, the average number of children per family was 1.8, between 2005 and 2009. (Census Bureau, 2009). In our

study, 42% of toddlers belonged to families with more than 2 children. The average number of children per family was higher than that of average American families. It was therefore relevant to look at the influence of birth order on the findings. Birth order appeared to correlate with vocabulary size and with phonological loop capacity. Research findings are inconsistent regarding the relationship between birth order and vocabulary size: some studies found no influence of birth order (David & Wei, 2008; Kastelová, 1976) whether other studies found an influence of birth order on vocabulary size (Maital, Dromi, Sagi & Bornstein, 2000). Our findings could be explained by the presence of an enriched language environment due to the presence of numerous siblings.

Our results also suggest that the phonological loop capacity is sensitive to social factors such as family size or maternal level of education. This result was unexpected, as previous research has shown that non-word repetition tasks are independent from IQ (Weismer et al., 2000) and from cultural and gender influence (Dollaghan & Campbell, 1998). It is important to explore that aspect further, as this finding suggests that working memory would also be affected by the child's social environment.

### **Clinical applications**

There are important clinical applications of these findings, especially in the approach to early detection of children at risk for language delays and

disorders. Today, the tools we have available for early identification are either parental reports or speech and language standardized tests. The challenge for reliably identifying toddlers who would benefit from early intervention lies in the complexities involved in developing an assessment tool independent from gender, socio-economic status and IQ. A well-controlled nonword repetition task, as a measure of phonological loop capacity, would respond to these constraints. This task is fast and easy to administer. If further research, especially longitudinal predictive studies, supports the hypothesis that phonological loop capacity is a sensitive predictive measure of later language disorders, nonword repetition tasks could be performed on toddlers at a very early age in order to specifically identify those in need of early speech and language intervention.

### **Limitations**

Some limitations of this study might affect the possibility to generalize findings to a larger population. First, as the sample size was relatively small, and not all results were statistically significant, the protocol needs to be replicated with a larger sample size to increase the external validity of this study. It is important however to note that Stokes (2009), sampling a similar population and using a protocol with parallels to the one used in this study, has found similar results on a much larger sample size. Second, Even though efforts were made to sample a varied population, most toddlers came from a

middle class suburban and urban population, mostly drawn from an orthodox Jewish population. The proportion of children whose family size exceeded the average size of an American family was very high, and almost all mothers were college educated, almost half of them held a masters degree. These population characteristics might have introduced a sample bias, constituting another threat to external validity, and replications of this study replication should examine different populations.

Use of tape recording appeared to have a negative impact on the reliability of the transcription. As toddlers' speech is often mumbled, and toddlers tend to move a lot while playing, background noise and lack of clarity inherent to verbal expression in young children made it impossible to use those audio-recordings for accurate transcription. A decision was made to record both nonword production and production of new words by hand at the time of testing. Each toddler's verbal production was transcribed and was complemented by visual information provided by lip reading the child, in case the production was unclear. Accordingly, no independent transcription could be performed after the session, and neither inter- or intra-rater reliability measure could be performed. The use of video recording with a high definition microphone might solve this issue, as it would provide for both the visual and the verbal information to very transcription.

It should be noted that our population sample included one set of fraternal twins. Even though fraternal twins only share some of their genetic material, their inclusion in our sample might have affected the data.

Studies of word learning measuring vocabulary knowledge don't allow for control for differences of word-learning opportunities between individual children. Rich learning environments are known to positively affect the richness of children's vocabulary. Likewise, it is possible to envision that toddlers with good working memory would be more responsive and in a way, trigger more interest from the adults around them, by that increasing their exposure to richer and more redundant language. As richness of interaction is typically difficult to quantify, this threat to internal validity is likely to remain hard to control.

Finally, our current knowledge of the mechanisms contributing to the role of working memory as a mediator for language acquisition is very limited. The model of working memory (Baddeley, 2000; Baddeley and Hitch, 1974) used in this study is comprised of a central executive, an episodic buffer, a verbal working memory system (phonological loop) and a visual working memory system (visuo-spatial sketchpad). This study has addressed the role of verbal working memory, as if it was an independent entity. We know however that all these components interact, but that the contribution of each one and the dynamics of the whole process are unknown at this point.



Therefore, there might be confounding factors at work, for both the nonword repetition task and the fast-mapping task. Those factors might constitute a threat to construct validity, but might be difficult to control, given our current state of knowledge.

## Chapter VI

### Conclusion

Our findings are consistent with Consistent with Baddeley's hypothesis of a dominant role of verbal working memory as a "language learning device" (Baddeley, Gathercole & Papagno, 1998). They are also consistent with Gathercole's hypothesis on the role of phonological loop capacity by extending the model to younger children.

This study supports the importance of verbal working memory in the early stages of vocabulary development. It provides preliminary evidence that verbal working memory may plays a dominant role in the ability of toddlers to learn new words, similar to the ability of older children. Gathercole's hypothesis, that verbal working memory plays a central role in the acquisition of new words, as it stores and processes new phonological information towards storage in long-term memory, may be applicable to typically developing toddlers. This study, supported by similar findings from Stokes (2009), extends the model to younger toddlers.

In order to examine the applicability of our findings to a wider population, this study should be replicated on a larger scale, and sampling populations with different ethnic, socio-economic, educational and cultural backgrounds. In order to increase the internal validity of word learning studies, further studies could include variables reflecting the richness of

exposure and type of interaction between parents and children. Future research direction should include replication studies examining both explicit and incidental word learning. Studies examining the role of visuo-spatial sketchpad, the visual and spatial component of working memory, in word learning, would enrich our understanding of the relative contribution of different components of the working memory system as processor of visual and verbal information. As findings of this study suggests direct clinical applications, the hypothesis of verbal working memory being a predictor for word learning abilities should be examined through longitudinal studies evaluating more specifically the relationship between toddler's working memory and later language outcomes.

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## Appendix A

### Abstract of the Pilot Study

The following abstract was accepted for poster presentation  
at the 2008 Annual Convention  
of the American Speech Language and Hearing Association

**MEASURING VERBAL WORKING MEMORY IN 24 TO 48 MONTHS  
TODDLERS.** France Weill, Doreen Stiskal

#### **Introduction**

Vocabulary acquisition plays a central role in toddlers' language development. This acquisition of new words is supported by the phonological loop, a component of working memory that allows the child to remember sequences of sounds for short periods of time, until those sequences are processed further by other cognitive structures. The capacity of the phonological loop therefore plays a central role in vocabulary acquisition. However, the vast majority of studies have examined the phonological loop capacity in children beyond the age of 48 months. As vocabulary acquisition is extremely rapid in children 24 to 48 months, research examining more specifically the applicability of this approach to children below 48 month of age.

#### **Methods**

Twelve typically developing, monolingual English speaking toddlers were recruited from a New-Jersey suburban community. In order to ensure that inclusion criteria were met, each parent was interviewed prior to testing. Each subject was then screened using the Mac Arthur Communicative Development Index (MCDI; Fenson et al., 1993) for children up to 29 months, and both the Peabody Picture Vocabulary Test (PPVT-III; Dunn et al., 1997)

and the Expressive Vocabulary Test (EVT; Williams, 1997) for children above the age of 30 months. Three age groups were considered: 24 to 29 months, 30 to 39 months, and 40 to 48 months. Each subject was then tested individually. The test consisted of repeating series of two-syllable, three-syllable and four-syllable nonwords. Responses were scored as right or wrong, and a mean was computed for each age group and for each syllable length.

## **Results**

Descriptive statistics revealed that as children get older, their performance in nonword repetition increases, and the variability of their performance decreases. Further data analysis revealed that 30 to 39 month old performed significantly better than 24 to 29 month old children for repetition of 3 syllable nonwords. However, no other significant differences were found between age groups. The small sample size probably did not allow detecting an effect. A power study confirmed this observation, indicating that a sample of 21 subjects per group would be needed to detect a small effect. Finally, the instrument used in this study showed very high internal consistency reliability, even on the small sample.

## **Discussion**

Results of this pilot study indicate that both the instrument and the design can be applied to a larger population sample of children 24 to 48 month, in the context of a word learning study.

Appendix B

**Letters of Approval from IRB**





OFFICE OF INSTITUTIONAL  
REVIEW BOARD

SETON HALL UNIVERSITY

January 13, 2010

France Weill, M.S., CCC-SLP  
1256 Emerson Avenue  
Teaneck NJ, 07666

Dear Ms. Weill,

The Seton Hall University Institutional Review Board has reviewed and approved as submitted under expedited review your research proposal entitled "The Role of Verbal Working Memory in New Word Learning in toddlers 24 to 30 Months Old". The IRB reserves the right to recall the proposal at any time for full review.

Enclosed for your records are the signed Request for Approval form, the stamped Recruitment Flyer and the stamped original Consent Form. Make copies only of these stamped forms.

The Institutional Review Board approval of your research is valid for a one-year period from the date of this letter. During this time, any changes to the research protocol must be reviewed and approved by the IRB prior to their implementation.

According to federal regulations, continuing review of already approved research is mandated to take place at least 12 months after this initial approval. You will receive communication from the IRB Office for this several months before the anniversary date of your initial approval.

Thank you for your cooperation.

*In harmony with federal regulations, none of the investigators or research staff involved in the study took part in the final decision.*

Sincerely,

Mary F. Ruzicka, Ph.D.  
Professor  
Director, Institutional Review Board

cc: Dr. Doreen Stiskal



Touro College

School of Health Sciences

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1700 Union Boulevard • Bay Shore, New York, 11706 • 631-665-1600 x 219 • email: josephindelicato@yahoo.com

## MEMO

To: France Weill, M.Sc., CCC-SLP Research Advisor:

Dr Doreen Stiskal -Galisewski, PT., Ph.D.

FROM: Joseph Indelicato, LCSW, PhD

Chair, Touro SHS, IRB

Date: January 12, 2010

Re: Project IRB Approval (IRB 9-30)

I am pleased to inform you that Touro College's School of Health Science IRB has approved your project application regarding The Role of Verbal Working Memory in New Word Learning in Toddlers 24 to 30 Months Old. Please send the committee a copy of any article, paper, or presentation that may result from this study. You will need to reapply for permission after a year if your study is not complete. .

Best wishes and good luck,

*Joseph Indelicato, LCSW, Ph.D*

Joseph Indelicato, LCSW, Ph.D.

Chair IRB – Touro College SHS



Touro College

School of Health Sciences

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1700 Union Boulevard • Bay Shore, New York, 11706 • 631-665-1600 x 6219 • email: touroirb@gmail.com

## MEMO

To: France Weill, M.Sc., CCC-SLP Research Advisor:

FROM: Joseph Indelicato, LCSW, PhD

Chair, Touro SHS, IRB

Date: December 16, 2010

Re: Project IRB Approval (IRB 9-30)

I am pleased to inform you that Touro College's School of Health Science IRB has been reapproved your project application regarding The Role of Verbal Working Memory in New Word Learning in Toddlers 24 to 30 Months Old. Please send the committee a copy of any article, paper, or presentation that may result from this study. You will need to reapply for permission in another year if your study is not yet completed. .

Best wishes and good luck,

*Joseph Indelicato, LCSW, Ph.D*

Joseph Indelicato, LCSW, Ph.D.

Chair IRB – Touro College SHS

## Appendix C

### Recruitment flier

#### **Recruiting toddlers between the ages of 24 and 30 month to participate to doctoral study**

My name is France Weill, M.S. CCC-SLP. I am an associate professor at the Graduate School of Speech Language Pathology at Touro College, School of Health Sciences, and a Doctoral student at Seton Hall University, South Orange, NJ.

I am currently recruiting typically developing, monolingual toddlers between the ages of 24 and 30 month to participate to my doctoral study.

The title of my study is: "The Role of Verbal Working Memory in New Word Learning in Toddlers 24 to 30 Months Old".

The purpose of my research is to help us understand how young children use their memory to learn new words.

The study will take place over the course of two meetings, either in your home, or at the Touro College Speech and Language Clinic in Brooklyn, NY. Your child will be asked to repeat sequences of sounds, to measure his or her memory. Your child will then be taught 5 new words, to evaluate his or her word learning capacity. Your child's participation to this study may last up to a total of two hours.

Your participation in this study is voluntary. There are no known risks or discomforts associated with this study. You may refuse to participate or withdraw your participation at any time. There is no cost involved in the participation to this study. If you decide to participate, you will be entitled to a free screening test of speech and language for your child.

You will be given a copy of the test results, and you will be informed if your child scores out of the normal range on the screening tests.

All information about your child's identity and the research data will be kept strictly confidential.

If you agree to participate to this study, I will send you a consent form that you should read, sign and return to me prior to the beginning of the study.

If you are interested in enrolling in this study, contact me at 718-787 1602 ext.206 or 917-626 6084 and at [france.weill@touro.edu](mailto:france.weill@touro.edu).

## Appendix D

### Recruitment e-mail

Hi!

My name is France Weill, M.S. CCC-SLP. I am an associate professor at the Graduate School of Speech Language Pathology at Touro College, School of Health Sciences, and a Doctoral student at Seton Hall University, South Orange, NJ.

I am currently recruiting toddlers between the ages of 24 and 30 month to participate to my doctoral study. The title of my study is: "The Role of Verbal Working Memory in New Word Learning in Toddlers 24 to 30 Months Old". The purpose of my research is to help us understand how young children use their memory to learn new words.

If you want your child to be part of this study, I will first give you a questionnaire that you will fill in at home. This questionnaire is used for measuring children language development.

We will then set up a meeting, either in your home, or at the Touro College Speech and Language Clinic. Once your child is comfortable, he/she will first be observed and asked to imitate simple gestures with his/her mouth, jaw and tongue. He/she will also be asked to repeat sequences of sounds. His/her responses will be recorded on an audiotape, to be analyzed and interpreted later.

A second meeting will then be scheduled, within a week of the first meeting. During the second meeting, your child will be taught 5 new words while playing with age appropriate toys. Responses will again be recorded on an audiotape, to be analyzed and interpreted later.

Your child's participation to this study may last up to a total of two hours.

Your participation in this study is voluntary. There are no known risks or discomforts associated with this study. You may refuse to participate or withdraw your participation at any time. There is no cost involved in the participation to this study. If you decide to participate, you will be entitled to a free screening test of speech and language for your child.

You will be given a copy of the test results, and you will be informed if your child scores out of the normal range on the screening tests.

All information about your child's identity and the research data will be kept strictly

confidential. Your child will be assigned a random code number that will be used to keep track of the research data. Identifying information will appear only on the consent form, and will be locked in a secure office for three years after completion of the study, and then be destroyed.

If you agree to participate to this study, I will send you a consent form that you should read, sign and return to me prior to the beginning of the study.

IF YOU ARE INTERESTED IN PARTICIPATING TO THIS STUDY, OR FOR ANY QUESTION, PLEASE CONTACT ME AT:

[france.weill@touro.edu](mailto:france.weill@touro.edu) or 917-626 6084

You can also contact Dr. Doreen Stiskal -Galisewski, my research advisor, at 973-275-2320 and at [Doreen.Stiskal-Galisewski@shu.edu](mailto:Doreen.Stiskal-Galisewski@shu.edu)

For questions about your rights as a research participant, you may contact the Institutional Review Board for the Protection of Human Subjects (IRB), Touro College School of Health Sciences 631-665-1600 ext 6219 and [josephi@touro.edu](mailto:josephi@touro.edu). You may also contact the Institutional Review Board for the Protection of Human Subjects (IRB), Seton Hall University (973) 313-6314 and at [irb@shu.edu](mailto:irb@shu.edu).

Thank you very much!

France Weill  
917-626 6084  
[France.weill@touro.edu](mailto:France.weill@touro.edu)

Appendix E

**Informed Consent Forms**





**TOURO COLLEGE**

**Graduate Program  
Speech-Language Pathology**

**1610 East 19<sup>th</sup> Street,  
Brooklyn, NY 11229  
Ph: (718) 787-1602  
Fax: (718) 787-1137**

INFORMED CONSENT FORM

1. Researcher's affiliation. France Weill, M.S. CCC-SLP, is the investigator of this study. She is a doctoral candidate at the School of Graduate Medical Education, Speech Language Pathology specialization track at Seton Hall University. She holds a M.S. in Speech Language Pathology and a certification from the American Speech Language and Hearing Association. She has been a clinical practitioner since 1993.
2. Purpose. The purpose of this research will be to study the role of memory and of word knowledge in the ability to learn new words in 24 to 30 months old toddlers. Children's participation in this study may last up to a total of two hours.
3. Procedure. 75 children ranging in age from 24 to 30 months will perform a repetition task, followed by an object learning task.
  - a. Children will be tested individually. The sessions will be preceded by a warm-up play period during which the child will become familiar with the setting and the researcher.
  - b. In the repetition task, each child will be presented with blocks of two, three and four syllable sequences and asked to repeat them. Two practice trials will be given before starting the actual test. If a child fails to respond to an item, two more trial opportunities will be given. If a child fails to respond to three items, he or she will not participate in further testing. Each child will be presented with a total of 30 nonwords.
  - c. In the object learning task, each child will then learn 5 new names, one for each of 5 new objects that he or she has never seen before. The child will be asked to recognize each new object among a larger group of objects, upon hearing the name. He/she will then be asked to name each new object upon seeing the object. The same learning procedure will be repeated later that day.
  - d. Responses will be recorded using a tape recorder, and subsequently transcribed, analyzed and interpreted.

Seton Hall University  
Institutional Review Board

JAN 13 2010

Approval Date

Expiration Date

JAN 13 2011

4. Questionnaire used in the research. The Mac Arthur Communicative Development Index (MCDI) is a parental questionnaire used for measuring vocabulary size, as an indicator of children language development.
5. Oral-motor screening used in the research. Each child will be observed and asked to imitate simple gestures with her mouth, her jaw and her tongue. The examiner will not touch the child's mouth.
6. Voluntary nature. Participation in this research is voluntary. The subject may refuse to participate or withdraw at any time. One of the subject's parents may refuse to participate and withdraw the child's participation at any time.
7. Sharing information. Parents will be provided a copy of the test results, and will be informed if the child scores out of the normal range on the screening tests.
8. Anonymity. Each subject will be assigned a random code number, prior to the study. This code number will be used to keep track of the research data. The same code number will be used to label the audiotapes used in the study. No records are kept that would allow subjects' identities to be matched with the code numbers. Identifying information will appear only on consent forms that will be locked in a secure office independently of the research data.
9. Confidentiality. All research data will be kept confidential. Written data will be stored on a USB memory key, and access will be protected by the use of a password. The memory key will be locked in a secure office at Touro College. All audiotapes used for the research will be stored in the secure office of France Weill at Touro College. Consent forms and research data will be stored for three years after the publication of the study and will then be destroyed. Data will be analyzed and presented only in an aggregate fashion.
10. Use of tape recorders. The subject's parent will give written permission for the interaction to be recorded. The subject will be identified on the tape by the same code number used to keep research data. Only the investigator (France Weill) and the Chair of the Dissertation Committee (Dr. Doreen Stiskal) will have access to the tapes. Both the investigator and a second investigator will listen to the tapes and will transcribe them. The tapes will be securely stored with the research records for three years after the publication of the study and will then be destroyed.

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Expiration Date

JAN 13 2011

- 11. Access to research records. Records will be kept confidential. Only the investigator (France Weill) and the Chair of the Dissertation Committee (Dr. Doreen Stiskal) will have access to the research data.
- 12. Risks. There are no known risks or discomforts associated with this research.
- 13. Benefits. There are no known benefits to the subject that would result from his/her participation in this research. This research may help to understand how children use their memory to learn new words.
- 14. Contact Information. Any question or concern regarding the study should be directed to France Weill (principal investigator) at 718-787-1602 ext. 206 or to Dr. Doreen Stiskal (research faculty advisor) at (973) 275-2320. Any question regarding the child's rights as a research participant should be directed to the Institutional Review Board, Seton Hall University, 400 South Orange Avenue, South Orange, NJ, 07079 at 973-313-6314 or [irb@shu.edu](mailto:irb@shu.edu) or to the Institutional Review Board, Touro College School of Health Science, 1700 Union Blvd, Bay Shore, NY 11706 at 631-665-1600 ext 6219 or [josephi@touro.edu](mailto:josephi@touro.edu)
- 15. Consent Form. Subjects' parent/guardian will be given a copy of the signed and dated Informed Consent Form before their participation begins. The subjects are the children; they can't sign.

\_\_\_\_\_  
Child's name

\_\_\_\_\_  
Date

\_\_\_\_\_  
Subject parent/guardian

\_\_\_\_\_  
Primary investigator

Seton Hall University  
Institutional Review Board

Expiration Date  
JAN 13 2011

JAN 13 2010

Approval Date

**Expiration Date**

JAN 13 2012

Seton Hall University  
Institutional Review Board

JAN 13 2011

**Approval Date**

5. Oral-motor screening used in the research. Each child will be observed and asked to imitate simple gestures with her mouth, her jaw and her tongue. The examiner will not touch the child's mouth.
6. Voluntary nature. Participation in this research is voluntary. The subject may refuse to participate or withdraw at any time. The subject's parent may refuse to participate and withdraw the child's participation at any time.
7. Sharing information. Parents will be provided a copy of the test results, and will be informed if the child scores out of the normal range on the screening tests.
8. Anonymity. Each subject will be assigned a random code number, prior to the study. This code number will be used to keep track of the research data. The same code number will be used to label the audiotapes used in the study. No records are kept that would allow subjects' identities to be matched with the code numbers. Identifying information will appear only on consent forms that will be locked in a secure office independently from the research data.
9. Confidentiality. All research data will be kept confidential. Written data will be stored on a USB memory key, and access will be protected by the use of a password. The memory key will be locked in a secure office at Touro College. All audiotapes used for the research will be stored in the secure office of France Weill at Touro College. Consent forms and research data will be stored for three years after the publication of the study and will then be destroyed. Data will be analyzed and presented only in an aggregate fashion.
10. Use of tape recorders. The subject's parent will give a written permission for the interaction to be recorded. The subject will be identified on the tape by the same code number used to keep research data. Only the investigator (France Weill) and the Chair of the dissertation committee (Dr. Doreen Stiskal) will have access to the tapes. Both the investigator and a second investigator will listen to the tapes and will transcribe them. The tapes will be securely stored with the research records for three years after the publication of the study and will then be destroyed.
11. Access to research records. Records will be kept confidential. Only the investigator (France Weill) and the Chair of the dissertation committee (Dr. Doreen Stiskal) will have access to the research data.

12. Risks. There are no known risks or discomforts associated with this research.
13. Benefits. There are no known benefits to the subject that would result from his/her participation in this research. This research may help to understand how children use their memory to learn new words.
14. Contact Information. Any question or concern regarding the study should be directed to France Weill (principal investigator) at 718-787-1602 ext. 206 or to Dr. Doreen Stiskal (research faculty advisor) at (973) 275-2320. Any question regarding the child's rights as a research participant should be directed to the Seton Hall Institutional Review Board at 973-313-6314 or [irb@shu.edu](mailto:irb@shu.edu) or to the Touro College School of Health Science Institutional Review Board at 631-665-1600 ext 6219 or [josephi@touro.edu](mailto:josephi@touro.edu)
15. Consent Form. Subjects' parent/guardian will be given a copy of the signed and dated Informed Consent Form before their participation begins. Subjects are the children; they can't sign.

\_\_\_\_\_  
Child's name

\_\_\_\_\_  
Date

\_\_\_\_\_  
Subject parent/guardian

\_\_\_\_\_  
Primary investigator

**Seton Hall University  
Institutional Review Board**

**JAN 13 2011**

**Approval Date**

**Expiration Date**

**JAN 13 2012**



**Father:**

Place of Birth: City \_\_\_\_\_ Country \_\_\_\_\_

Occupation: \_\_\_\_\_

Highest degree completed: High school Bachelor Master Doctorate

**Mother:**

Place of Birth: City \_\_\_\_\_ Country \_\_\_\_\_

Occupation: \_\_\_\_\_

Highest degree completed: High school Bachelor Master Doctorate

Does the child attend **daycare/preschool**? Yes No

If yes, how many hours/days a week? \_\_\_\_\_

What language is spoken in daycare? \_\_\_\_\_

Is the child also under the care of another **caretaker**?

If yes, how many hours/days a week? \_\_\_\_\_

What language does the caretaker speak? \_\_\_\_\_

Is there any member of the family diagnosed with a Speech/Language/Hearing Problem?

Relationship to child	Type of problem





## Appendix G

## Nonword Stimuli

	<b>Klattese</b>	<b>Nonword IPA</b>	<b>Syllables</b>	<b>Transcription</b>
1	txkEs	t ə k ɛ s	2	
2	kxbUn	k ə b U n	2	
3	dcbU	d ə b U	2	
4	sxbUn	s ə b U n	2	
5	bEdR	b ɛ d ɜ	2	
6	sefi	s e f i	2	
7	bUSx	b U s ə	2	
8	sxbU	s ə b U	2	
9	ckxd	ɔ k ə d	2	
10	ikck	i k ə k	2	
1	bxdcka	b ə d ɔ k a	3	
2	afefi	a f e f i	3	
3	siseme	s i s e m e	3	
4	tazedu	t a z e d u	3	
5	kibesa	k i b e s a	3	
6	dEfemi	d ɛ f e m i	3	
7	gosudu	g o s u d u	3	
8	ekevos	e k e v o s	3	
9	amizat	a m i z a t	3	
10	yededo	j e d e d o	3	
1	isctuvi	i s ɔ t u v i	4	
2	amUdap@	a m U d a p ə	4	
3	kEzEdcsE	k ɛ z ɛ d ɔ s ɛ	4	
4	dibcgada	d I b ɔ g a d a	4	
5	pas@didi	p a s ə d I d i	4	
6	osopame	o s o p a m e	4	
7	tisenEpa	t I s e n ɛ p a	4	
8	@zip@gi	æ z I p ə g i	4	
9	tubif@to	t u b I f ə t o	4	
10	kisodEfi	k I s o d ɛ f i	4	

## Appendix H

## New words and known words stimuli

## Set of known words

	Label	Number syllables
1	Cup	1
2	Book	1
3	Ball	1
4	Hat	1
5	Baby	2
6	Bubbles	2
7	Teddy	2
8	Doggie	2
9	Cookie	2
10	Bunny	2

## Set of new words

	Origin	New label	New label IPA	# syllables
1	Duck (MCDI)	Wug	<b>ʌʌg</b>	1
2	Adam & Gathercole, 1995	Mot	<b>mɔt</b>	1
3	Baldwin & Markman, 1996	Toma	<b>toma</b>	2
4	Houston-Price, 2005	Soofy	<b>sʊfl</b>	2
5	Houston-Price, 2005	Goppen	<b>gopən</b>	2