

Verbal short-term memory and fluid vocabulary skills in toddlers

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Table of Contents

Preface.....	4
Acknowledgments.....	5
1.0 Introduction.....	6
2.0 Working Memory.....	6
2.1 <i>Central Executive</i>	8
2.2 <i>Visuospatial Sketchpad</i>	8
2.3 <i>Phonological Loop</i>	8
2.4 <i>Episodic Buffer</i>	9
2.5 <i>VSTM and typical language development</i>	10
2.6 <i>Relationship between VSTM and language impairment/disorder</i>	14
2.7 <i>Nonword repetition skills in toddlers</i>	17
2.8 <i>VSTM and Vocabulary Use</i>	18
2.9 <i>Summary of the relationship between NWR and language skills</i>	19
3.0 Vocabulary.....	19
3.1 <i>A framework of word learning</i>	20
3.2 <i>Vocabulary knowledge and vocabulary use</i>	22
4.0 Ways of measuring lexical diversity.....	29
5.0 Study Aim.....	31
6.0 Research Question.....	31
7.0 Method.....	31
7.1 <i>Participants</i>	31
7.2 <i>Procedure</i>	31
7.2.1 <i>Parent-report questionnaires</i>	31
7.2.2 <i>Vocabulary Knowledge</i>	32
7.2.3 <i>Nonword repetition task</i>	32

7.2.4	<i>Language sample analysis</i>	33
8.0	Results.....	33
8.1	<i>Descriptive statistics</i>	34
8.2	<i>Relationships among variables</i>	34
8.3	<i>Regressions</i>	39
9.0	Discussion.....	40
9.1	<i>NWR and language knowledge</i>	40
9.2	<i>Language knowledge and language use</i>	41
9.3	<i>Contribution to the literature</i>	42
10.0	Study Limitations.....	46
11.0	Future implications.....	46
12.0	References.....	47

Preface

The research for this Master's thesis was carried out between February 2011 and March 2012, while the Master's candidate was enrolled in the Department of Communication Disorders, University of Canterbury. The research was based at Child Language Centre at the University of Canterbury and was supervised by Prof Stephanie Stokes and Associate Professor Catherine Moran. The material presented in this thesis is the original work of the candidate except as acknowledged in the text, and has not been previously submitted, either in part or in whole, for a degree at this or any other University.

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1.0 Introduction

The relationship between working memory (WM) and vocabulary acquisition has been the focus of much research and a close relationship between these two aspects has been identified (e.g., Gathercole & Baddeley, 1990, Gathercole, Willis, Emslie, & Baddeley, 1992). In particular, verbal short-term memory (VSTM), a component of working memory, has been implicated in the acquisition of words. However in most of the studies of VSTM and vocabulary acquisition, vocabulary has been examined in the context of word *knowledge* (Gathercole & Baddeley, 1989, 1990), as opposed to word *use*. Although there have been a few exceptions (e.g. Adams & Gathercole, 2000), the role of VSTM in vocabulary use remains under-explored. Adams and Gathercole (2000) examined the relationship between VSTM and word use in spontaneous speech, however they failed to take the speaker's word knowledge into account. As word use must be dependent on word knowledge to some degree (Gupta & Tisdale, 2009), then word knowledge must be controlled if the role that VSTM plays in vocabulary use is to be explored. Furthermore, the children in the study were aged four years, meaning that little is known about word use in very young children who are at the earliest stages of vocabulary development. The aim of this study is to examine the relationship between working memory, in particular VSTM, and word use in young children (aged 2 years) while controlling for word knowledge.

2.0 Working memory

In order to examine the relationship between working memory and vocabulary use, it is first important to have a clear understanding of working memory. Working memory was put forward by Baddeley and Hitch (1974) as a cognitive system responsible for the temporary storage and processing of visual and verbal information. The definition of working memory has evolved to where it can be viewed as an active interface between perceptual

processing and long term memory that allows for the management, manipulation and transformation of information from both. This is accomplished through the temporary maintenance and simultaneous processing of information (Bayliss, Jarrold, Baddeley, Gunn, & Leigh, 2005; Hulme & Mackenzie, 1992). The end result is the support of cognitive process underlying thinking and learning. Overall then, working memory can be construed as an operational system that enables access of information from long term memory (Dehn, 2008), by providing an interface between long term memory, perception and goal directed actions.

We adopt a particular model of working memory in this research, that of Baddeley and colleagues (e.g., Baddeley, 1986). This model of working memory was proposed as a multicomponent system made up of the central executive, phonological loop, and visuospatial sketchpad. In 2000, Baddeley added a third subsystem to his model (Figure 1), the episodic buffer. A description of the components of Baddeley’s (1986; 2000) model follows. Particular emphasis is placed on the phonological loop and its sub-components as the phonological loop represents VSTM – the focus of this study.

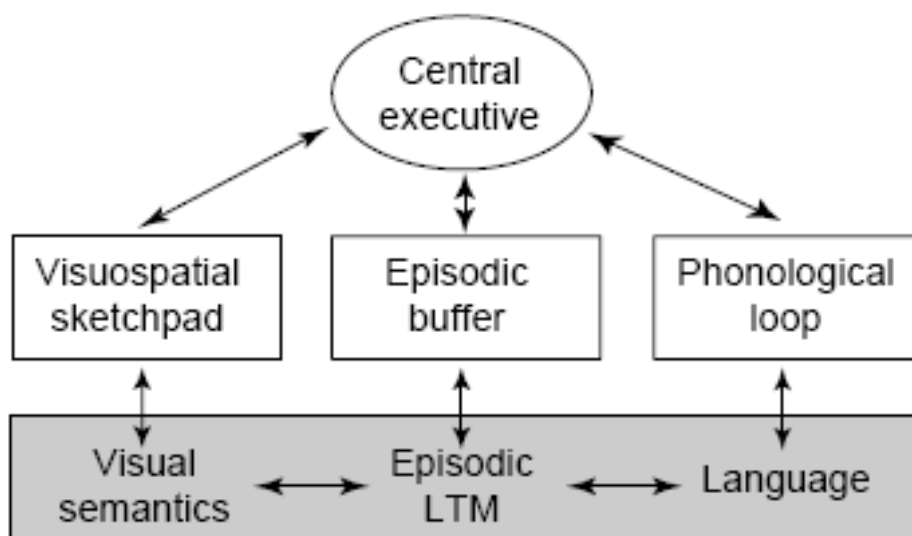


Figure 1: Development of the Working Memory model, Baddeley (2000)

2.1 Central Executive

The central executive acts as a supervisory system that controls the flow and coordination of information to and from the two temporary storage systems (the visuospatial sketch pad and the phonological loop). The central executive is involved in the control, activation and retrieval of information from long-term memory; and the focus and switching of attention (Baddeley & Logie, 1999; Baddeley, 1986).

2.2 Visuospatial sketch pad

The visuospatial sketch pad is one of the two temporary storage systems in working memory. It specialises in the processing of visual and spatial material. It also temporarily stores and processes verbal information that is transformed to visual information (Baddeley, 2000). The interpretation of the language/memory association regarding commonalities of phonological processing, proposes the association to be specific to phonological memory skills and therefore little relationship between language development and visuo-spatial sketchpad or central executive skills or other components of the model of working memory (Adams & Gathercole, 2000).

2.3 Phonological Loop

The phonological loop is a component of working memory specific to the temporary storage of verbally coded information (Baddeley, 1986). The phonological loop can be separated into two components: a passive storage system, and an active rehearsal system. The passive storage system represents information in a phonological code which decays over time, a matter of seconds. The active rehearsal system involves a subvocal rehearsal process that refreshes the decaying information so that it can be maintained over a longer period of time. In addition, the subvocal rehearsal process takes non-auditory information such as printed words and turns them into phonological information that can be stored. The

phonological loop, like other components of working memory is limited however, in both capacity and duration of activation (Baddeley & Logie, 1999). Only a set amount of information can be retained in the phonological loop and for a set amount of time. Evidence of the temporal and capacity constraints of the phonological loop has been collected in studies examining articulatory suppression (Baddeley, 1986; Gathercole & Baddeley, 1993a; Murray, 1967), word length (Baddeley, Thomson, & Buchanan, 1975; Ellis & Hennesly, 1980), phonological similarity (Conrad & Hull, 1964; as cited in Baddeley, 1986), and neuropsychological evidence (Baddeley & Logie, 1999; Vallar & Baddeley, 1984). It has been suggested that information will decay after 1- 2 seconds if not rehearsed. It has been shown that the phonological loop plays an important role in long-term phonological learning, in addition to short-term storage (see Gathercole and Baddeley, 1993a, for a review). As such it is associated with the development of vocabulary in children, and with the speed of acquisition of foreign language vocabulary in adults. Children with developmental disorders of language have been shown to have very poor phonological memory skills (Gathercole & Baddeley, 1990; Montgomery, 1995; Gillam & van Kleeck, 1996), which index the functions of the phonological loop.

2.4 Episodic Buffer

The episodic buffer has the function of coordinating perceptual information for processing and organises episodic information for coherent processing (Eysenck & Keane, 2010). In addition to representing the components of working memory, Figure 1 also displays the connections that exist between working memory and long-term memory which stores language and visual semantics. The shaded area of the model represents the latter.

2.5 VSTM and typical language development

There is compelling evidence to suggest that VSTM is important in the acquisition of vocabulary knowledge (e.g. Archibald & Gathercole, 2006; Gathercole & Baddeley, 1990; Gathercole et al., 1992).

From the large body of research, there is evidence that one of the primary roles of the VSTM is to support learning of the phonological structure of language (Baddeley, Gathercole & Papagno, 1998b). With regard to word learning, a representation of the phonological structure is held in VSTM which mediates the creation of a phonological entry within the long-term lexical store (Baddeley et al., 1998b). It is thought that the rehearsal component underlying VSTM also underlies vocabulary acquisition. In VSTM, the system rehearses phonological information so that the phonological representation is maintained in an active state. In vocabulary acquisition, a similar rehearsal component aids the formation of a new vocabulary item, by allowing the learner to strengthen the memory by allowing repeated access to the form (Gupta & Macwhinney 1997). Thus, phonological memory skills make a significant contribution to vocabulary development, i.e., good memory skills contribute to good vocabulary growth.

Before outlining the studies that provide evidence for the role of VSTM in vocabulary acquisition it is essential to first understand how VSTM is measured. There are a number of ways to measure VSTM. One measure of VSTM is Immediate Serial Recall (ISR). In ISR tasks, individuals repeat sequences of unrelated digits or words (e.g. Archibald & Gathercole, 2006). An alternative to ISR is nonword repetition (NWR; e.g. Dollaghan & Campbell, 1998). Nonword repetition involves having children repeating sequences of phonemes that combine to make a ‘nonword’. The nonwords obey the phonological rules of English but have no semantic representation. Examples of nonwords include [fupim] and [dafu]. NWR

has been widely used to examine the relationship between VSTM and vocabulary knowledge (e.g. Gathercole & Baddeley, 1990; Gathercole et al., 1992). Gathercole et al., (1992) noted that NWR provides a more sensitive measure of immediate verbal memory than more conventional serial recall measures. This is probably a result of both its simple task demands and the use of non lexical materials (Gathercole & Baddeley, 1990). Both ISR and NWR appear to be robust measures of VSTM and are frequently used. NWR appears to be particularly useful however in identifying children with Specific Language Impairment (SLI; for example Graf Estes, Evans, & Else-Quest, 2007), as will be discussed later in the thesis.

Gathercole and Baddeley (1989) carried out a longitudinal study of 104, four and five year old typically developing children, wherein they measured NWR, the sound mimicry component of Goldman, Fristo and Woodcock (1974) test, nonverbal intelligence and receptive vocabulary at four years and then at five years. The results of the tests at age four and the subsequent one at five years showed that the correlation between receptive vocabulary and NWR was highly significant. This research provided evidence in support of et al.'s (1998a) proposal that the primary role of short term memory is to support learning of the phonological structure of language. In a subsequent longitudinal study of vocabulary acquisition, Gathercole et al., (1992) assessed the nature of the relationship between phonological memory measures and acquisition of vocabulary knowledge. They followed 80 children at ages four, five, six, and eight years, using the cross-lagged correlation technique, which involved comparing the correlations obtained between two variables, a phonological memory measure and a vocabulary measure, across two time intervals. A test of nonword repetition was given at each of the four waves, where in the child was required to repeat a nonword spoken by the experimenter. Between four and five years of age, they found that phonological memory skills appeared to make a significant contribution to vocabulary

development. This finding fits with the notion that short term phonological traces in working memory are used as an important basis for constructing durable long term representation of new words (e.g., Gathercole & Baddeley, 1989).

In another study Gathercole, Hitch, Service and Martin (1997) assessed the NWR and digit recall abilities of a large group of five year old children (N = 65) who were also tested on a range of standardized measures of vocabulary knowledge and four word learning tasks. They found that NWR scores were closely related to vocabulary scores. The results explain the close links occurring between the long term phonological learning component of vocabulary acquisition and the phonological short term memory, which is tapped through NWR (Baddeley, Gathercole, & Papagno, 1998b).

In addition to vocabulary knowledge, there is indirect evidence for a relationship between phonological memory and expressive speech and language as well. For instance, children with developmental disorders of language, who also have poor vocabulary knowledge, and short and syntactically immature utterances (Scarborough, Rescorla, Tager-Flusberg, Fowler, & Sudhalter, 1991; Stark & Tallal, 1981) may also have very poor phonological memory skills (Gathercole & Baddeley, 1990; Taylor, Lean, & Schwartz, 1989). From this, it can be predicted that the memory system plays a crucial role in the development of expressive language in a child (Adams & Gathercole, 1995), but this is a relatively unexplored area of research. A correlational study by Adams and Gathercole (1995), aimed to determine the presence of any link that exists between phonological memory skills, articulatory abilities and the maturity of speech output. They selected children of high and low phonological memory ability from a group of 108 children between the ages 34 and 37 months, who were also participating in an ongoing longitudinal study (Gathercole & Adams, 1993). These children had language skills within the normal range and had no

hearing problems reported. Nonword repetition test was designed to assess the phonological memory abilities of these children during the preschool years (Gathercole & Adams, 1993). In the first wave of the longitudinal study, a test of auditory digit span was also given. In order to produce the estimate of children's phonological memory skills based on both measures, z-scores were calculated for each the above mentioned tests. The group selection was based on maximizing the difference in these z-score estimates of phonological memory skills across two groups. To measure articulatory skills, each child was asked to repeat the word pair "cat, nose", as fast as possible. If this was successfully achieved by the child, he or she was asked to repeat the pair twice and then thrice. Articulation rate was calculated as the mean number of words per second produced by each child for a repetition. In this study, Adams and Gathercole (1995) classified productive vocabulary and the length of utterances as quantitative indices of the children's speech production. The following measures were acquired for each transcript, the number of different word roots, based on the number of unique free morphemes; the Type-Token Ratio (TTR) calculated as the ratio of the number of different word roots: total number of words in the first 50 utterances; the mean length of utterance in morphemes (MLU-m). In addition to that, a qualitative analysis of grammatical/syntactic complexity of children's utterances was provided by applying the Index of Productive Syntax (IPSyn) developed by Scarborough (1990), which is a speech classification system designed to identify the occurrence of key grammatical forms in the child's speech. It has four subscales: noun phrases, verb phrases, question/negation constructions and sentence structure. The study demonstrated that a close relationship is present between phonological memory skill and language production in the preschool period, in terms of quantity and quality of spontaneous speech produced by the child, but the direction of causation between different abilities cannot be explicitly determined on the basis of correlational information.

2.6 Relationship between VSTM and language impairment/disorder

It is also observed that NWR (as a measure of VSTM) has the potential to distinguish typically developing children from children with SLI. [Children with SLI display deficits in language acquisition and use, despite having normal hearing and non verbal intelligence, as well as no history of frank neurological impairments or emotional disturbances (Leonard, 1998).] The skills tapped in NWR tasks were proposed to play an important role in language impairments. There is a significant amount of evidence to support the credibility of a NWR task in the identification of children with SLI. Early evidence for this was shown in one study by Gathercole and Baddeley (1990). They predicted that if VSTM provided an important developmental constraint on vocabulary acquisition, then it would be expected that children with poor memory skills would show delayed vocabulary growth. They examined a group of six children with language disorders (LD), three boys and three girls, ranging in age from 7;02 to 8;10 years. Each child in the LD group was matched as closely as possible with one control child of equivalent nonverbal intelligence and with one child of equivalent language ability. The experimenters measured repetition of nonwords (NWR) and ordered recall of a list of unconnected items in these children. The results of their study were consistent with their prediction. The LD group of children performed significantly poorer on tests of immediate phonological memory than a group of younger control children of equivalent vocabulary knowledge. NWR performance accurately discriminated between children with LD and their controls. Thus, these data provided encouraging support for the hypothesis that impaired short-term memory skills may play a central role in disordered language development. Similar results have been reported by Taylor, et al., (1989) with reading impaired children.

Archibald and Gathercole (2006) explored VSTM abilities in children with SLI using a different measurement paradigm, that of Immediate Serial Recall (ISR). Seventeen children

with SLI in the age range of 7-11 years were recruited for their study. Here the subjects repeat sequences of unrelated digits or words, which were presented in the auditory or visual mode. The responses were verbal or written. Based on the longest sequence repeated correctly by the individual, his/her performance in the task can be measured. Archibald and Gathercole (2006) found VSTM deficits in children with SLI on measures of digit and word recall in addition to a test of NWR. This finding supported the proposal that short term memory impairment may be a contributing factor to vocabulary learning difficulties in SLI, supporting earlier claims (Gathercole & Baddeley 1990, Baddeley et al., 1998b). Baddeley et al. suggested that short term memory plays a significant role in learning new words by generating a phonological representation of brief and novel speech events thereby mediating the creation of a phonological entry within the long term lexical store. Evidence in support of the claim came from Gathercole and Baddeley (1989), who compared children with SLI, with a mean age of eight years with a controlled population of typically developing (TD) children with matched reading and vocabulary skills on a test of VSTM. The children with SLI had difficulty in NWR and digit span recall. The NWR scores of the SLI group were equal to four year olds and vocabulary scores were equal to that of six year olds. Thus, the results suggested that the same abilities were present for NWR, ISR and vocabulary acquisition, because all the three skills were impaired in these children.

As noted earlier, Gathercole and Baddeley (1989) suggested that the phonological representation of novel words generated in short term memory leads to more durable phonological entries in the lexical store of long term memory. Therefore the severe deficits of verbal short term memory in individuals with SLI (manifested in NWR) may reflect less durable phonological representations as a primary cause of impairments in vocabulary learning (Archibald & Gathercole, 2006). With a large body of literature confirming earlier reports, Graf Estes, et al., (2007) conducted a meta-analysis of the differences in the NWR

performance of children with and without SLI. Children with SLI displayed deficits in language acquisition and use, despite having normal hearing and nonverbal intelligence. They also showed considerable deficits in NWR compared to children with typical language skills (Bishop, North, & Donlan, 1996; Edwards & Lahey, 1998; Weismer, Tomblin, Zhang, Buckwalter, & Chynoweth, 2000; Gathercole & Baddeley, 1990; Montgomery, 1995). This meta-analysis demonstrated that the characteristics of NWR tasks matter for the magnitude of the SLI deficit found, and the actual test chosen may affect the application of NWR as an identifier of children with SLI. The authors concluded that NWR holds promise for identifying children with SLI at many ages.

The conclusion from the meta-analysis and other related research was that children with SLI performed poorly in repeating multisyllabic nonwords. The consistency of the NWR deficit indicated that measures of NWR would be useful for identifying children with SLI across development, from preschool age to adolescence. The meta-analysis also showed that children with SLI were impaired at all nonword lengths, with greater deficits observed for longer nonwords (three and four syllables) than for shorter nonwords (one and two syllables; Graf Estes, et al., 2007).

Limitations in the phonological working memory capacity of children with SLI have been suggested not only as a correlate of language impairment, but also as a possible source of pervasive language impairment (Gathercole & Baddeley, 1990; Montgomery, 2002; 2004). Montgomery (2002) and Gathercole and Baddeley (1990) claimed that the difficulty that children with SLI had with increasing length from shorter to longer nonwords reflected limitations in phonological working memory resources. According to Montgomery (2000a) reduced complex memory span reflects a general information processing inefficiency in SLI that constrains language development. According to this, the individual's ability to comprehend and produce language will be dependent on the ability to actively maintain and

integrate linguistic information within working memory. NWR is beginning to be used broadly in studies intended to identify children with SLI language impairments (Graf Estes, et al., 2007). Conti-Ramsden and Botting, (2001) suggested NWR ability to be a clinical marker for SLI. Therefore, screening these skills in toddlers may identify children whose working memory skills would put them at risk for poor subsequent language learning (Stokes & Klee, 2009).

2.7 Nonword repetition skills in toddlers

Of particular note is that most studies that have looked at VSTM and vocabulary acquisition have focused on children who were four years of age or older. However, given that children produce early words around 12 to 18 months of age, to truly understand the role of VSTM and acquisition of vocabulary, it is important to examine young children as well. Stokes and Klee (2009) evaluated the value of NWR in predicting expressive vocabulary development of two-year-old children. The aim of the study was to explore associations among demographic, cognitive, linguistic and psycholinguistic factors and to determine the value of these factors as predictors of the expressive vocabulary scores of two-year-old children. They found that NWR was the strongest predictor of vocabulary development. The finding is important because vocabulary size in infancy is considered strongly related to early lexical and grammatical development (Bates, Bretherton, & Snyder, 1988). Individual differences in phonological working memory correlates with vocabulary development in preschool and school aged children (Gathercole & Baddeley, 1993b), and processing limitations related to working memory are central to theories of language disorder (Montgomery, 2002).

Gathercole and Baddeley, (1993a) pointed out that for native speakers the size of phonological short term memory plays a less important role in vocabulary learning as learners age. Phonological memory plays a crucial role during the developmental period

because activation of phonological representations in very young children is thought to be a controlled process (Adams & Gathercole, 1995). Phonological short term memory may play less of a role in a skilled speaker because output is achieved by means of direct activation of a phonological representation, possibly combined with a specialized speech output buffer (Bock, 1982). The more words you know, the easier it is to learn new words because of the phonological features that the new words share with already known words (Nation, 2001). Therefore, the role of phonological memory should be critical in vocabulary acquisition and usage in children, during their developmental period.

2.8 VSTM and Vocabulary Use

While there is a substantial body of research on the relationship between verbal short term memory (VSTM) and vocabulary *knowledge* in childhood (Gathercole & Baddeley, 1989; 1990), the relationship between VSTM and vocabulary *deployment* in young children during conversation has received little attention. An exception is Adams and Gathercole (2000), who examined lexical diversity in the spontaneous speech of two groups of four-year-old children, matched for non-verbal ability, but who had either relatively good or poor NWR skills. The purpose of that study was to identify whether a deficit in VSTM abilities constrained the language development of these children. They reported that children aged four years who were classified on a task of NWR as having relatively good phonological memory abilities produced spontaneous speech with greater lexical diversity, longer sentence length, and greater variability of syntactic structures than children classified as having relatively poor phonological memory abilities. While the study provided useful information on the lexical diversity of four-year-old children, it did not control for the total number of words used by children in conversation when calculating lexical diversity. Not imposing a control means that any differences in lexical diversity between children with good and poor

NWR could simply be attributable to differences in verbosity (Carlson Lee & Rescorla, 2008). The question of whether or not VSTM skills are related to children's ability to use words in conversation remains almost unexplored and little is known about lexical diversity in very young children in the earliest stages of word use.

2.9 Summary of the relationship between NWR and language skills

The developmental findings of association between phonological memory and vocabulary acquisition lend considerable weight to the hypothesis that adequate phonological memory skills are a pre requisite for normal vocabulary development, even at the earliest phases of vocabulary use (Gathercole et al., 1992). Also, it is evident that, in individuals with SLI, a deficit in VSTM may be the principal component of their impairment in vocabulary learning. It is also clear that NWR is an effective tool to measure VSTM. Hence, from these studies, it can be concluded that the skills observed to be poor in an NWR task play a critical role in the development of language. Thus, these studies have demonstrated the presence of a significant relationship between NWR, which measures VSTM, and language abilities in both typically developing children and children with SLI. It should also be noted that these studies have all focused on the relationship between VSTM and vocabulary knowledge and there is little known about the relationship between verbal short term memory and vocabulary use. It is important not only to explore the relationship between VSTM and vocabulary *knowledge*, but also how VSTM may be related to vocabulary *use*. In the next section, the importance of exploring the relationships among vocabulary knowledge, vocabulary use and working memory are discussed.

3.0 Vocabulary

In this thesis, vocabulary knowledge is taken to mean the information that is stored in long term memory. Vocabulary use is taken to mean the words that are expressed by the

speaker in real time processing during conversation. The relationships are situated within a framework of word learning (Gupta & Tisdale, 2009, Figure 2).

3.1 A framework of word learning

It is helpful to think about vocabulary knowledge and use within a functional framework of word learning. According to Gupta and Tisdale (2009), vocabulary acquisition refers to the overall phenomenon of acquiring a vocabulary of words over an extended time period. Word learning refers to the specific phenomenon of learning one or a small number of new words in a relatively short period of time. These authors posited a word-learning framework to clarify the components involved. They identified three functional components: word form, word meaning, and links. Word form is the phonological representation that is formed from the processing of an auditorily experienced human speech stimulus, that is, the spoken language and not the written language. The auditory stimulus could be a known word or a novel word. Meaning is an internal representation of an objects, action, event or abstract entity/entities. This internal representation is termed a semantic representation that can exist independently of a name. The meaning of a word form to a particular individual is the semantic representation that is evoked via activation of the word-form. The links are connections between representations, whose existence allows the one representation to activate the other. There are two links that must be considered, one from the word-form representation to the semantic representation (the receptive link) and one from the semantic representation to the word-form representation (the expressive link; Gupta & Tisdale, 2009).

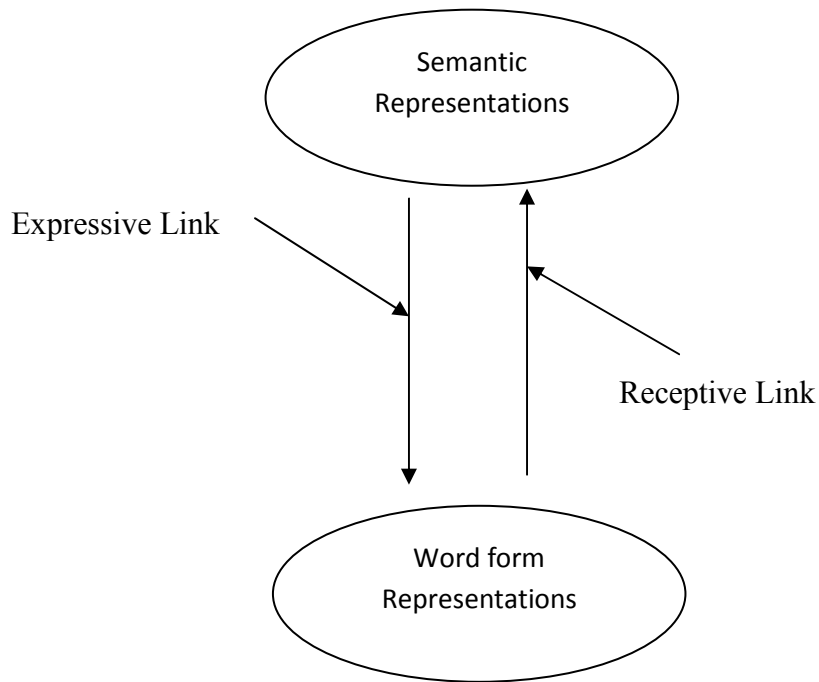


Figure 2: Functional aspects of word learning (Gupta & Tisdale 2009)

The framework explains that learning “a word” requires creation of a word-form representation, creation of a semantic representation, creation of an expressive link and creation of a receptive link. Learning a word-form representation, learning a semantic representation, learning an expressive link and learning a receptive link can thus be thought of as core functional components of word learning (Gupta & Tisdale, 2009).

The literature review above has provided evidence of the relationship between word learning and VSTM (e.g. Gathercole & Baddeley 1990, Baddeley et al., 1998b, Archibald & Gathercole 2006), which means that VSTM plays an important role in the learning of word-form (phonological) representations. We know from Atkinson and Shiffrin (1968), and Baddeley et al., (1986) that VSTM plays an important role in learning new words by generating a phonological representation of brief and novel speech events thereby mediating the creation of a phonological entry within the long term lexical store. Therefore, from all the

studies mentioned above, we can conclude that, VSTM is directly proportional to vocabulary knowledge, that is, good VSTM indicates good vocabulary knowledge in early childhood.

3.2 Vocabulary knowledge and vocabulary use

It has been pointed out that although VSTM has been shown to be associated with vocabulary knowledge, relatively little work has been conducted in the area of word use. In order to understand the difference between word knowledge and word use in the context of working memory, it is useful to examine the Gupta and Tisdale (2009), and Baddeley (2000) models again. The reader may recall that the shaded areas in Figure 1 represent *crystallized* cognitive systems capable of accumulating long-term knowledge. These systems were language, semantic knowledge and episodic long-term memory. These are essentially the systems of long-term memory where knowledge is stored. The unshaded components of the model – central executive, the visuo-spatial sketchpad, the phonological loop, and the episodic buffer - can be thought of as *fluid* cognitive systems.

The notion of cognitive systems as being crystallised or fluid originated in the general field of intelligence. Psychologist Raymond Cattell (1963) first proposed the concepts of fluid and crystallized intelligence and further developed the theory with Horn (1967). The Cattell-Horn theory of fluid and crystallized intelligence suggested that intelligence was composed of a number of different abilities that interacted and worked together to produce overall individual intelligence.

Fluid intelligence involves being able to think and reason abstractly and solve problems (Cattell, 1963). This ability is considered independent of learning, experience, and education. Examples of the use of fluid intelligence include solving puzzles and coming up with problem-solving strategies. Crystallized intelligence involves knowledge that comes from prior learning and past experiences. Situations that require crystallized intelligence

include reading comprehension and vocabulary exams. This type of intelligence is based upon facts and is rooted in experiences. As we age and accumulate new knowledge and understanding, crystallized intelligence becomes stronger (Catell, 1963; Horn & Catell, 1967). Both types of intelligence are equally important in everyday life (Knox, 1977).

Fluid intelligence (*Gf*) is a complex human ability that allows us to adapt our thinking to a new cognitive problem or situation (Carpenter, Just & Shell, 1990). *Gf* is critical for a wide variety of cognitive tasks (Gray & Thompson, 2004), and it is considered one of the most important factors in learning. Moreover, *Gf* is closely related to professional and educational success especially in complex and demanding environments (Gottfredson, 1997). There is considerable agreement that *Gf* is robust against influences of education and socialization (Gray & Thompson, 2004), Catell (1963), Baltes, Staudinger, & Lindenberger, 1999). It has been argued that the strong relationship between working memory and *Gf* primarily results from the involvement of attentional control being essential for both skills (Halford, Cowan, & Andrews, 2007).

With regard to vocabulary, the notions of crystallised and fluid intelligence can be utilised as well. For instance, vocabulary knowledge has been described as static or crystallised knowledge. On the contrary, the ability to use a wide range of different words in conversation can be conceptualized as one type of fluid knowledge (Hayashi, Kato, Igarashi, & Kashima (2007). How then can vocabulary use as a type of fluid knowledge be conceptualised within Gupta and Tisdale's (2009) model? We understand that the acoustic traces that we hear generate the word form phonological representations, and the word form representations evoke a semantic representation to yield meaning. We also know that VSTM, as a mechanism of learning word-form representations, serves as an antechamber prior to the establishment of more durable long term memory traces, or stored vocabulary (crystallised) knowledge. With this information in hand, let us consider the Figure 3 as a framework for

understanding the relationships among vocabulary knowledge (crystallised knowledge), vocabulary use (fluid knowledge), and the role of verbal short-term memory.

It is important to define the difference between vocabulary knowledge (crystallised knowledge) and vocabulary use (or fluid knowledge, or deployment, measured by lexical diversity in conversation speech) in children. The left side of Figure 3, involving activation of the expressive link, indicates that some cognitive processing is involved in retrieving a word form for a referent and producing it in conversational speech. In models of psycholinguistic processing (e.g., Stackhouse & Wells, 1997), the ability to use words in conversation depends not only on the strength of phonological representations, but also on the ability to rapidly assemble a motor programme and the associated motor plan, and to then articulate it. We proposed that this sequence of tasks draws on VSTM abilities (represented by the dashed line in Figure 3), and that the ability to access a word for use in conversation must be somewhat determined by VSTM skills.

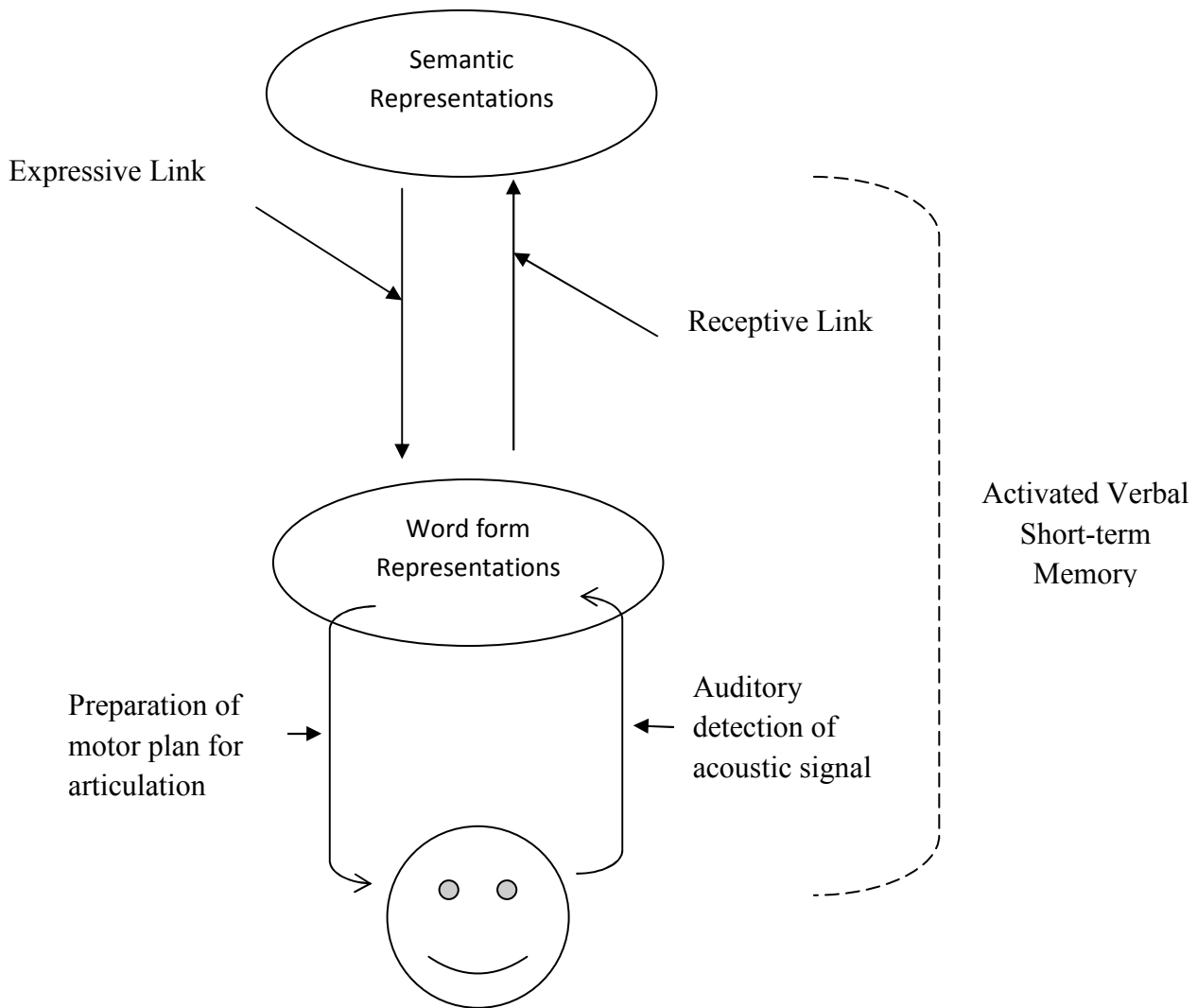


Figure 3. A modification of the Gupta and Tisdale (2009) framework to reflect situated vocabulary use.

As previously noted, knowing a word may not necessarily indicate that it is used. Stokes and Fletcher (2000; 2003) reported a reduced deployment of aspect markers in children with SLI in comparison with their language-matched and age-matched peers. The conclusion was that while children with SLI had knowledge of aspect markers, they did not use them in the same way as children without SLI. Klee, Stokes, Wong, Fletcher, and Gavin (2004) determined the validity and clinical utility of the language sampling measures in Cantonese to explore lexical diversity. This was evaluated by examining how Cantonese-

speaking children with SLI (N = 15; Mean age = 56 months) compared to age-matched (N = 15) and language matched (N = 15; Mean age = 36 months)) peers on the measures of utterance length and lexical diversity and whether these three groups can be differentiated on the basis of these measures. The tests of group differences showed that TD children had significantly higher MLU and lexical diversity scores than SLI children of the same age. The authors concluded that lexical diversity was compromised in children with SLI.

Earlier work had been conducted with English-speaking children. A total of 75 monolingual English speaking preschool-age children participated in a study carried out by Watkins, Kelly, Harbers and Hollis (1995). The children consisted of 25 with SLI, 25 TD children equated to the children with SLI on the basis of language ability (LE), and 25 TD children equated to the children with SLI on the basis of chronological age (AE). Based on calculation of the number of different words used in 50- and 100-utterance samples, it was revealed that the AE group exceeded the LE and SLI groups. This finding suggested that number of different words used by SLI was less than that used by their age equivalent peers.

From the point of view of productive knowledge and use, knowing a word mainly involves being able to say it with the correct pronunciation including stress (Nation, 2001). Production also involves being able to write a word with correct spelling, being able to construct it using the correct word parts in their appropriate forms, being able to produce the word in different contexts to express a range of meanings, and being able to produce the synonyms and antonyms of the word (Nation, 2001). Finally, productive word knowledge also involves being able to use it correctly in a sentence, and being able to decide to use (or not use) the word to suit the situation (Nation, 2001).

The questions is whether there is evidence of greater productive vocabulary in children with better phonological memory skills that mirrors previous evidence of differences

in vocabulary comprehension found to be associated with phonological memory ability. Thus, if the strength of phonological representations is proposed to be a function of the efficiency of short-term memory, then there may be implications of the role of VSTM on not only vocabulary comprehension but also for production. If a child has weak phonological (word) representations relative to TD peers, then it is possible that poor working memory will mean that a restricted range of words may be activated for conversation. While the child's vocabulary knowledge may be equivalent to his/her peers, it is possible that only the words with the most robust phonological representations will be retrieved for production. Presumably, these would be the words that have a high resting activation. It is proposed that children with strong VSTM skills are able to access, retrieve, and produce a diverse range of words in conversation because they have greater flexibility in the range of phonological representations that can be activated in running speech. Conversely, children with weaker VSTM abilities are able to access, retrieve, and produced a restricted range of words in conversation because they have reduced flexibility in the range of phonological representations that can be rapidly activated in running speech.

The restricted range of syntactic constructions found in the language corpora of children with poor NWR skills, compared with their peers with better NWR skills, is entirely in accordance with this proposal (Speidel, 1989). This impoverished use of varied grammatical constructions may indeed reflect the influence of phonological memory abilities which are crucial in the short-term retention of adult syntactic models which eventually come to form a storehouse of syntactic constructions which are subsequently employed as templates for spontaneous utterances. By this view, children with better phonological memory abilities would be presumed to have a more extensive range of syntactic models with high resting activations on which to draw when producing utterances. The incorporation of

these templates into an intended utterance may reduce the demands on processing resources such that more complex and longer utterances can be produced (Adams & Gathercole, 2000). Speidel's (1989) theory would then predict that children with poorer phonological memory skills would be expected to produce relatively shorter utterances and a less comprehensive range of syntactic constructions in their speech, as well as a reduced range of lexical types (Adams & Gathercole, 2000). Only using a restricted number of words would effectively reduce short-term memory demands, and this would be reflected in a child's poorer lexical diversity counts in connected speech.

It is evident from the above literature that a deficit in VSTM may be the primary contributor to impairment in vocabulary learning of children with SLI. We can conclude that children with reduced use of language may also show evidence of reduced NWR ability. Although there has been considerable research examining the relationship between VSTM and vocabulary knowledge, there has been very little research examining the relationship between VSTM and vocabulary use in early childhood.

Adams and Gathercole (1995) had shown that three-year-old children with typically developing language but with either good or poor phonological memory skills, classified on the basis of NWR and digit span performance, differed significantly both in the extent of their productive vocabulary and in the sophistication and the breadth of the grammatical forms they produced in spontaneous speech. Blake, Austin, Cannon, Lisus, and Vaughan (1994) also found that memory span for words was significantly related to the mean length of utterance (MLU) of the spontaneous speech of three-year old (although not four-year-old) children. A further experiment in their study, in which the spontaneous speech of a group of children with a mean age of 32 months was analysed, revealed that memory span for words shared a significant amount of unique variance with MLU, over and above that which could

be accounted for in terms of more general maturational and intellectual factors such as age or non-verbal ability. However, these studies are the few that have examined this question.

One possible reason for this lack of research is that earlier studies of skilled adult speakers failed to demonstrate any direct associations between short-term memory and language production (see Gathercole & Baddeley, 1993a). As a result, there is minimal evidence regarding the correlation between VSTM, which is measured using NWR, and the number of different words used during conversation by a child. One reason why phonological memory processes may support the production of spoken language in children but not adults is that the automated modular system of skilled adult speech production seems unlikely to characterize adequately the speech of children in the process of mastering this complex skill (Adams & Gathercole, 1995). Bock (1982) has proposed that speech production processes may operate within a limited capacity processing system, and that the development of spoken language skills may constitute a progression from controlled to automated processing.

In Figure 3, the acquisition of receptive language and the relationship between VSTM and vocabulary knowledge is clear, but the proposed role of VSTM in vocabulary use is unproved. From the studies mentioned above, we can hypothesise that fluid knowledge (vocabulary use) should be related to processing mechanisms, and VSTM memory in particular. The hypothesis is that children who use a restricted set of words in conversation, (that is, they have poorer lexical diversity) also have poorer VSTM skills, as measured by a NWR task. However, it is unknown whether children with good VSTM have good lexical diversity. Before addressing this question, we describe measures of lexical diversity.

4.0 Ways of measuring lexical diversity

Johnson (1944) named the ratio of different words (types) to total words (tokens) the type-token ratio (number of word types divided by the total number of word tokens in a

language sample). He introduced it as an experimental metric to be investigated as a measure of vocabulary flexibility or variability, designed to indicate certain aspects of language adequacy. The type-token ratio has also been described as a measure of vocabulary diversity (Cramblit & Siegel, 1977), a measure of vocabulary richness (Andolina, 1980) and a tool to be used in the identification of language impairment (Manschreck, Maher, & Ader, 1981). The type-token ratio (TTR) has been utilized in various ways in research. It has been used as a measure of lexical diversity to determine developmental trends in the vocabulary performance of children (Templin, 1957; Bowerman, 1973; Andolina, 1980). Gibson, Gruner, Kibler and Kelly (1966) utilized the TTR to compare the vocabulary diversity of oral and written language samples. Watkins, Rice and Moltz (1993) compared the verb types, verb tokens, and verb type token ratios (TTRs) collected from 14 children with SLI, 14 age-equivalent peers, and 14 language-equivalent peers of children. The children with SLI had significantly lower verb TTRs than did their age- and language-equivalent peers (.42 for the children with SLI, .50 and .48 for the language-equivalent and age-equivalent peers, respectively). Informal analysis of the types and tokens composing the verb TTRs revealed that children with SLI produced fewer verb types and tokens than their age-equivalent peers.

Miller (1991) evaluated the use of a different measure of lexical diversity, that of the number of different words that a child could generate in a language sample of spontaneous speech. The extent to which the number of different words produced (NDW) and the number of total words used (NTW) correlated with age and mean length of utterance (MLU). NDW and NTW contributed significantly to the prediction of age based on MLU, which suggested that MLU, NDW, and NTW were each measuring different aspects of language proficiency. According to Miller, NDW provides a measure of semantic proficiency, and NTW represents a more global language facility, including skills such as speaking rate, utterance formulation

ability, and speech-motor maturation. Miller (1991) recommended that measures of language production be applied to the task of differentiating children with language impairment from their TD peers, and in identifying different types of language impairment. It is a measure of NDW that is used in the current research.

5.0 Study aim

The aim of this study was to explore the relationship between a child's vocabulary use and NWR scores. The hypothesis was that not only is NWR ability related to vocabulary knowledge (as measured by tests of receptive and expressive vocabulary) but it is also significantly related to vocabulary use.

6.0 Research question:

Is there a significant relationship between verbal short term memory and fluid vocabulary skills when crystallised vocabulary skills are controlled?

7.0 Method

7.1 Participants

Participants were 130 monolingual, English-speaking children aged 24-30 months ($M = 27.00$, $SD = 1.43$) of whom 70 were female, with no diagnosed developmental disability, as determined from the demographics questionnaire (see below). Children were sourced from local nurseries and parent-toddler groups or a university research database.

7.2 Procedure

7.2.1 Parent-report questionnaires. Parents were mailed an information sheet explaining the study, an informed consent form and two questionnaires, which they were asked to complete in no particular order. One questionnaire addressed family/child demographics, including the child's birth date, age, sex, birth order, medical history including

ear infections, family history of speech/language delay, parents' education level, concern about language development, and languages spoken in the home. The other questionnaire focussed on the child's expressive language development, using a form of the MacArthur-Bates Communicative Development Inventory: Word and Sentences (CDI, Fenson et al., 1993) adapted to British English (Klee & Harrison, 2001). This parent-report measure consists of a vocabulary checklist of 672 words as well as a checklist of grammatical constructions that, children between 16-30 months of age are likely to use.

7.2.2 Vocabulary Knowledge. The Expressive One-Word Picture Vocabulary Test (Brownell, 2000a) and the Receptive One-Word Picture Vocabulary Test (Brownell, 2000b) were administered to gain an estimation of the size of children's expressive and receptive lexicons. Following Adams and Gathercole (1996), we generated the mean Z-score of the two tests, yielding a variable called vocabulary knowledge (VK). The Z scores were generated as a function of age in months (i.e. a Z score for 24, 25, 26 months, etc), to control for the effects of age.

7.2.3 Nonword repetition task. Stokes and Klee (2009) developed a test of NWR that would be suitable for children two years of age. The Test of Early Nonword Repetition (TENR) was designed to assess the NWR ability of very young children by using CV/CVC repeated structures that contained consonants that were within the phonetic inventories of two year olds. Further, the task was motivating for young children (Stokes & Klee, 2009). The TENR contained 15 one-, two-, three-, and four-syllable nonsense words that were presented in live voice. The child rolled a ball down a chute as a reward for attempting to imitate the nonsense word. Each correct phoneme was awarded a point and the total percentage correct was calculated. The children included in this research were the 130 children who attempted each nonword on the test.

7.2.4 Language sample analysis. Play sessions between the parents/caregivers and children of 20 minutes duration were video recorded. The children were provided with a standard set of toys, including a farm house, a dolls house, a train set, and a tea set. Language samples were transcribed using the Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1992) software, and manual instructions were followed for utterance segmentation and mark up. Variables generated for analysis were the number of different word roots (NDW), mean length of utterance (MLU) in words, total number of complete utterances (TNU) and total main body words (TNW). Our main variable of interest was the lexical diversity that a child displayed in a conversational sample (the NDW). The number of complete and intelligible utterances varied across children (Table 1), and this difference in verbosity may have contributed to a difference in the number of different word roots across children (Hoff, 2003). Some studies have used the metric of the number of different words per 100 utterances (Klee, 1992), or per 100 word tokens, while other studies use the raw NDW value without controlling for number of utterances or number of tokens (e.g., Bedore, Pena, Gillam, & Ho, 2010; Heilmann, Nockerts, & Miller, 2010). In order to take verbosity into account, we divided the NDW by the total number of utterances, to generate a variable labelled as NDW_{TNU} .

8.0 Results

The research question was: Is there a significant relationship between verbal short-term memory and fluid vocabulary skills when crystallized vocabulary skills are controlled? The hypothesis was that children's verbal short term memory ability (VSTM) is an important factor in the range of different words that children are able to deploy during a conversation. Before addressing this specific question, descriptive statistics and the relationships among the study variables are presented.

8.1 Descriptive statistics

Table 1 presents the minimum, maximum, mean scores and standard deviations of the descriptive variables NWR, age, vocabulary knowledge, NDW, total number of utterances, and number of complete utterances. Data for the verbosity-controlled lexical diversity measure (NDW/TNU) are also included.

Table 1: Descriptive Results

	N	Minimum	Maximum	Mean	Standard Deviation
Vocabulary knowledge	130	-2.19	2.19	.00	.89
Total number of utterances	130	24	305	123.88	46.39
Total number of words	130	25	706	284.45	143.77
Number of different words	130	12	164	90.45	30.39
^a NDW _{TNU}	130	.20	1.12	.75	.19
Age	130	24	30	27.00	1.43
Nonword repetition	130	30.00	100.00	80.40	13.93

Note. ^a indicates Number of Different Words divided by the Total Number of Utterances

8.2 Relationship among variables

The correlations among variables are shown in Table 2. There were significant correlations among all variables, ranging from weak relationships (for example age by NDW_{TNU}, $r(130) = .21, p < 0.02$) to moderately strong (vocabulary knowledge by nonword repetition, $r(130) = .56, p < 0.001$). The correlations indicate that when bivariate

relationships were explored, NWR accounted for 32% of the variance in VK, and it accounted for 30% of the variance in NDW_{TNU} .

Table 2: Bivariate Correlations (N = 130)

	${}^aNDW_{TNU}$	Nonword repetition	Age
Vocabulary knowledge	.46**	.56**	.24**
${}^aNDW_{TNU}$	-	.55**	.21*
Nonword repetition		-	.27**

Note. ^a indicates Number of Different Words by the Total Number of Utterances

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Visual representations of the relationship between the variables are presented in Figures 4, 5 and 6. The figures illustrate the variability of scores around the regression fit line, but clearly show the strong relationship between vocabulary knowledge and lexical diversity (Figure 4), NWR scores and lexical diversity (Figure 5) and NWR and vocabulary knowledge (Figure 6).

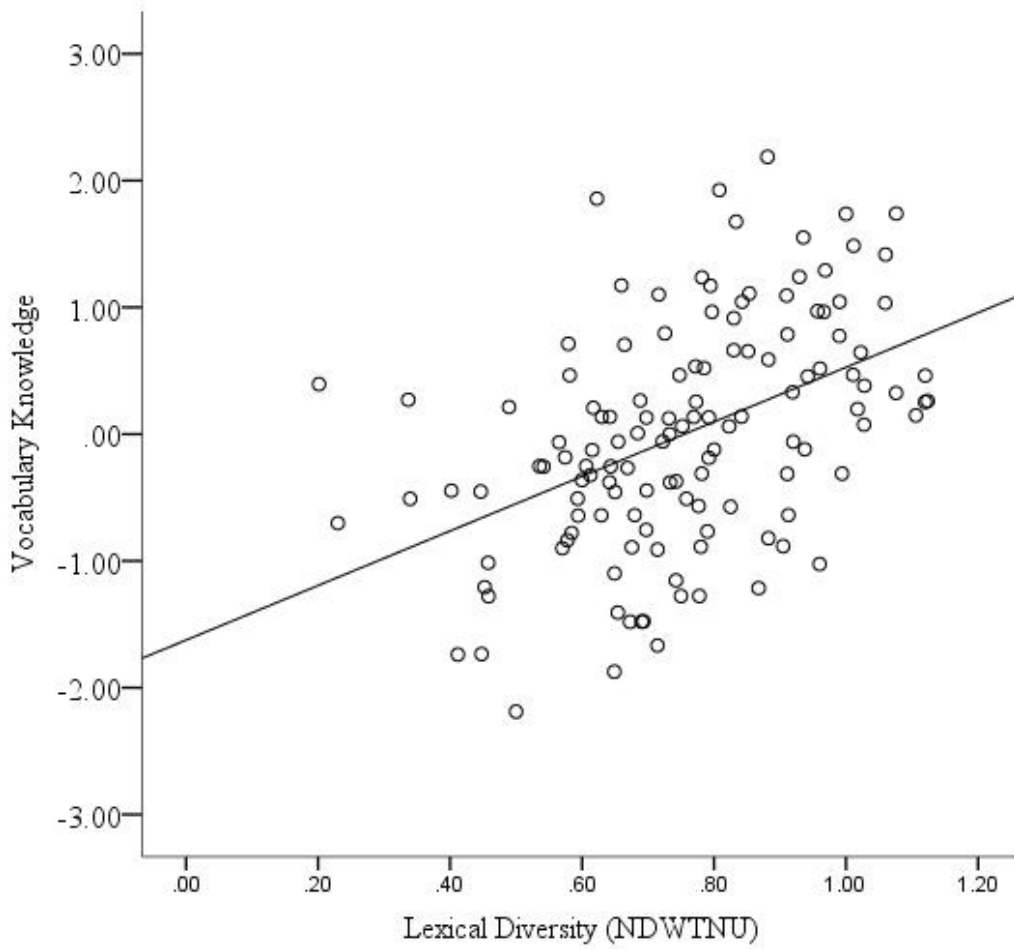


Figure 4: Scatterplot of the Relationship Between Vocabulary Knowledge by Lexical Diversity (NDW_{TNU})

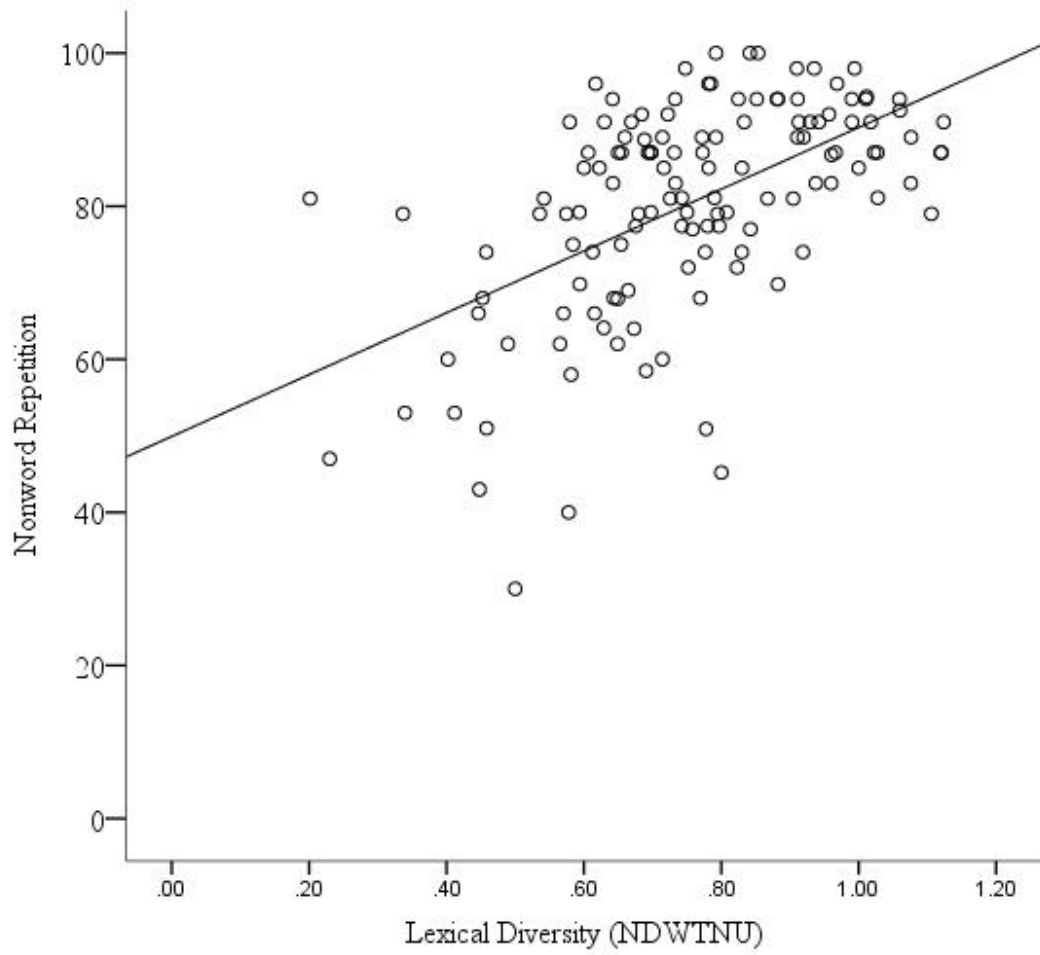


Figure 5: Scatterplot of the Relationship Between Nonword Repetition by Lexical Diversity (NDW_{TNU})

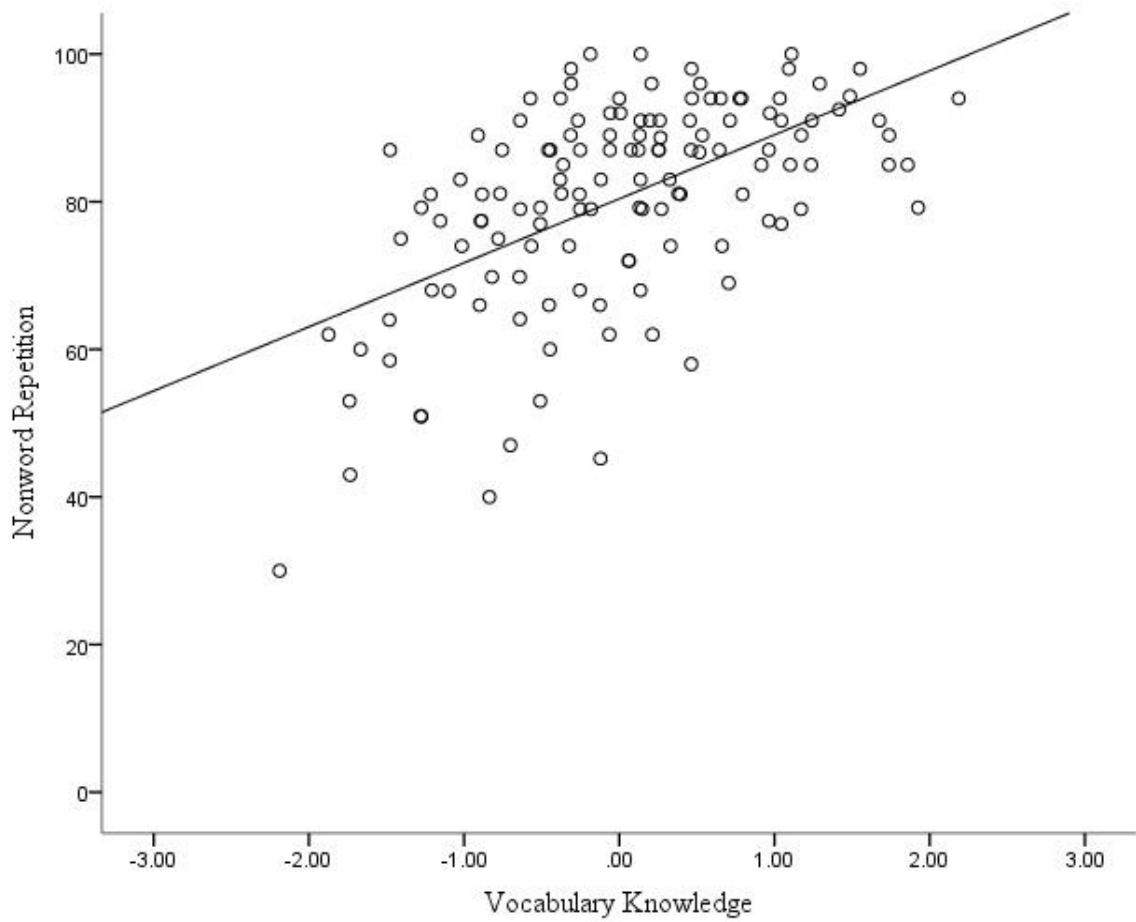


Figure 6: Scatterplot of the Relationship Between Nonword Repetition by Vocabulary Knowledge

8.3 Regressions

The research question 'Is there a significant relationship between verbal short-term memory and fluid vocabulary skills when crystallized vocabulary skills are controlled' was determined by a multiple regression using the forward entry method. This allows for exploration of the relationship between VSTM and NDW_{TNU} , with the effect of VK taken into account. The model was significant ($F(1,127) = 32.26, p < .001$), with NWR and VK together accounting for 34% of the variance in NDW_{TNU} scores. Of most relevance here, is that NWR accounted for 31% of the variance in NDW_{TNU} scores ($F(1,128) = 56.17, p < 0.01$), with VK accounting for an additional 3.2% of unique variance. Age was not a significant predictor once NWR and VK were entered in the model. Table 3 shows the coefficients.

Table 3: *Regression Coefficients with NWR, Age and Vocabulary Knowledge as Predictors of NDW_{TNU} .*

Model		Standard Error	t	p	95.0% CI ^a for B		
					Lower	Upper	
1	(Constant)	.15	.08	1.79	.08	-.02	.31
	NWR ^b	.01	<.01	7.50	<.01	<.01	.01
2	(Constant)	.28	.01	2.89	.01	.09	.47
	NWR	<.01	<.01	4.96	<.01	<.01	.01
	VK ^c	.05	.02	2.47	.02	.01	.08

Note. ^aindicates Confidence Intervals; ^bindicates nonword repetition scores; ^cindicates vocabulary knowledge (see text).

Summary of the results: Nonword repetition ability was a significant predictor of vocabulary deployment during conversation, even when vocabulary knowledge was controlled.

9.0 Discussion

There are many studies which demonstrate that nonword repetition (NWR) is a valid and reliable measure of VSTM (Gathercole & Baddeley, 1990; Gathercole, et al., 1992). There are just as many studies that demonstrate that there is a significant relationship between VSTM and vocabulary acquisition, that is, good VSTM indicates good receptive language scores (Gathercole & Baddeley 1990; Baddeley et al., 1998b). For example, Gathercole and Baddeley, (1990) showed that the children with poor language skills showed poor NWR scores, which demonstrated that NWR is a good predictor of language acquisition skills in children. It seems that common processes underlie both VSTM and vocabulary acquisition (Gupta & Macwhinney 1997). The relationship doesn't stop there. There are as many studies again that have demonstrated that children with poor language development, and those with specific language impairment (SLI) also have poor NWR skills, despite having normal hearing and non verbal intelligence (Graf Estes, et al., 2007). NWR has gained a lot of attention in the recent years not only because of its importance in the process of language acquisition occurring in children especially with learning new vocabulary, but also because of its significant clinical value. The question is why do we see these relationships?

9.1 NWR and language knowledge

NWR mimics part of the processing involved in new word learning, where we learn a novel word by repeating its phonological form (Archibald, Joanisse, & Shepherd, 2008). Consistent with this, NWR is highly associated with vocabulary knowledge for a speaker's native language (e.g., Gathercole & Baddeley, 1989; Gupta, 2003) and their ability to learn a foreign language (e.g., Cheung, 1996; Masoura & Gathercole, 1999). In experimental studies, poor NWR has been linked with slower or less accurate new word learning (Gathercole, et

al., 1997; Papagno & Vallar, 1995), and difficulties acquiring foreign vocabulary (Palladino & Cornoldi, 2004).

It is clear that vocabulary size is a major determiner of the success of NWR. That is, a learner with a vocabulary size of, say, a 10000 words is expected to have a greater phonological knowledge than a learner with a vocabulary size of a 2000 words, and this greater knowledge would facilitate learning further new words (Gupta & Tisdale, 2009). This role of vocabulary size is prominent when we talk about repetition of novel word forms or nonwords (Gupta & Tisdale, 2009). When the sequence of input sounds which constitutes a novel or known word form is introduced to the system, an internal representation of that word form is evoked, which consists of a sequence of sublexical units such as phonemes or syllables. This internal representation of the word form when evoked, in turn evokes any associated semantic representation through the receptive link. On the other hand, if a semantic representation is activated in the system, it can activate any associated internal word-form representation, through the expressive link (Gupta & Tisdale, 2009). By phonological input or via semantics, when an internal word-form representation is activated, it allows formation of a motor program and motor plan in order to produce the word form, as output sublexical unit sequences. If the internal word-form representation was activated through semantics, this production would constitute naming or if it was activated through an input phonological sequence, it would constitute repetition (Gupta & Tisdale, 2009). Gupta and Tisdale's (2009) findings showed that NWR was causally affected by the vocabulary size, and vocabulary knowledge influences vocabulary growth.

9.2 Language knowledge and language use

It is clear then that the notion of vocabulary knowledge needs to be separated from the notion of vocabulary use if one wants to explore how a fluid memory system (verbal working

memory) is related to the ability to use words in conversation. Vocabulary knowledge is considered as static or crystallized knowledge and the ability to use a wide range of different words in conversation is regarded as one type of fluid knowledge (Hayashi, et al., 2007). Crystallized cognitive systems are capable of accumulating long-term knowledge (e.g. language and semantic knowledge). Fluid capacities, such as attention and temporary storage, and vocabulary use occur online in real-time processing. Using these definitions, the aim of this study was to investigate the relationship between verbal short term memory (VSTM) and vocabulary use in young children, when vocabulary knowledge was controlled

Although there was a significant previous study by Adams and Gathercole (2000) on typically developing 4 year old children, who reported that children with good phonological memory produced wider repertoire of words and syntactic constructions, on average longer utterances in their spontaneous speech, their study they did not control for the total number of words. Unlike Adams and Gathercole (2000), the Total Number of Utterances was controlled for in this study. Thus the research question in this study focused on examining whether the scores of NWR correlated with that of the Number of Different Words_{TNU} (NDW/number of total utterance) used in conversation, when vocabulary knowledge was controlled. VSTM was reliably measured using a NWR task and lexical diversity (NDWTNU) was calculated using SALT software.

9.3 Contribution to the literature

The results presented in this thesis show a clear trend in the expected direction, that is, there was a significant correlation between verbal short term memory skills and lexical diversity in children. The statistical analyses show that there was a noteworthy correlation between NWR scores and lexical diversity used in conversation. Various studies have established the fact that good NWR scores indicate good VSTM and therefore good

vocabulary knowledge/crystallised knowledge. But the relationship between VSTM and lexical diversity/fluid vocabulary skills is an area which has been little explored. The current study established the fact that children with good VSTM ability used a greater variety of different words in their conversation than children with poorer VSTM ability, which also means that the former group had good fluid vocabulary skills.

Adams and Gathercole (1996) explained the implications of phonological memory skills in the development of automated speech output. Firstly, phonological memory is crucial in the long-term learning of lexemes; secondly, in the absence of lexemes, there would be a reliance on temporarily created phonological representations as the motor program for articulatory output is compiled. They explained that phonological memory would serve to maintain this representation. Thirdly, the availability of lexemes would make the phonological information which is required for construction of the motor program for articulatory output automatically available. Therefore, when children learn to speak, the phonological form of a produced utterance makes demands on the limited capacity resources of phonological memory. Such an account proposes that it is the relationship between phonological memory and expressive language development reflects the processing of phonological information when there is little lexical representational support for word production (Adams & Gathercole, 1996). 'Phonological memory may be required as a speech output buffer when the articulatory motor program of an intended utterance cannot be compiled from long term phonological knowledge' (Adams & Gathercole, 1996, p. 219).

There have been many proposals for a dissociation between lexical and non-lexical processing in the pronunciation of words. Snowling and colleagues (1981; Snowling, Goulandris, Bowlby, & Howell, 1986) suggested that children with dyslexia had greater difficulty in repeating nonwords than words due to non-lexical item repetition relying on

phonological processing, in the absence of any support from semantics. To be more specific, if the word is in a child's spoken vocabulary, it can be presumed that lexical activation may result in the automatic access of a motor program for articulation. The greater association seen between language development and NWR ability can be best explained in terms of a common reliance on the efficiency of the processes of temporary storage and retrieval of novel phonological forms, in the (relative) absence of a support from long-term phonological representations (Adams & Gathercole, 1996). One proposal for a contribution of phonological memory to spoken language development is in terms of its involvement in the creation of lexically stored phonological representations that are subsequently applied in speech production (Adams & Gathercole, 1996). The proposal that phonological memory would play a more critical role during speech production even in the absence of long-term phonological representations of words, and possibly phrases, aligns closely with theories that propose and advance in language development as a process of moving from controlled to automated word production and articulation (e.g., Bock, 1982).

Adams and Gathercole (1996) also suggested that the association between the ability to maintain phonological information over short time periods and spoken language acquisition in young children will be greatest to the extent that lexical support for both tasks is minimized. This is also consistent with Montgomery's (2000a) statement on an individual's ability to comprehend and produce language. That is, this ability will depend on the capability to actively maintain and integrate linguistic information within working memory.

In order to form a hypothesis about why working memory would have such a strong relationship with vocabulary use, a modified framework of functional word learning and use was presented (Figure 3). The accompanying text argued that poor lexical diversity in conversation reflected poorer working memory skills, such that only words with strong/robust

phonological representations would be accessed during conversation. This robustness can be thought of as word forms that grow stronger from repeated use (the definition of low lexical diversity in conversation), whereas forms that are infrequently used are not accessed, and the counts of lexical diversity are lower. On this account, accessing the stronger phonological representations is less taxing of working memory, leaving more resources for engaging in other tasks such as maintaining focus of attention on play or the interlocutor.

Hence, from the model that we described earlier (Figure 3) and the results about phonological memory and fluid vocabulary skills, we can conclude that children with poor phonological memory (including those with language impairment) have poorer lexical diversity scores (see Gupta & Tisdale, 2009; Leonard, 1998; Klee, Stokes, Wong, Fletcher, & Gavin, 2004) because the symbiotic relationship between VSTM and lexical retrieval. From the results of our study with typically developing children, this knowledge can be extended to conclude that children with good verbal short term memory use a vocabulary which is diverse and richer (Cramblit & Siegel, 1977; Andolina, 1980), because more diverse representations can be activated via stronger VSTM abilities. Importantly, this was demonstrated while crystallized vocabulary skill was controlled.

A measure of phonological short-term memory (PTSM - NWR) and a measure of vocabulary knowledge together explain 34% of the variance in vocabulary use in conversation. Importantly, PSTM contributed 31% to the variance accounted for. We have found a strong role for PSTM in vocabulary use, over and above the influence of vocabulary knowledge. The multiple regression results suggest that children with good NWR scores are likely to have good expressive vocabulary and good lexical diversity in their speech. This research has made a unique and novel contribution to the literature on relationships among cognitive processes, and word use and VSTM in particular.

10.0 Study Limitations

The measure of lexical diversity was controlled by the number of utterances in a child's conversation. The study should be replicated using the control of total number of words in a child's sample. Further, the explanation of the finding raises the question of frequency of activation of word forms, but frequency was not directly measured in this study. This also requires follow-up.

11.0 Future implications

There are a number of studies that could be planned to apply and extend the novel findings presented here. NWR as a measure of vocabulary skills in children has great potential to be used as a preliminary screening in two year olds to identify potential language problems. In future studies, we hope to demonstrate in much greater detail the validity of this study in a variety of children, for example, children who are in a wider age range, and children who are not typically developing. If verbal short term memory problems are a reason for poor expressive vocabulary skills in children, then finding a way to improve this function could potentially be advantageous in children with poor expressive language skills. Finally, further research should explore how the frequency of word selection in conversational speech is related to lexical diversity and NWR skills.

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