THE ROLE OF PHONOLOGICAL MEMORY IN VOCABULARY DEVELOPMENT IN ESL CHILDREN

by

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy
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Abstract

The Role of Phonological Memory in Vocabulary Development in ESL Children

Doctor of Philosophy

2000

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There is evidence that phonological memory skills contribute to the learning of unfamiliar phonological sequences in English-as-a-first-language (EL1) children (Baddeley, Gathercole, & Papagno, 1998) and older English-as-a-second-language (ESL) children (Service, 1992; Service & Kohonen, 1995). The present study investigated the specificity of the role of phonological memory skills in the vocabulary development of young ESL learners. Ninety-eight first-graders, 40 EL1 children and 58 native speakers of Punjabi learning English as a second language participated in a longitudinal study. Measures of phonological memory, phonological awareness, vocabulary, and word recognition were administered at age 6 and again 1.5 years later. With the exception of a phonological memory task consisting of Hebrew pseudowords (administered for the purposes of reducing the influence of existing long-term phonological knowledge on performance), all other tasks used English-language stimuli. Cross-lagged correlational and hierarchical regression analyses suggest that the ability to repeat unfamiliar phonological sequences, a measure of
phonological memory, is a significant predictor of later vocabulary knowledge in
EL1 and ESL children alike. Commonality analyses further suggest that for both
native and second-language learners, the role played by phonological memory
skills in vocabulary development is largely independent of other phonological
processing skills such as phonological awareness. Parallels are drawn between
the interrelatedness of phonological memory and phonological awareness skills
in explaining vocabulary development and in explaining reading development.
These results extend the already established link between phonological memory
skills and native vocabulary development to the realm of second-language
learning. The present findings also suggest that the role played by phonological
memory skills continues to be critical in vocabulary development into the early
elementary school years.
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Chapter 1: Introduction

One of the greatest cognitive achievements of childhood is the capacity to learn new vocabulary. Although the majority of children acquire new verbal information with relative ease, the rate of acquisition can vary enormously. While children diagnosed with specific language impairment (a disorder characterized by poor language development without accompanying intellectual deficits) demonstrate particular impairments in learning new vocabulary (Stark & Tallal, 1981), significant individual differences in so-called “normal” populations have also been noted.

One explication put forth to explain individual differences in vocabulary development has been the role of the phonological loop component of Baddeley and Hitch’s (1974) model of working memory (see Baddeley, Gathercole, & Papagno, 1998). There is a growing body of literature, both experimental and developmental, pointing to an association between children’s ability to hold in memory temporarily the phonological features of incoming verbal stimuli (measured most commonly by word span and pseudoword repetition tasks) and their level of vocabulary knowledge (for a review of the literature see Gathercole, Hitch, Service, & Martin, 1997). According to this view, phonological codes in the lexicon are established by abstracting the relevant speech sounds of the verbal items from representations held in phonological memory.

While the majority of research aimed at delineating the relation between phonological memory and vocabulary development has focused on the learning of native vocabularies, there is evidence to suggest that a similar association may exist with respect to the acquisition of a foreign language. Although many of
these studies have been experimental in nature, demonstrating, for example, that children’s ability to learn unfamiliar toy names is significantly associated with their ability to repeat back pseudowords (e.g., Gathercole & Baddeley, 1990b; Michas & Henry, 1994), there are preliminary findings from a longitudinal study which suggest that phonological memory skills may also underlie foreign-language development (Service, 1992; Service & Kohonen, 1995). If phonological memory skills do indeed contribute to the learning of unfamiliar phonological sequences, then it follows that there should be an association between such skills and the development of a foreign vocabulary.

While the task of outlining the cognitive mechanisms underlying foreign-vocabulary development is an important endeavour in and of itself, it is also critical in the sense that it contributes to the debate over whether or not the phonological loop is a language-dependent or independent system. Finding an association between phonological memory skills and new vocabulary learning irrespective of whether it is a native or foreign language would lend support to the notion that the phonological loop is language independent. At the same time, there is also evidence to suggest that performance on measures of phonological memory is sensitive to the learner’s already established phonological specifications in long-term memory (Gathercole, Willis, Emslie, Baddeley, 1991) as well as to their existing knowledge of the structure of the language (Metsala, 1999; Snowling, Chiat, & Hulme, 1991). This notion that earlier language experience influences the extent to which phonological memory is called on in new word learning most certainly has implications for the type of language being learned, namely, the extent to which the to-be-learned vocabulary items share the structural features of the native language.
Despite a plethora of evidence pointing to an association between the ability to hold in memory unfamiliar phonological sequences and native (possibly even foreign) vocabulary development, there has been little effort to make clear the specificity of that relation. In other words, is it the case that the observed association between immediate phonological memory performance and vocabulary knowledge is an artifact caused by the effect of a more general phonological processing ability (i.e., the ability to use phonological information to process language), or is there something unique about the role of the phonological loop in new word learning which sets it apart from the influence of other phonological processing skills. One approach to assessing the uniqueness of the role of phonological memory skills in vocabulary development is to measure the relative roles of phonological memory and other phonological processing skills in vocabulary learning. Results from two studies (Gathercole, Willis, & Baddeley, 1991; Metsala, 1999) examining the contributions made by both phonological memory and phonological awareness to vocabulary knowledge have yielded conflicting results, with phonological memory being a more or less potent predictor of vocabulary than phonological awareness.

A more concerted effort to delineate the relative roles of phonological memory and phonological awareness has been carried out in the area of reading acquisition, yielding somewhat more definitive results. In a series of longitudinal studies, Wagner and Torgesen along with their colleagues (e.g., Torgesen, Wagner, & Rashotte, 1994; Wagner, et al., 1997) present data which suggest that while both phonological memory and phonological awareness appear to be tapping a common underlying phonological processing component, only phonological awareness explains unique variance in word-level reading. It is
important to note, however, that there is some evidence which points to both phonological processing skills explaining independent variance in word recognition (e.g., Gottardo, Stanovich, & Siegel, 1996).

Given that the preponderance of the evidence in the reading literature points to phonological memory and phonological awareness tapping a common phonological ability, it is conceivable that a similar pattern of results will emerge with respect to vocabulary development. Establishing whether phonological memory and phonological awareness are similarly associated with vocabulary and reading development is critical if researchers are to make clear whether or not the interrelatedness between these two phonological processing skills is domain-specific, exerting differential effects on reading and vocabulary learning.

In an attempt to address some of the unreconciled issues brought to light in this brief review of the literature pertaining to the role of the phonological loop in vocabulary development, the present study posed the following questions:

1. Is there a relation between phonological memory and vocabulary development in children learning English as a second language (ESL)? If so, does it differ from that found in native English-speaking (EL1) children?

2. Is there a relation between phonological memory and reading development in ESL children? If so, does it differ from that found in EL1 children?

3. Do phonological memory skills make an independent contribution to native and second-language vocabulary development apart from the
influence of phonological awareness skills?

4. Do phonological memory skills make an independent contribution to native and second-language reading development apart from the influence of phonological awareness skills?
Chapter 2: Literature Review

2.1 Overview

In this chapter, literature from a number of different research areas is reviewed. While some of the topics are discussed in great detail, others are only touched on briefly. While these latter topics are not to be considered unimportant, they are not immediately relevant to the questions at hand.

The chapter is divided into several different sections. The first, entitled Working Memory Model, briefly describes the components of Baddeley and Hitch's (1974) working memory model, while outlining in greater detail the experimental investigations carried out in an attempt to assess the sound-based nature of the phonological loop. The process through which phonological representations are established in memory is also discussed.

Studies examining the association between phonological memory skills and vocabulary knowledge are reviewed under two headings, Relation Between Phonological Memory and Vocabulary and Relation Between Phonological Memory and Foreign-language Vocabulary Development. The first, a discussion of the association between phonological memory skills and native vocabulary learning focuses on three lines of research: (a) developmental, (b) experimental, and (c) neuropsychological. An alternate theory to that put forth by Gathercole and her colleagues explaining this relation is also reviewed. A review of Cheung and Service's work on the possible association between phonological memory skills and foreign-language vocabulary learning follows.

In the next two sections, Specificity of the Relation Between Phonological Memory and Vocabulary and Specificity of the Relation Between Phonological Memory and Reading, studies examining the relative
roles of phonological memory and phonological awareness in the domains of vocabulary and reading acquisition are reviewed.

2.2 Working Memory Model

Baddeley and Hitch's 1974 model of working memory was offered as a response to criticism surrounding the unitary view of the so-called modal model\(^1\) of human memory, of which Atkinson and Shiffrin's (1968) model was the most influential. A central concern for Baddeley and Hitch was the question of whether short-term memory could best be described as working memory, "a system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks such as comprehension, learning, and reasoning" (Baddeley, 1986, p. 34).\(^2\) The theory held by many researchers was that it was indeed the case that rather than simply being a storage system with a capacity of only six or seven digits, short-term memory was a dynamic memory process capable of performing a number of concurrent operations. This prevalent theory remained experimentally unsubstantiated until the mid-1960s.

The model, as it was put forth by Baddeley and Hitch in 1974 and in its subsequent revisions (Baddeley, 1986, 1990), is a multicomponent system (see Figure 1 for a schematic representation) which comprises broadly, a modality-free central executive and two modality-dependent storage systems, the visuo-spatial sketchpad and the phonological or articulatory loop (also referred to

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\(^1\)The central feature of the modal model (consisting of sensory buffer stores, a limited capacity short-term memory store, and a larger capacity long-term memory store) is the short-term store, which functions primarily as a holding store for information which is being either transferred to or extracted from long-term memory.

\(^2\)While short-term memory and working memory are clearly related, they are very much distinct constructs. Short-term memory is typically described as involving the passive storage of information (e.g., holding a street address in mind), while working memory considers the role of short-term storage in information processing (e.g., holding a street address in mind while attending to directions to that particular address).
Figure 1. A simplified representation of the working memory model (adapted from Baddeley, 1986).

as phonological memory or verbal short-term memory). A conceptualization of the working memory system as these compromising constituent parts has for some time been supported by experimental studies and more recently by neuroscientific data (see Gathercole, 1998, for a review of the literature).

The central executive is the main seat of control. Its primary function is to control the regulation and processing of information within the system, allocating inputs to other subsystems as well as retrieving information from long-term memory. Being of limited capacity, its efficiency is limited by its processing resources; processing overload results in the “downloading” of information to other memory systems. While relatively little is known about this aspect of working memory, it is thought that the central executive plays an important role in higher-level cognitive operations such as problem solving, reasoning, and decision making.

The primary function of the visuo-spatial sketchpad is to store and process material that is visual or spatial in nature. There is a large body of evidence which points to the existence of a temporary store for both visual and spatial information (thought to be involved in reading, imagery mnemonics and movement planning). Yet, there is debate over whether the two domains would
best be represented by a single system or two independent systems (for reviews of the literature, see Baddeley, 1996; Logie, 1993). Equally unclear is the relation between the visual-spatial system and the central executive. Contrary to the other working memory components, the phonological or articulatory loop, has been amply researched, and given its importance in the present context, will be reviewed in detail.

2.2.1 Phonological Memory

The phonological memory system, as its name suggests, is responsible for temporarily storing and maintaining verbal information. The phonological loop itself is further comprised of two subsystems; a phonological store and an articulatory rehearsal process (see Figure 2 for a schematic representation).

The phonological store holds the input as a phonological representation or code, which through a process of phonological coding, is derived from acoustic, temporal, and sequential features that comprise the sensory trace. The articulatory rehearsal process serves to refresh the rapidly decaying representation via subvocal rehearsal. It also functions to translate a nonspeech input such as a printed word into a phonological code through a process of phonological recoding, which can then be stored in the phonological store.

Verbal information, unlike nonspeech inputs, gains direct access to the phonological store. From a developmental perspective, it is thought that the phonological store is present in very young children, while the rehearsal component of the phonological loop does not become evident until around age seven (Gathercole & Hitch, 1993), at which point children slowly begin to develop increasingly sophisticated rehearsal strategies (Gathercole, 1998).

Experimental attempts to investigate the nature of the phonological loop
have revealed that immediate memory span\(^3\) (referring to the total number of items which can be recalled) is sensitive to the phenomena of phonological similarity, articulatory suppression, and word-length effects.

2.2.1.1 Nature of Phonological Memory: Phonological Similarity Effect

The phonological nature\(^4\) of this memory component was first noted by Conrad (1964; Conrad & Hull, 1964) and subsequently by Baddeley (1966a, 1966b). Initial studies revealed that recall of aurally-presented phonologically similar items (e.g., “cat,” “rat,” “mat”) was impoverished compared to that of phonologically dissimilar items (e.g., “cat,” “house,” “bear”). This so-called phonological similarity effect was also noted for stimuli which were visually presented, suggesting that the visual input was subsequently translated into a

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\(^3\)The memory span test, with its origins as a measure of mental capacity in the 1880s (cited in Baddeley, 1996), remains an important tool both from an applied perspective, as it is part of the most widely used battery of intelligence testing for both adults (WAIS-III, Wechsler, 1997) and children (WISC-III, Wechsler, 1991), as well as from a theoretical perspective, as it is often called on in experimental paradigms investigating the nature of short-term or working memory.

\(^4\)In the present context, as in the working memory literature, no distinction is made between information which is coded phonologically (i.e., codes which incorporate the phonemic and phonotactic character of the language) and that which is coded phonetically (i.e., codes which incorporate information on the acoustic variations of a single phoneme). Both kinds of coding are grouped together under the term phonological coding.
phonological code. From a working memory perspective, because phonological codes are prone to decay, the probability of contaminating or losing a phonetic feature which discriminates between items held in memory is greatest when there are the fewest number of differentiating features, thus making recall of the individual items difficult. The source of the phonological similarity effect is thought to be the phonological store (Baddeley, 1986).

2.2.1.2 Nature of Phonological Memory: Articulatory Suppression Effect

Experiments involving articulatory suppression have also been critical in shedding light on the nature of the phonological loop. There is a large body of evidence which suggests that asking subjects to repeat words such as "the" or "blah" while being presented with sequences of words or digits, has the effect of depressing accuracy of recall (e.g., Estes, 1973; Murray, 1967). The interpretation of these results within a working memory framework is that prevention of subvocal rehearsal which is required to maintain the phonological or verbal input in the phonological store, results in the decay of the verbal information. Furthermore, in the case of visually-presented stimuli, articulatory suppression has the effect of removing the phonological similarity effect (Levy, 1971; Murray, 1968; Paterson & Johnson, 1971). These findings have been interpreted as evidence for the importance of subvocal rehearsal in the recoding of nonspeech input into phonological codes. In other words, if subvocal rehearsal has been suppressed, then the phonological codes on which the similarity effect is based, have failed to be established.

2.2.1.3 Nature of Phonological Memory: Word-Length Effect

A final source of evidence for phonological coding in short-term memory comes from a series of experiments, conducted by Baddeley and his colleagues,
in which subjects were asked to recall lists of words with a varying number of syllables (Baddeley, Thomson, & Buchanan, 1975). In an initial experiment, subjects were found to recall lists of one-syllable words with greater accuracy than lists of five-syllable words (known as the word-length effect).

A subsequent study revealed that it was not the number of syllables per se that influenced the rate of accuracy, but rather the length of articulation; the more time required to articulate a word, the more time required for rehearsal. According to the working memory model, the number of items which can be successfully maintained in the memory store is directly dependent on both the rate of decay and rate of rehearsal. It follows, that sequences for which the rate of decay is lower than the rate of rehearsal will be more successfully maintained than sequences for which the opposite is true, namely, where the rate of rehearsal is lower than the rate of decay (Baddeley, 1986). Thus, the more time that is required to rehearse a single item, the fewer number of items can be expected to be maintained. Finally, under conditions of articulatory suppression, the word-length effect is removed for visually-presented stimuli (Baddeley et al., 1975), a finding lending further support to the theory that the representational processes involved in the temporary storage of verbal information operate on the basis of phonological features as opposed to those of a visual or semantic nature (Baddeley, 1986; Lachman, Lachman, & Butterfield, 1979).

2.2.1.4 Phonological Representations

It has been theorized that the difficulties demonstrated by learning-disabled children on phonological memory tasks are related to their inability to use phonological representations to store verbal information in the short-term memory store (Torgesen, 1988). It is not known, however, if the problem lies
with the codes themselves or whether the problem is more related to depressed processing of intact codes.

Phonological representations or codes are believed to be established through repeated exposure to the relevant speech sounds of the verbal items. It is through these repeated encounters that features of the speech sequence come to be sufficiently distinct and stable, thereby resulting in a permanent and accessible phonological trace in long-term memory (see Baddeley, 1986). It has been suggested that the quality and nature of the representation as well as its accessibility in long-term memory, severely impacts the ease with which it can be analyzed, processed, and held in memory (Fowler, 1991). From an experimental perspective, when a word is encountered in a phonological memory task (of which the memory span and pseudoword repetition tasks are the most widely used), the more stable and accessible the representation in long-term memory, the more easily it will be activated and recalled when re-encountered. In line with this argument is the finding that real words are recalled at a significantly higher rate than words with unfamiliar phonological forms (Gathercole & Baddeley, 1993a).

In the case of the pseudoword repetition paradigm (in which subjects are required to repeat back words consisting of phonologically unfamiliar sequences), superior repetition of highly “wordlike” pseudowords as compared with less wordlike pseudowords (termed the wordlikeness effect; Gathercole, Willis, Emslie, et al., 1991), is explained via a representational process referred to as redintegration (Schweikert, 1993). Redintegration is a process whereby phonological codes of familiar words are activated and become linked with the phonological sequences of novel words. Pseudowords which are more like real
words, when encountered, will activate a greater number of lexical representations with similar phonological codes, and on the basis of the overlapping features of these established representations, a phonological trace is constructed (Gathercole, Willis, Emslie, et al., 1991). Phonological traces which have lexical support thus require fewer working memory resources and will be more easily remembered.\(^5\)

Activation of the phonological codes in long-term memory is thought to occur via two different routes, depending on whether the information to-be-recalled is presented visually or aurally. In the case of the former, phonological codes are activated through a process known as \textit{articulatory coding} (Baddeley, 1986), referring to the role of subvocal rehearsal. When stimuli are presented aurally, on the other hand, the phonological codes are activated automatically, not requiring articulatory processes (Salame & Baddeley, 1982). However, under certain circumstances, for example, in order to strengthen the representation, articulatory processes are thought to still be employed (Baddeley et al., 1975).

Snowling, Goulandris, Bowlby, and Howell (1986) put forth a two route model (see Figure 3) of how the phonological codes of spoken speech units are accessed, taking into account the person’s familiarity with the incoming stimuli. The first route involves direct access to the articulatory output of the target word through the activation of the phonological code in long-term memory. This route is most successful for familiar words. The second route, most likely

\(^5\)The phonological loop as conceived of by Baddeley and Hitch in its original version (1974) and in its subsequent revisions (Baddeley, 1986, 1990), is not equipped to incorporate findings such as the \textit{lexicality effect} (which refers to the superior recall of real words compared to pseudowords; Hulme, Maughan, & Brown, 1991) or the wordlikeness effect, because of its lexical nature. A recent model by Gathercole and Martin (1996) accommodates these lexical effects by proposing an interactive link between the processes involved in the analysis of the incoming phonological sequence and the learner’s existing knowledge of the phonological characteristics of the language.
employed for processing unfamiliar words (real or pseudo) without corresponding representations in long-term memory, involves phoneme analysis of the speech sequence prior to the execution of the articulatory output. (A similar model is described for visually-presented items, with the exception of an additional step involving translation of the item from a nonspeech input into a speech input.)

2.3 Relation Between Phonological Memory and Vocabulary

One of the language processes in which phonological memory has been most heavily implicated is vocabulary learning. Baddeley and his colleagues contend that the phonological loop component of working memory is critical not so much for remembering familiar words, but rather for learning new words (Baddeley et al., 1998). According to Baddeley and Hitch’s working memory model, phonological memory mediates the long-term memory of phonological representations along with their lexical referents. It is through the temporary storage and maintenance of the phonological representation, that the word eventually finds its way into long-term storage as a stable memory trace and a part of the lexicon.
While both subcomponents of the phonological loop, the phonological store and rehearsal process, are considered important for the long-term retention of lexical items, it is the capacity of the phonological store to hold, temporarily, unfamiliar phonological sequences in memory, which is thought to be the most critical. Evidence for the importance of phonological memory in vocabulary learning stems from three lines of research: developmental, experimental, and neuropsychological.

2.3.1 Developmental Evidence

The majority of research pointing to a link between phonological memory and vocabulary learning has been of a developmental nature. One of the earliest and most important studies in this area is a longitudinal study conducted by Gathercole and Baddeley (1989a). In this study, 104 four- and five-year-old preschoolers, tested on two separate occasions one year apart, were administered a series of tasks measuring phonological memory (pseudoword repetition and sound mimicry), vocabulary, and nonverbal intelligence. Correlational analyses yielded strong intercorrelations between pseudoword repetition and vocabulary, both at age four and age five. Regression analyses with age and nonverbal intelligence partialled out, revealed that a significant percentage of the variance in the vocabulary scores, at age four and five, was accounted for by both pseudoword repetition and sound mimicry. It is important to note, however, that when sound mimicry followed pseudoword repetition in the regression equation, it failed to account for any additional variance beyond that explained by pseudoword repetition.

A particularly important result is the finding of a developmental relation between pseudoword repetition and vocabulary. With age, nonverbal ability,
and most importantly, vocabulary knowledge at age four accounted for, pseudoword repetition continued to explain a significant proportion of the variance in the vocabulary scores one year later. Gathercole and Baddeley argued that the predictive value of the pseudoword repetition measure was not simply a by-product of vocabulary knowledge one year earlier.

Since that study, there has been much effort to replicate and extend Gathercole and Baddeley's findings. These research endeavours have examined the role of phonological memory in vocabulary knowledge and development, both in "normally" developing children (e.g., Gathercole & Adams, 1993, 1994; Gathercole & Baddeley, 1989b; Gathercole, Willis, & Baddeley, 1991; Gathercole, Willis, Emslie, & Baddeley, 1992; Michas & Henry, 1994) and in children with disordered language development (e.g., Gathercole & Baddeley, 1990a; Montgomery, 1995).

2.3.1.1 Normal Language Development

A consistent finding in the studies of normally developing children is a link between the ability of young children to hold pseudowords in memory, and their level of vocabulary knowledge. Also frequently reported is the finding that the strength of the correlation between phonological memory and vocabulary diminishes over time.

One notable study attempted to delineate the causal structure of the relation between phonological memory and vocabulary across the preschool and early elementary years (Gathercole et al., 1992). Using the method of cross-lagged partial correlations\(^6\) with age and nonverbal ability partialled out,

\(^6\)This statistical method involves comparing two correlations across time, with a higher correlation expected in the causal direction (see also Crano & Mellon, 1978).
Gathercole and her colleagues found evidence of a changing causal relation between phonological memory and vocabulary (see Figure 4). Specifically, it was found that between the ages of four and five, early repetition scores were more closely associated with later vocabulary, than early vocabulary was with later repetition ability, suggesting a greater causal link in the forward direction between pseudoword repetition and vocabulary, than vice-versa. From age five and onward, however, the causal structure changes, with the link between early vocabulary and later pseudoword repetition being significantly stronger than that between early pseudoword repetition and later vocabulary. This latter finding suggests that past age five, long-term lexical knowledge appears to have a greater influence on phonological memory development, than phonological memory does on vocabulary development. This pattern of association between pseudoword repetition and vocabulary was maintained even when vocabulary knowledge at age four was controlled.

Numerous explanations have been put forth in an attempt to explain the apparent shift in causal direction. One suggestion relates to the maturational development of the phonological memory component; namely, that with age, the memory system becomes so sophisticated in handling incoming phonological information, that it fails to hold any constraints on vocabulary learning (Gathercole et al., 1992). It should be noted, however, that while children's phonological memory skills develop most significantly during primary school, individual differences in pseudoword repetition can still be found in adults (Nicolson, 1981). A greater reliance on analogies in new word learning (Gathercole, Willis, Emslie, et al., 1991), and a more sophisticated development of
Figure 4. Cross-lagged partial correlations between pseudoword repetition and vocabulary over a four year span (adapted from Gathercole et al., 1992).

* p < .01

2.3.1.2 Disordered Language Development

Evidence from children with developmental language impairments, who are characterized as having impaired vocabulary growth (see Stark & Tallal, 1981), suggests a similar relation between phonological memory and vocabulary to that found in their "normally" developing counterparts (Gathercole & Baddeley, 1990a; Montgomery, 1995; Taylor, Lean, & Schwartz, 1989). Gathercole and Baddeley (1990a) have proposed a direct causal link between a depressed phonological memory capacity and the delayed acquisition of various linguistic abilities. In their study, Gathercole and Baddeley compared the

semantic and conceptual skills required to handle the more abstract linguistic environment of the older child (see Gathercole & Baddeley, 1993b, for a more detailed discussion), have also been suggested. The role of reading as a pacemaker in later vocabulary development has also garnered much support (e.g., Cunningham & Stanovich, 1991; Gathercole et al., 1992; Nagy & Anderson, 1984). Cunningham and Stanovich (1991) found, for example, that differences in children's vocabulary knowledge could be explained in part by their familiarity with book titles, suggesting that exposure to print is related to vocabulary learning.
pseudoword repetition skills of children with specific language impairment (SLI) with control groups matched on verbal ability and nonverbal intelligence. The results showed that compared to the two control groups, SLI children repeated fewer longer syllable pseudowords relative to 1- and 2-syllable pseudowords. According to Gathercole and Baddeley, SLI children’s sensitivity to the word-length effect, in the absence of any perceptual processing or articulation difficulties, suggests that a depressed phonological store may be at the root of at least this type of disordered language development.7

2.3.1.3 Summary

Taken together, these developmental studies lend considerable support to the hypothesis that “adequate” phonological memory skills are needed for normal vocabulary development, and conversely, that deficits in this area may result in serious language impairments, with implications for language abilities beyond the domain of vocabulary knowledge. It should be pointed out, however, that researchers have yet to make clear the level of competency required for normal or optimal vocabulary development, and the level of competency below which deficits in language development are to be expected.

A caveat posited against these results is that claims of a direct causal relation based on correlational data are necessarily open to criticism. It is of course conceivable that instead of phonological memory skills being directly responsible for early vocabulary development, it is variation in the richness of children’s linguistic environment which simultaneously affects both their phonological memory skills and their level of word knowledge. Also, the studies

7While the majority of studies looking at the phonological memory capacity of individuals with SLI have found a reduced memory capacity, others (e.g., van der Lely & Howard, 1993) have failed to replicate this finding.
reviewed so far have been limited to making a case for an association between holding phonological sequences in memory and offering knowledge of the meaning of a particular word, without directly addressing the question of the role that memory for phonological features (to the exclusion of the nonphonological features) plays in vocabulary learning (Baddeley et al., 1998). Experimental paradigms simulating natural vocabulary learning have attempted to address some of these issues.

2.3.2 Experimental Evidence

Converging evidence from experimental studies directly examining the relation between phonological memory and the word learning process have involved both children and adults.

2.3.2.1 Word Learning in Children

Word learning in children was first considered in a study by Gathercole and Baddeley (1990b). In that study the learning rates of phonologically familiar (e.g., “Thomas”) and unfamiliar (e.g., “Pimas”) toy names were examined in young children with low and high pseudoword repetition skills. In line with Gathercole and Baddeley’s theory, children in the low-memory skills group took significantly longer to learn the unfamiliar toy names compared with the high-memory skills group. Moreover, this group difference was not apparent in the learning rates of the familiar toy names. Finally, children with high phonological memory skills significantly outperformed their low memory skills counterparts, when asked to recall the newly learned labels one day later.

Similar results were obtained in a study by Michas and Henry (1994), in which children were asked to learn three new real words (“gondola,” “platypus,” and “minstrel”) along with their definitions. The children’s
production, comprehension (measured by a picture recognition task in which children were asked to point to the picture of the object they had learned), and recall of the definitions of these words, was tested one week after the learning session. The results showed that phonological memory, even with age and spatial memory already accounted for, significantly predicted children's production and comprehension of the target words. A relation between phonological memory and definition recall was not established, however.

A comparable finding was reported in a recent study in which young children were given a paired-associate learning task (Gathercole et al., 1997). In this task, children were asked to learn pairs of words which in one condition consisted of two familiar words (e.g., "chicken"- "lion") and in another condition consisted of one familiar word and one pseudoword (e.g., "fairy" - "bleximus"). The study revealed a significant association between children's ability to repeat back pseudowords and the rate with which they learned the word-pseudoword pairs (with age, nonverbal ability and current vocabulary knowledge controlled for). A similar association between phonological memory and word learning was not found in the case of the familiar word pairs.

2.3.2.2 Word Learning in Adults

Similar paired-associate learning paradigms have been employed with adults. These studies have for the most part examined the learning rates for familiar and unfamiliar word pairs under various conditions known to adversely affect the efficacy of the phonological loop. The theory is that associations between familiar and unfamiliar (either foreign or pseudo) words are based at least in part on the phonological features of the words in the absence of any lexical support, making the ease with which these associations are learned
vulnerable to such experimental manipulations. Conversely, associations between familiar word pairs would not be affected by such phonological manipulations because the learning of these associations is largely based on existing lexical knowledge, with minimal reliance on the phonological loop.

In line with this view, Papagno, Valentine, and Baddeley (1991) hypothesized that under conditions of articulatory suppression, phonologically unfamiliar word pairs (consisting of familiar [Italian] and unfamiliar [Russian] stimuli) would be significantly more difficult to learn than phonologically familiar word pairs (consisting of two familiar [Italian] stimuli). The word pairs were presented both visually and aurally, given that the mechanism thought to be affected by articulatory suppression would vary for the two modes of presentation, with phonological recoding being impeded in the visual condition (Baddeley et al., 1975) and rehearsal of the phonological code in the absence of visual support being impeded in the aural condition (Vallar & Baddeley, 1984). Results of the study confirmed the hypothesis, with subjects requiring significantly more trials to learn unfamiliar than familiar word pairs.

A replication of the study using English-speaking subjects failed to show comparable suppression effects. Interviewing subjects as to their strategies for learning the unfamiliar word pairs revealed that the English-speaking subjects, unlike their Italian counterparts, established semantic links between the English-Russian word pairs (Russian is phonologically more similar to English than Italian), making the need for phonological coding or recoding less necessary. In a subsequent trial in which the unfamiliar words were made less familiar to the

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6The Russian stimuli used in the paired-associate learning paradigms were pronounceable words based on Russian words transliterated into Italian from Cyrillic script. They were selected on the basis that they did not resemble any Italian words.
English speakers (using pseudowords or words adopted from Finnish), results were found to be similar to those of the original Italian study.

In another series of experiments, Papagno and Vallar (1992) examined the learning rates of familiar and unfamiliar word pairs when the phonological similarity and word-length features of the stimuli were manipulated. As predicted, learning of longer and phonologically similar words was significantly impaired in the case of unfamiliar word pairs, but not familiar word pairs.

2.3.2.3 Summary

On the basis of the experimental studies just reviewed, there is strong evidence to suggest that in the absence of any existing lexical support, both young children and adults rely on short-term memory of the phonological characteristics of unfamiliar words to assist them in their long-term retention. Conversely, acquiring associations between highly familiar words requires little if any support from the phonological memory system and depends instead on existing lexical structures. These experimental findings complement those reported in the correlational studies, but go further in the sense that they directly address some of the limitations inherent in the correlational data.

2.3.3 Neuropsychological Evidence

The majority of the neuropsychological evidence pointing to the importance of the phonological loop in new word learning stems from observations of a single patient, PV, with an acquired and specific deficit to the short-term memory system. In a series of studies using the paired-associate learning paradigm just described (Baddeley, Papagno, & Vallar, 1988; Vallar & Baddeley, 1984), PV was asked to learn pairs of familiar words (in her native Italian) as well as pairs of words consisting of Italian and Russian (unfamiliar)
words. As was the case with the “normal” adults in Papagno’s studies (Papagno et al., 1991; Papagno & Vallar, 1992), PV showed no difficulties in learning to associate familiar pairs of words. Rather, her difficulties were in learning to associate familiar and unfamiliar words, despite being able to phonologically process non-word material (Vallar & Baddeley, 1984). (Similar results were found in a study examining the phonological memory capabilities of a patient who showed no evidence of employing rehearsal strategies but demonstrated adequate learning ability in tasks with less phonological emphasis [Trojano & Grossi, 1995].)

Subsequent learning trials, did, however, show that PV was able to learn familiar word-unfamiliar word pairs when a semantic or orthographic link between the words could be established. These findings provide further evidence of the role of phonological memory in learning tasks involving unfamiliar phonological sequences, while at the same time lending support to the notion that in situations where other coding processes, such as those based on semantic or orthographic codes, can be called upon, the link between phonological memory and long-term memory can be circumvented.

2.3.4 Criticism of Phonological Memory Account of Vocabulary Development

Taken together, the studies reviewed thus far make a strong case for the involvement of phonological memory in explaining at least some of the individual differences found in vocabulary development. Despite support for their findings, Gathercole and Baddeley’s interpretation of their findings has come under criticism. Snowling and her colleagues (Snowling et al., 1991), for example, have proposed an alternate theory to explain the link between
pseudoword repetition and vocabulary development. It is their contention that it is not good phonological memory skills that contribute to successful performance on the pseudoword repetition task, but rather knowledge of the structure of the language. More specifically, Snowling and her colleagues have suggested that knowledge about the prosodic, morphological, and phonetic status of words is mediating the observed association between pseudoword repetition and vocabulary (e.g., "thickery" should be considerably easy to process and subsequently repeat given the affix -ery). This knowledge, they posit, is gained through increased exposure to the language. Snowling and her colleagues claim that children with larger lexicons will have greater numbers of established phonological sequences in their repertoire from which they can construct a memory trace closely resembling that of the to-be-repeated pseudoword. While Gathercole and her colleagues (e.g., Gathercole et al., 1992; Gathercole & Baddeley, 1993b) concede that there may be a shift in the causal structure between phonological memory and vocabulary development across the ages, with lexical knowledge playing an increasingly important role in supporting new phonological sequences in memory, they maintain that phonological memory continues to play a role in the acquisition of new vocabulary items (e.g., in the case of foreign-language learning, Service, 1992).

Snowling and her colleagues have also questioned the validity of the pseudoword repetition task as a true measure of the ability to hold phonological

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9 Metsala (1999) presents a similar theory in which she delineates the representational processes underlying the development of children's knowledge of language structure (see Specificity of the Relation Between Phonological Memory and Vocabulary for a more detailed review of Metsala's account).

10 Gathercole and her colleagues (Gathercole, Willis, Emslie, et al., 1991) found that while repetition performance decreased with increased word-length and lower wordlikeness ratings, it was not affected by the number of familiar morphemes.
information in temporary memory. They stress the multi-faceted nature of the task, positing that successful performance on the pseudoword repetition task could be attributed to any number of cognitive operations needed in order to execute a successful articulatory output, and that, "it is a gross oversimplification to subsume such knowledge under the rubric of 'memory'" (p. 371). It may be, they claim, that individuals who are better at perceiving phonological differences, segmental analysis, assembling the necessary articulatory instructions, or even executing the motor output, are those who acquire vocabulary more easily.

With some notable exceptions, there has been little attempt to address the theoretical and methodological concerns put forth by Snowling and her colleagues. In assessing the possible mediating role of speech perception in the relation between pseudoword repetition skills and vocabulary knowledge, Gathercole and Baddeley (1990a) found that language-disordered children with low pseudoword repetition scores failed to demonstrate difficulties on a minimal pairs discrimination task (a task which requires subjects to identify word and pseudoword pairs as identical or varying in no more than a single speech contrast), suggesting the absence of speech perception deficits. In another study, Michas and Henry (1994) presented data which shows comparable associations between vocabulary and a number of phonological memory measures varying in the degree to which they depend on children’s segmentation and articulation skills. This finding belies Snowling’s claim that it is these latter skills and not phonological memory which best explains the association between pseudoword repetition skills and vocabulary knowledge.
While the two aforementioned studies support the theory proposed by Gathercole and her colleagues, there is some contradictory evidence (e.g., Metsala, 1999), which suggests that segmentation ability may be a key component in explaining the phonological memory-vocabulary relation. It is clear that more converging evidence is required, before conclusive statements can be made regarding the possible mediating roles of other cognitive and linguistic variables in the observed relation between performance on the pseudoword repetition task and vocabulary knowledge.

2.4 Relation Between Phonological Memory and Foreign-Language Vocabulary Knowledge

The relation between phonological memory and vocabulary development has recently been extended from native to foreign-language learning. While the foreign-language learning literature has highlighted the importance of memory-based learning strategies in new vocabulary learning (e.g., Skehan, 1989, has outlined three language-learning profiles including one characterized by superior memory strategies), it has had little to say about the precise nature of the processes underlying those memory strategies.

According to Cheung (1996), research into the association between phonological memory and foreign-vocabulary learning is significant for a number of reasons. First, there is the overall importance of studying foreign-language learning. Given the multi-lingual nature of many of the world’s societies, and hence the need for many to learn additional languages, understanding better the underlying processes of new word learning, the cornerstone of proficiency in any language, is paramount.
Cheung also asserts the importance of assessing the extent to which the relation between phonological memory and vocabulary learning in foreign-language development follows a similar or different developmental pathway from that found in native language development. Although there is a whole body of literature which is dedicated to gaining a better understanding of the "cross-linguistic" aspects of language processes (see for example, Sparks & Ganschow, 1993; Sparks, Ganschow, & Patton, 1995), there has been less effort to elucidate whether the relation between second-language vocabulary development and other psychological factors (e.g., phonological memory) is comparable to that observed in first-language vocabulary development. Moreover, as Cheung points out, there is some evidence to suggest that lexical processing in a second language may be qualitatively different from that in a first language. For example, Kroll and Stewart (1994, as cited in Cheung, 1996) found that the strength of the relation between lexical items and their underlying concepts differed depending on whether it was a first- or second-language lexicon, with the latter having a more superficial association to its referent concept. However, Chen and Leung (1989, as cited in Cheung, 1996) found that age of the second language learner was a critical determinant of the extent to which the first-language lexicon was called upon during second-language lexical processing. The younger learner was found to depend less on the first-language lexicon when processing second-language meanings, than the older learner.

The research studies which have considered the role of phonological memory in foreign-language learning, while few in number, have been primarily of two kinds: (a) paired-associate learning paradigms in which adults are asked
to learn familiar (native language)-unfamiliar (foreign language) word pairs (Papagno et al., 1991, Papagno & Vallar, 1992, 1995); and (b) more naturalistic studies in which the relation between children's performance on indices of phonological memory and foreign-language proficiency is tracked over time (Service, 1992; Service & Kohonen, 1995), or examined experimentally (Cheung, 1996).

Given that the paired-associate experiments conducted by Papagno and his colleagues have already been reviewed in the context of the relation between phonological memory and word learning, the present discussion will limit its focus to the developmental and word learning studies examining the role of phonological memory in foreign-language learning in children.

With the exception of Service (Service, 1992; Service & Kohonen, 1995) and Cheung (1996), there has been little effort to extend the relation between phonological memory and vocabulary development found in naturalistic observations of native language development to foreign-language development.

2.4.1 Developmental Evidence

In a longitudinal study, Service (1992), examined the correlation between measures of phonological memory (pseudoword repetition and delayed-copying of visually-presented pseudowords\footnote{Delayed copying of pseudowords (a task in which subjects are shown a series of letter strings which they are required to copy after the stimuli have been removed from view), unlike pseudoword repetition, has no auditory perception or spoken output component. This task is suspected to tap an articulatory recoding process which leads to a representational code in the phonological store.}--both based on English-sounding pseudowords and overall English proficiency (a rating derived at from a six-point scale completed by the classroom teacher), with the goal of establishing a
set of criteria predictive of success in the acquisition of a second language. The subjects were 9- and 10-year-old native speakers of Finnish who had had no significant exposure to English prior to being enrolled in a primary-level English class. Results showed that children's performance on both measures of phonological memory at the beginning of the study was significantly correlated with overall school grade in English two-and-a-half years later. A significant correlation between phonological memory and English proficiency was maintained, even after performance on a mathematics test was partialled out, suggesting that general ability was not mediating the phonological memory-language proficiency relation.

In a subsequent study, Service and Kohonen (1995) reported on data from the original study as well as follow-up data which were collected one year later. The time interval between the first measure of pseudoword repetition and the subsequent measures of English achievement was approximately three-and-a-half years. In addition to finding a comparable association between early pseudoword repetition skills and later overall English proficiency to the one found a year earlier, results from this study suggest a specific link between phonological memory and foreign-language vocabulary development. While the merits of the vocabulary test used to measure vocabulary size are somewhat suspect,¹² Service and Kohonen observed a significant correlation between early phonological memory skills and later vocabulary knowledge.

A series of fixed-order multiple regression analyses was performed to ascertain if the reported relation between pseudoword repetition and overall

¹²Test items were arrived at on the basis of three teachers' recollection of the vocabulary words encountered over the course of the four years of English instruction.
English proficiency was indeed mediated by vocabulary knowledge. Entering vocabulary knowledge prior to pseudoword repetition in the equation resulted in eliminating the significant relation between pseudoword repetition and overall English proficiency. A similar result was not found when performance on a written production task was entered in step 2 of the equation followed by pseudoword repetition, suggesting that the failure to maintain a significant relation between pseudoword repetition and overall English proficiency once English vocabulary was partialled out, was not simply due to the strong correlation between a measure of English learning (vocabulary or written production) and English proficiency. Based on her findings, Service concluded that, "repetition and copying accuracy [are] specifically related to language learning" and that, "the ability to represent unfamiliar phonological material in working memory underlies the acquisition of new vocabulary items in foreign-language learning" (1992, p. 21).

2.4.2 Experimental Evidence

Cheung (1996) found a similar relation between phonological memory and foreign-vocabulary learning to that reported by Service. Unlike Service, however, who measured natural vocabulary development over a number of years, Cheung investigated the phonological memory-foreign-vocabulary knowledge relation by directly examining the word learning process.

Similar to the paradigm employed by Gathercole and Baddeley (1990b) in their study with young children learning unfamiliar toy names, Cheung measured subjects' efficiency (number of trials required) in learning unfamiliar words in their second language. In the study, Cantonese-speaking 7th graders learning English as a second language (formal English instruction commenced at
age three or four), were asked to learn the words, "egregious," "succulent," and "jocular." Of particular interest in the present context is the finding of a significant negative correlation between subjects' skill at holding in memory a sequence of phonologically unfamiliar items and the number of trials required to learn the new vocabulary items. Subsequent analysis, however, revealed an interaction between subjects' long-term phonological knowledge, operationalized as English vocabulary knowledge, and the relation between pseudoword span and new word learning. More specifically, it was found that only in the case of subjects with relatively poor vocabulary knowledge, was pseudoword span predictive of the number of trials required to learn the new words. As Cheung suggests, these results point to an "interaction between phonological memory and long-term [lexical] phonological knowledge during second-language vocabulary learning" (1996, p. 87).

2.5 Specificity of Relation Between Phonological Memory and Vocabulary Knowledge

Despite the overwhelming evidence for an association between the ability to hold phonological information in memory and the ease with which new vocabulary is learned, little attention has been paid to establishing the specificity of that relation. In other words, it is unclear whether the reported association between phonological memory and vocabulary is a reflection of the influence of a general phonological processing ability (i.e., the ability to use phonological information to process language), or whether there is something unique about the role of phonological memory in vocabulary development which sets it apart from the influence of other phonological processing skills.
Wagner and Torgesen (1987) have outlined in detail what they consider to be the three main phonological processing abilities involved in the processing of oral and written language. Included among these processing skills is *phonological awareness*, the ability to make judgments regarding the sound structure of spoken language, which is commonly measured by tasks requiring children to segment or blend together individual phonemes, delete and replace a target phoneme, or demonstrate knowledge of rime units contained within a series of words; *phonological recoding in lexical access*, the ability to gain access to a target lexical referent through the translation of written symbols into phonological codes, which is measured by such tasks as rapid automatized naming of letters or objects; and *phonetic recoding to maintain information in working memory*, the ability to translate written symbols into phonological codes for the purposes of maintaining the information in short-term memory, a process which as already discussed, is implicated in phonological memory.

One avenue to assessing the uniqueness of the role of phonological memory in vocabulary development is to measure the relative roles of other phonological processing skills in vocabulary learning. With the exception of a handful of studies, there has been little focus on addressing this issue.

**2.5.1 Relative Roles of Phonological Memory and Phonological Awareness in Vocabulary Knowledge**

One study which attempted to shed light on this issue examined the roles of both phonological awareness and phonological memory on vocabulary (and reading) development in young children (Gathercole, Willis, & Baddeley, 1991). The hypothesis is that if both phonological measures reflect a common phonological processing ability, then they should show similar patterns of
association with vocabulary. If on the other hand, phonological memory has a unique relationship with vocabulary development, as Gathercole and her colleagues claim, then the patterns of association should differ.

In this cross-sectional study, children (aged four and five) were administered measures of rhyme awareness, pseudoword repetition, digit span, and vocabulary. Factor analysis revealed that all three phonological measures loaded onto a single phonological processing factor. A series of fixed-order hierarchical regression analyses, with age and nonverbal ability entered in steps 1 and 2 of the equation, however, failed to establish rhyme awareness as a significant predictor of vocabulary knowledge for either age group, while replicating the already established finding of a significant relation between phonological memory and vocabulary. These results led Gathercole and her colleagues to conclude that while both phonological awareness and phonological memory skills share a common phonological component (a view supported by Bowey, 1996, who found associations of comparable strength between digit span and vocabulary and between phoneme identity and vocabulary), they also appear to “tap dissociable skills which make differential contributions to language development during the early school years” (Gathercole, Willis, & Baddeley, 1991, p. 400).

The relative associations between phonological awareness, phonological memory, and vocabulary were again explored in a more recent study by Metsala (1999). In her study, preschool children were required to complete a series of tasks measuring skills in onset-rime blending, phoneme blending, phoneme isolation, pseudoword repetition, and vocabulary (as well as a host of other measures not directly relevant to the present discussion). Contrary to the
findings reported by Gathercole and her colleagues (Gathercole, Willis, & Baddeley, 1991), Metsala found significant associations between phonological awareness measures and vocabulary. A significant association between pseudoword repetition and vocabulary was, however, replicated. Regression analyses were performed in order to assess the unique and overlapping contributions made by each of the phonological processing skills to vocabulary knowledge. A series of analyses was performed with the final variable entered being either a measure of phonological awareness or pseudoword repetition. In all cases, when a measure of phonological awareness followed pseudoword repetition in the equation, it explained significant unique variance in the vocabulary scores. Moreover, in such cases the significant contribution made by pseudoword repetition in explaining vocabulary was rendered statistically insignificant, suggesting that the variance contributed by pseudoword repetition could be explained entirely by phonological awareness.

Metsala interpreted these findings as being incongruent with the theory put forth by Gathercole and her colleagues that the basis for the observed relation between pseudoword repetition skills and vocabulary knowledge is individual differences in short-term phonological memory. She proposes instead, a theory similar in nature to that proposed by Snowling and her colleagues (1991), namely, that it is knowledge of relevant language structures (e.g., morphological and phonetic features of words) that is critical in explaining this association. Metsala elaborates on Snowling’s original proposal by providing a detailed account of the representational processes underlying the development of children’s knowledge of language structure. It is her contention that individual differences in the complexity with which lexical items are represented
in memory (segmented versus holistic), are at the root of the pseudoword repetition-vocabulary relation. According to the developmental account of the emergence of the phoneme as a phonological unit critical for reading (see Jusczyk, 1995), it is through the ever-increasing need for finer discriminations between words in long-term memory (a result of spoken vocabulary growth), that children come to represent learned lexical items in a more segmented phonemic form.

Phonological awareness tasks, which require the manipulation of individual phonemes, are necessarily constrained by the representational nature of the speech units. In other words, a child who represents speech units holistically, will be unable to successfully isolate a single target phoneme. Metsala goes on to claim that performance on the pseudoword repetition task is less dependent on short-term memory processes, and more dependent on the nature of these lexical representations, so that children who represent speech units in a segmented form, will be more successful at holding in memory unfamiliar phonological sequences.

On the basis of the aforementioned studies, it is clear that no conclusive statement regarding the specificity of the role of phonological memory in vocabulary development can be made. Additional research assessing the relative roles of phonological awareness and phonological memory in vocabulary is clearly warranted. An important component of this future research should involve assessing the respective roles of the various phonological processing skills in not only vocabulary knowledge but also vocabulary growth (i.e., from a longitudinal perspective), an issue neither the Gathercole (Gathercole, Willis, & Baddeley, 1991) nor the Metsala (1999) study broached.
2.6 Specificity of Relation Between Phonological Memory and Reading

One area of language development in which there has been substantial effort to tease apart the varying contributions of phonological awareness and phonological memory, has been reading acquisition. Much of the early research on word decoding failed to consider the interrelatedness of the underlying phonological processes and as a result, evidence for the contributions made by each of the various phonological processing skills has developed to some degree in isolation. More recently, however, there has been a movement towards ascertaining the unique and overlapping variance which can be attributed to these phonological processing skills in explaining individual differences in word decoding skills (see Wagner & Torgesen, 1987; Wagner, Torgesen, & Rashotte, 1994; Wagner et al., 1997).

Considering each of the three main phonological processing skills (phonological awareness, phonological memory, lexical access) separately, there is ample evidence to suggest that each plays an important and possibly causal role in reading acquisition. With the goal of drawing parallels between the reading and vocabulary literatures, the present discussion will be limited to reviewing the roles of phonological awareness and phonological memory in reading acquisition.

2.6.1 Relation Between Phonological Awareness and Reading

Beginning with phonological awareness, there is no shortage of evidence to support the claim that the ability to make judgments about as well as manipulate the sound structure of the language plays a critically important role in the development of reading skills (e.g., Bradley & Bryant, 1978, 1983, 1985; Calfee, Lindamood, & Lindamood, 1973; Mann & Liberman, 1984; Morais, Cary,
Alegria, & Bertelson, 1979; Rosner, 1986; Share & Stanovich, 1995; for extensive reviews of the literature see Adams, 1990; Blachman, 1997b; Wagner & Torgesen, 1987). This research has involved the examination of the correlational and causal links between phonological awareness skills and reading ability in both normal and dyslexic readers. Overwhelmingly, the evidence points to phonological awareness being a necessary skill for learning to read, a skill if not acquired, can produce detrimental effects in other areas of language development.

2.6.2 Relation Between Phonological Memory and Reading

Similar to the findings pointing to a critical link between phonological awareness and reading acquisition, there is an impressive body of literature which suggests that phonological memory also plays an important role in the development of reading skills (e.g., Gathercole & Baddeley, 1993b; Gathercole, Willis, & Baddeley, 1991; Mann, 1984; Mann & Liberman, 1984; Liberman, Mann, Shankweiler, & Werfelman, 1982; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979; for reviews of the literature see Jorm, 1983; Wagner & Torgesen, 1987). For example, Liberman and her colleagues (1982) found that poor readers who were asked to recall lists of phonologically familiar and unfamiliar words performed significantly less well than good readers. Further analysis revealed that the memory deficit pertained only to verbal material, suggesting a phonological memory deficit and not a general memory problem. The majority of this research, however, has been of a cross-sectional nature, with few studies tracking the relation between phonological memory and reading skills across the primary school years. The absence of a longitudinal analysis
necessarily precludes statements about the causal direction of the observed relation.

The longitudinal studies which have been conducted (e.g., Gathercole & Baddeley, 1993b; Mann & Liberman, 1984) lend support to the notion of a causal link in the forward direction between phonological recoding skills in phonological memory and reading acquisition. For example, Gathercole and Baddeley (1993b) reported findings of an earlier study in which the association between pseudoword repetition and reading achievement (measured by a forced-choice reading test in which children were required to fill in the missing word of a sentence—the word options were either provided in the form of an accompanying picture or the written forms of the words) was measured across a four year span. It is important to note that subjects (four-year-old preschoolers) at the first wave of testing were given a reading measure and deemed nonreaders (i.e., they failed to recognize a single word on the reading measure). This is a critical component in eliminating the argument that it is the influence of early reading ability on phonological memory development which explains the observed relation between pseudoword repetition and reading skills later on (Wagner & Torgesen, 1987). The most critical finding revealed by the study is a significant partial correlation, with age and nonverbal ability controlled for, between pseudoword repetition performance at age four and reading achievement at age eight.

Gathercole and Baddeley's interpretation of this result is that phonological memory skills place constraints on the development of a phonological recoding strategy. They go on to suggest that the mediating effect of phonological memory may be expressed in one of two ways (possibly even
both ways). Poor phonological memory skills may, for example, impede the ease with which the grapheme-phoneme correspondences are learned and subsequently employed for successful decoding of unfamiliar words. Along similar lines, poor phonological memory skills may also prevent the maintenance of a sequence of individual phonemes arrived at through the segmentation of the word into phonemes during the decoding process. If the segmented phonemes cannot be held in temporary memory, than the blending together of these phonemes for the purposes of rendering an output, (i.e., reading) becomes problematic.

As Torgesen points out (1988), the role of phonological memory skills in reading is especially critical during the early stages of reading acquisition, “when words are likely to be processed as a series of separately encoded phonological elements” (p. 610). It is also conceivable, however, that phonological memory plays a role in the decoding of low frequency words for even the most fluent readers.

2.6.3 Relative Roles of Phonological Memory and Phonological Awareness in Reading

As this brief review of the literature suggests, phonological awareness and phonological memory alike make important contributions to the development of early reading skills. This research does not, however, address the

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13The role of phonological memory in reading comprehension is considerably less certain compared with reading accuracy of contextualized or decontextualized words (see Logie, 1993). While there is evidence to suggest that normal comprehension takes place 'on-line' in the absence of any dependence on a short-term memory store (Butterworth, Campbell, & Howard, 1986), there is another body of literature which suggests that phonological memory may be important particularly in situations where the to-be-comprehended material is exceedingly difficult (McCarthy & Warrington, 1987). In a recent study, for example, Gottardo and her colleagues (1996) found phonological memory to be the most significant unique predictor of a measure of reading comprehension in a group of third graders.
specificity of the relation between each of the phonological processing skills and reading. It may be the case that phonological awareness and phonological memory, as well as tapping a common underlying phonological construct, each make unique contributions to reading. Alternatively, it may be that the variance they explain in reading is largely common variance shared by the two processing skills.

Over the last decade and a half, there has been some attempt to ascertain which of these two alternatives best fits the data (e.g., Adams, 1990; Gathercole, Willis, & Baddeley, 1991; Goswami & Bryant, 1990; Mann & Liberman, 1984; Wagner & Torgesen, 1987). For example, Gathercole, Willis, and Baddeley (1991) found that in predicting reading performance (based on a forced-choice reading measure) in four- and five-year-old preschoolers, phonological awareness, with age and nonverbal ability controlled for, explained significant additional variance for both age groups, while pseudoword repetition and digit span explained unique variance only in the case of the five-year-olds. These findings suggest differential developmental associations between the two phonological processing skills and reading (for similar findings see Torgesen et al., 1994; Wagner et al., 1994). These studies do not, however, make clear whether the variance explained by the phonological processing skills is unique or common to both.

Other studies have, however, considered the unique contributions of phonological awareness and phonological memory to reading. In a series of longitudinal studies, Wagner and Torgesen along with their colleagues

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14As was reported earlier in the discussion on the relation between phonological awareness, phonological memory, and vocabulary, the three phonological measures loaded highly onto a single factor.
(Torgesen et al., 1994; Wagner et al., 1994; Wagner et al., 1997) tracked the development of phonological processing skills as well as the influence of each on reading development. Of particular importance to the present discussion is their finding that although both phonological awareness and phonological memory appear to be causally linked to reading development (controlling for prior reading skills and general verbal ability), when their contributions were considered simultaneously in a structural equation model, only phonological awareness was found to be predictive of subsequent reading development. The interpretation of these data offered by Wagner and his colleagues is that the “causal influences of the phonological processing abilities on decoding are redundant with one another” (1994, p. 81). In other words, while both phonological awareness and phonological memory may be tapping a common underlying phonological processing ability, phonological awareness measures are more sensitive and direct indices of the core phonological processing system. They explain unique variance in word-level reading (across all ages from kindergarten to fourth grade), while phonological memory does not contribute independently to later reading (Wagner et al., 1997). This finding was echoed by Rohl and Pratt (1995) in their longitudinal study of young children’s reading and spelling ability.

Other researchers have reported findings which suggest that both phonological awareness and phonological memory explain independent variance (albeit relatively small amounts in the case of phonological memory), in word-level reading (e.g., Gottardo et al., 1996; Hansen & Bowey, 1994). In a recent study, for example, Gottardo and her colleagues (1996) found that while phonological memory was predictive of grade 3 reading ability, the specificity of
the link between phonological memory and reading was dependent upon the type of reading measure. In the case of the pseudoword reading measure, phonological memory did not explain any unique variance once phonological awareness (and syntactic processing) was controlled for, while it did explain a significant, albeit small amount, of unique variance in two word recognition measures. It is clear from examining results from the commonality analysis that much of the variance explained by phonological memory when it was entered first into the regression equation, was variance shared with other phonological processing skills. The finding that phonological awareness and phonological memory tap a common phonological processing ability has been echoed in numerous studies (see Gottardo et al., 1996, for a brief review of the literature).

2.6.4 Nature of the Relation Between Phonological Memory and Phonological Awareness

While there is no general consensus among researchers as to whether or not phonological memory tasks have any value in predicting individual differences in reading ability apart from that attributed to phonological awareness measures (in Ehri’s, 1979, words, phonological memory is a correlate of reading while phonological awareness is a prerequisite of reading), there is some agreement that both phonological processing skills tap to some extent a common underlying phonological ability. This notion certainly has intuitive appeal. It seems reasonable that these two phonological skills would correlate given that in order to perform many of the tasks used to measure phonological awareness (e.g., Bradley & Bryant’s 1983 rhyme awareness task in which children are asked to choose which of three words does not share the same rime unit, e.g., “peg,” “mat,” “cat”), an ability to hold items in temporary memory is
called for. It is, therefore, not surprising to find that a young child has difficulty with Bradley and Bryant's rhyming task (which requires the child to make at minimum two comparisons), given that the word span of an average four-year-old is approximately two or three words (Hulme, Thomson, Muir, & Lawrence, 1984). While it seems plausible that phonological memory is a necessary component in phonological awareness tasks (Rohl & Pratt, 1995), it is considerably less clear what role phonological awareness plays in phonological memory tasks.

Some researchers even wonder if it is possible to separate the influence of phonological memory on tasks measuring phonological awareness. For example, Tunmer and Rohl (1991) in a study looking at the role of phonological awareness in spelling, found that as the number of phonemes in a phoneme segmentation task increased, the performance of the weak spellers significantly declined. The interpretation of this result is unclear, given that no independent measure of phonological memory was administered, making it equally likely that the basis for the impoverished performance of the weak spellers was phonological memory and not phonological awareness. Also, in an analysis of ten commonly used phonological awareness measures, Yopp (1988) found that all included a phonological memory component, with the more complex tasks requiring more memory resources. Further, it is interesting to note that the phonological awareness tasks most predictive of reading ability have an inherently large phonological memory component (Brady, 1991; Yopp, 1988).

It has also been suggested by many researchers (e.g., Brady, 1991; Fowler, 1991; Gathercole & Baddeley, 1989a; Mann & Liberman, 1984; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993), that the quality of children's
phonological representations may be at the root of the observed association between phonological awareness and phonological memory. More specifically, it has been posited that the ease with which children acquire phonological awareness is likely dependent on the quality of their phonological representations in short-term (and long-term) memory, which consequently affects their learning of the grapheme-phoneme correspondence rules which underlie reading acquisition.

2.6.5 Summary

Finally, if indeed there is evidence to suggest that both phonological processing skills tap a common phonological ability in reading, then it is conceivable that a similar pattern would be revealed with respect to vocabulary development. Alternatively, it could be the case that the interrelatedness between phonological awareness and phonological memory in language development is domain-specific, exerting differential effects on reading and vocabulary. While there is substantive evidence pointing to the importance of phonological memory in vocabulary learning, phonological awareness as a predictor of individual differences in vocabulary knowledge, has not been widely tested. Assessing the predictive value of phonological awareness with respect to vocabulary development is essential if researchers are to ascertain not only the specificity of the relation between phonological memory and vocabulary, but also provide further evidence of the existence of a general phonological processing component which underlies language development.
2.7 Present Study

2.7.1 Research Objectives and Questions

The present study was designed with two objectives in mind. The first was to investigate the relation between phonological memory and vocabulary development in young children learning a second language (L2). As was previously discussed, with the exception of the work by Service (1992; Service & Kohonen, 1995), there has been little research conducted in this area. The present study attempted to extend Service’s findings by: (a) examining the developmental relation between phonological memory and vocabulary with the goal of directly comparing the causal structure of this relation in L2 children to that reported in native-language learners (L1) (Gathercole et al., 1992); (b) administering more objective and direct measures of vocabulary; and (c) untangling the confounding effects of speech perception and output articulation on the relation between phonological memory and vocabulary development. An added component of the present study was the examination of the role of phonological memory in children’s L2 reading development, a research area which to the author’s knowledge has yielded no published findings.

The second objective of the study was to assess the relative contributions of phonological memory and phonological awareness to L2 vocabulary development. As was previously discussed, while a few studies have attempted to tease apart the varying contributions of phonological awareness and phonological memory skills to L1 vocabulary knowledge (Gathercole, Willis, & Baddeley, 1991; Metsala, 1999), there are no reported studies examining the relative roles of these phonological processing skills in vocabulary development.
(i.e., from a longitudinal perspective), L1 or otherwise. While comparable yet inconclusive research exists in the L1 reading literature (pointing to the presence of an underlying phonological processing component with phonological awareness skills playing a significant and unique role in reading development), there is no consensus among researchers as to whether this general underlying phonological processing ability, tapped by both phonological awareness and phonological memory, is specific to reading or whether it is more domain-general in nature. For the purposes of comparing across language domains, the present study considered the relative contributions made by phonological awareness and phonological memory to both vocabulary and reading development in L1 and L2 children.

To sum up, the following research questions were posed:

1. Is there a relation between phonological memory and vocabulary development in children learning English as a second language (ESL)? If so, does it differ from that found in native English-speaking (EL1) children?

2. Is there a relation between phonological memory and reading development in ESL children? If so, does it differ from that found in EL1 children?

3. Do phonological memory skills make an independent contribution to native and second-language vocabulary development apart from the influence of phonological awareness skills?

4. Do phonological memory skills make an independent contribution to native and second-language reading development apart from the
influence of phonological awareness skills?
Chapter 3: Methodology

3.1 Design

As part of a larger study, children were tested twice a year across a time span of two years. Test batteries were administered across four testing sessions, each lasting approximately 30 minutes. While the batteries were administered in a random order, tests within the batteries were administered according to a fixed random order. Children were tested on an individual basis by one of a number of experienced graduate students.

The present study focuses on data from only two testing periods: the first testing wave (Time 1) which took place in the first term of grade 1, and the second wave of testing (Time 2) which was conducted one-and-a-half years later when children were in grade 2. Only measures relevant to the immediate research questions are considered.

3.2 Subjects

EL1 (English-as-a-first-language) and ESL (English-as-a-second-language) subjects were recruited from the same four primary schools in the greater Toronto area. Ninety-eight children, 40 native speakers of English and 58 native speakers of Punjabi (deemed ESL learners by the school board), participated in this longitudinal study (see Appendix A for a demographic profile of the subject sample). The subjects’ language status was determined by the local school board and subsequently confirmed by the classroom teacher. All ESL children in the present study had a minimum of 1 year of schooling (e.g., kindergarten or preschool) in which English was the language of instruction, prior to the first wave of testing. As well, the first testing period did not begin
until well into the first term of the grade 1 school year, giving children the chance to be exposed to the rudiments of language and literacy instruction.

At initial testing (Time 1), the mean age of the children in the sample was 6 years and 4 months (range 5 years and 11 months to 7 years and 0 months). At Time 2, the mean age was 7 years and 9 months.

Due to absences during the Time 2 testing phase, data from 12 EL1 subjects were lost, as were partial test results from seven additional subjects (four EL1 and three ESL subjects) at initial testing. All statistical procedures were performed on a pair-wise basis.

3.2.1 Subject Variables

An analysis of nonverbal ability by language revealed that both EL1 and ESL subjects performed at an age-appropriate level on a standardized measure of non-verbal ability (Matrix Analogies Test; Naglieri, 1989). Further, an analysis of variance did not reveal a statistically significant difference between the two language groups on this measure, $F(1, 95) = .324, p > .05$.

To rule out the possibility that individual differences on the pseudoword repetition task (measure of phonological memory) might reflect differences in the quality of the articulatory output, performance on the Goldman and Fristoe Test of Articulation (1986) was analyzed. The analysis revealed that six children (all from the ESL sample) had articulatory problems which affected their performance on the pseudoword repetition tasks. Scoring on the pseudoword repetition tests for these children was thus adjusted to compensate for any articulation discrepancies. For example, if a child pronounced the /s/ in "sleeping" as /th/ on the articulation test, then his/her response of "thubid" to
the pseudoword "subid" on the Hebrew pseudoword repetition test (see below for a detailed description of the task), was considered correct.

3.3 Measures and Procedure

Across the two waves of testing, children were tested on measures of phonological memory, phonological awareness, phonological discrimination, vocabulary, word recognition, nonverbal intelligence, and articulation. All measures, with the exception of one of the phonological memory tasks (the Hebrew pseudoword repetition task), consisted of English stimuli, either real words or pseudowords which followed the rules of English phonology and morphology. As well, instructions accompanying the various tasks were carried out in English. It should be mentioned that although ESL children by definition are less proficient in English than their EL1 counterparts, ESL children in the present study had sufficient knowledge of the English language to comprehend all task instructions.

3.3.1 Phonological Memory Measures

To test phonological memory, two pseudoword repetition tasks were employed, this despite the fact that the most commonly used measures of short-term memory, both clinically and educationally, are those measuring memory span (be it digit or real word span). The pseudoword repetition task was chosen for reasons pertaining primarily to its so-called lexical-free nature and from a more methodological perspective, its child-friendly nature.

While considerably less widely employed, the pseudoword repetition task is considered by many to be a purer measure of phonological memory compared
with the digit or word span,\textsuperscript{15,16} demonstrating greater sensitivity to phonological memory constraints. Unlike the digit and word span measures which involve memory for familiar items, pseudowords have the advantage of being "new" to all children with a minimal amount of lexical influence as a source of individual variation (Gathercole et al., 1994). Tasks involving the repetition of single words also place fewer demands on other cognitive processes compared with tasks which require subjects to retain in memory sequences of words.

The simplistic nature of the pseudoword repetition task has proven to be particularly beneficial in the testing of young children. The experimental paradigm of asking children to repeat unfamiliar words is not a situation they are unaccustomed to; they are constantly being bombarded with new phonological forms, and their propensity for imitating them is evident. Gathercole and Adams (1993) have found that children as young as two are capable of understanding the demands of the pseudoword repetition task. Specifically, the simplicity of the task is suggested to have the effect of reducing problems related to motivation, attention, and use of strategies (Gathercole & Baddeley, 1989a). A related point is the problem of output interference (where the act of recalling the stimuli has a detrimental effect on maintaining the representations of the remaining to-be-recalled items) which has been found to be associated with span tasks (Dempster, 1981), a moot point in the case of the pseudoword repetition task. Unlike the pseudoword repetition task, span tasks are considerably more

\textsuperscript{15}It should be noted, however, that in young children, digit and word span measures have been found to correlate highly with the pseudoword repetition task (Gathercole, Willis, Baddeley, & Emslie, 1994).

\textsuperscript{16}Moreover, there is substantial evidence to suggest a closer association between pseudoword repetition and vocabulary than between digit span and vocabulary (for reviews of the literature see Baddeley et al., 1998).
susceptible to subtle shifts in attention and other extraneous factors, making test reliability a concern.

Finally, given that the majority of research examining the link between phonological memory and vocabulary development in young children has employed the pseudoword repetition task as the key measure of short-term memory, cross-study comparisons would be better served if a similar measure were used in the present study.

Two measures of pseudoword repetition were administered: an adapted version of a task developed by Gathercole and her colleagues (1994), and a repetition test characterized by pseudowords which follow rules of Hebrew morphology (Geva, 1997a).

Pseudoword repetition tasks are characterized by lists of pseudowords with varying numbers of syllables. These tests require children to repeat back a single pseudoword presented either by the experimenter or in a taped format. Both repetition tasks in the present study were presented in a taped format.

The adapted version (hereafter referred to as the standard English pseudoword repetition task) of the Children's Test of Nonword Repetition (Gathercole et al., 1994) was developed using 25 of the original 50 items (see Appendix B). All items were pseudowords which followed the rules of English phonology and morphology. The test items were divided into four sets of stimuli. Each set contained words with 2, 3, 4, or 5 syllables (ten 2-syllable, five 3-syllable, five 4-syllable, and five 5-syllable pseudowords). Unlike the original

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17Test items for both measures of pseudoword repetition were professionally recorded by a native speaker of English. Although pronunciation of the phonemes for both tasks followed English rules of phonology, in the case of the Hebrew pseudowords, great care was taken to ensure that the stress patterns resembled those found in the Hebrew language.
test, one-syllable items were not included. Minor intra-word changes also characterized the test (e.g., “doppelate” to “doppetate”). These changes were made to further decrease the perceived wordlikeness of the pseudowords.

The second pseudoword repetition task was similar in nature to the standard one, with the exception that the pseudowords followed Hebrew rules of morphology (Geva, 1997a; see Appendix C). The rationale for the development and inclusion of a Hebrew version of the pseudoword repetition task was to further reduce the effects of wordlikeness, believed to affect performance on real word repetition tasks as well as the standard pseudoword test. Moreover, by including such a task, the confounding effect of potential EL1-advantage due to familiarity with typical morphological markers (e.g., -ine, -ous, -ic), was minimized. The test included eight 2-syllable, eight 3-syllable, six 4-syllable, and five 5-syllable pseudowords.

The two pseudoword repetition tasks were introduced to children by the examiner saying, “I’m going to say some silly words to you. They’re not real words, so you won’t recognize them. Listen carefully to each word. After you hear the word, say it exactly the same way.” The experimenter then presented children with a number of practice items after which the role of the tape recorder was introduced. Additional taped practice items were then administered followed by the test items.

Children were told, for example, “If I say ‘kivven,’ what do you say?” Appropriate feedback was then provided. If a correct response was given, the tester then said, “Good. Let’s try another word, ‘puppid.’” If an incorrect response was given, the child was told, “That was a good try, but let’s try it again. Listen carefully and say the word exactly the way I say it” (the word was
then repeated). If the child proceeded to respond incorrectly on the second trial, the tester provided the child with the correct response. Children were provided with a minimum of two practice items.

Then children were told, “Now let’s listen to some more silly words. We’re going to listen to them on this tape recorder. First you’ll hear a bell, and then you’ll hear a word. I want you to say the word exactly the way the lady on the tape says it” (the first taped practice item was then presented). Children were given three taped practice items followed by the test items. Test items were not administered until children were able to successfully repeat all practice items. Both versions of the pseudoword repetition task were administered in their entirety.

Children’s repetitions were scored as either correct or incorrect. Items which children failed to repeat were scored as incorrect. The total number of correctly repeated pseudowords was calculated for each test.

3.3.2 Phonological Awareness Measure

A measure of phonological awareness, an adapted version of Rosner and Simon’s Auditory Analysis Test (1971), was administered. In this test, children were presented with highly frequent words and asked to delete target syllables and phonemes. Unlike in the Rosner and Simon test, the remaining morphemes were all high frequency real words. The syllables to be deleted were in either first or final position, while the phonemes were either single consonants (first or final phoneme position) or part of a blend with the target phoneme being either the first or second consonant of an initial blend or the first consonant of a final
blend (see Appendix D). The test consisted of a total of 20 words, with four syllable deletions (two in first position and two in final position), and 16 phoneme deletions including six single consonant deletions (three in first position and three in final position), and 10 phoneme-within-a-blend deletions (three in first position of an initial blend, three in first position of a final blend, and four in second position of an initial blend). All practice and test items were verbally presented by the experimenter.

The task was introduced to children by the examiner saying, "Let's play a word game. I'm going to say a word and I want you to say it after me. Let's try an example, say, 'cowboy.' Now say the word again, but don't say 'boy.' Which part of the word is left?" Appropriate feedback was then provided. If a correct response was given, the tester then said, "Good. Let's try another example, say 'barefoot.' Now say it again, but don't say 'bare.' Which part of the word is left?" If an incorrect response was given, the child was told, "That was a good try, but let's try it again. Listen carefully. Say 'cowboy,' now say it again, but don't say 'boy.' Which part of the word is left?" If the child proceeded to respond incorrectly on the second trial, the tester provided the child with the correct response. Children were provided with a minimum of four practice items. Test items were not administered until children were able to successfully respond to all practice items.

The test was discontinued after five consecutive errors. The total number of items for which the target phonemes or syllables were correctly deleted, was calculated.

To eliminate possible ceiling effects, five additional words were administered at Time 2: three involving deletions of the second phoneme of an initial blend, one involving a single phoneme (consonant cluster) deletion in the final position, and one involving a medial deletion of a single phoneme.
3.3.3 Phonological Discrimination Measure

To address Snowling and her colleagues' (1991) concern that children's ability to discriminate between sounds may be mediating the relation between phonological memory and vocabulary, an adapted version of Wepman's Auditory Discrimination Test (1994), was administered. In the original Wepman test children are asked to discriminate between real word pairs. Children in the present study were presented with pseudoword pairs and asked whether the two words were the same or different (Geva, 1997b). The test was limited to pseudowords to reduce the influence of lexical knowledge on task performance (i.e., possible EL1-advantage). The test consisted of 34 one-syllable pseudoword pairs (Appendix E), and was presented to children in a taped format.

The pseudoword discrimination task was introduced to children by the examiner saying, "I'm going to say some silly words to you. They're not real words, so you won't recognize them. I'm going to say two words at a time. After you have listened carefully to the two words, I want you to tell me if they sound the same or different." The experimenter then presented children with a number of practice items after which the role of the tape recorder was introduced. Additional taped practice items were then administered followed by the test items.

Children were told, for example, "'yeb' - 'yeb,' do they sound the same or different?" Appropriate feedback was then provided. If a correct response was given, the tester then said, "Good. Let's try two more words, 'mide' - 'fide.'" If an incorrect response was given, the child was told, "That was a good try, but let's try it again. Listen carefully to the two words, and tell me if they sound the same or different" (the pseudoword pair was then repeated). If the
child proceeded to respond incorrectly on the second trial, the tester provided the child with the correct response. Children were provided with a minimum of two practice items.

Then children were told, “Now let’s listen to some more silly words. We’re going to listen to them on this tape recorder. First you’ll hear a bell, and then you’ll hear two words. Tell me if the words sound the same or different” (the first taped practice item was then presented). Children were given three taped practice items followed by the test items. Test items were not administered until children were able to successfully discriminate all practice items. The test was administered in its entirety, and the total number of correctly discriminated pseudoword pairs was calculated.

3.3.4 Vocabulary Measures

Two standardized measures of vocabulary were administered. The first, the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981), is a receptive measure which requires children to select one of four pictures (line-drawings) which corresponds to a label given by the experimenter. The test consists of 175 items including nouns, verbs, and adjectives. Testing is discontinued after eight consecutive responses containing six errors. The other measure, The Expressive One-Word Picture Test-Revised (EOWPT; Gardner, 1990), is an expressive measure of vocabulary in which children are asked to give a one-word label to a line-drawing presented to them. The test, which includes 100 nouns and verbs is discontinued once a criterion of six consecutive errors has been established. The total number of correct responses was calculated for both vocabulary tests.
3.3.5 Reading Measure

A standardized measure of word recognition, the Wide Range Achievement Test 3 (WRAT3; Wilkinson, 1993), was also administered. This test of single real word reading consists of 15 uppercase letters as well as 42 monosyllabic and polysyllabic words (nouns, verbs, adjectives and propositions). The test is discontinued after 10 consecutive errors. The total number of correctly read words was calculated.

3.3.6 Nonverbal Intelligence Measure

Children were also asked to complete the Matrix Analogies Test (MAT; Naglieri, 1989), a measure of nonverbal intelligence. In this test, children are presented with an illustration of an incomplete visuospatial matrix and asked to complete it by locating the missing piece among five or six patterned segments. The test consists of four subtests (pattern completion, reasoning by analogy, serial reasoning, and spatial visualization), each of which is comprised of 16 matrices. Testing is discontinued after four consecutive errors within a subtest. The total number of correctly assembled matrices was calculated.

3.3.7 Articulation Measure

Finally, children were administered the Sounds-in-Words subtest of the Goldman and Fristoe Test of Articulation (1986). In this test, children are presented with a series of coloured pictures and asked to name the objects or actions (all high frequency words such as “car,” “fishing,” “wheel”) depicted in the illustrations. This test assesses the majority of single consonant sounds and blends (in varying positions) found in the English language. The test was administered in its entirety (total of 44 responses) and difficulties in the articulation of target phonemes were noted.
Chapter 4: Results

The following analyses were performed: (1) correlational analyses (involving simple pair-wise correlations and cross-lagged correlations), to assess both the strength and direction of the relation between phonological processing skills (phonological memory and phonological awareness) and vocabulary and between phonological processing skills and word recognition; (2) hierarchical regression analyses, to assess the amount of variance accounted for by phonological memory and phonological awareness in predicting vocabulary and reading development; and (3) commonality analyses, to assess the covariance relations between phonological memory and phonological awareness (in predicting vocabulary and reading development). Analyses of variance were also performed to examine changes in task performance over time. With the exception of the analyses of variance, all statistical procedures were performed separately for EL1 and ESL subjects.

4.1 Change in Task Performance Over Time (ANOVAs)

A series of repeated measures analyses of variance (ANOVAs) was performed for the measures of phonological memory (hereafter, EPR and HPR, referring to the standard English pseudoword repetition task and the Hebrew pseudoword repetition task, respectively), phonological awareness (hereafter, AAT, referring to the auditory analysis task), phonological discrimination (hereafter, PDT), vocabulary (hereafter, PPVT and EOWPT, referring to the receptive and expressive measures of vocabulary, respectively), and word recognition (hereafter, WRAT). Table 1 presents summary statistics associated with EL1 and ESL performance on the above-mentioned tasks, as a function of time.
Table 1

EL1 and ESL Performance on Measures of Phonological Memory, Phonological Awareness, Phonological Discrimination, Vocabulary, and Word Recognition as a Function of Time: Summary Statistics (Mean Number Correct)

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<td>WRAT</td>
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Note. * = Standard English Pseudoword Repetition Task (max. 25); ** = Hebrew Pseudoword Repetition Task (max. 27); * = Auditory Analysis Task (Time 1 max. 20, Time 2 max. 25); * = Phonological Discrimination Task (max. 34); * = Peabody Picture Vocabulary Test-Revised (max. 175); * = Expressive One-Word Picture Vocabulary Test-Revised (max. 100); * = Wide Range Achievement Test 3 (max. 57)

ANOVA summary tables for the respective variables are shown in Appendix F. In all analyses, the dependent measures (EPR, HPR, AAT, PDT, PPVT, EOWPT, WRAT) were treated as the repeated measure while native language (EL1 vs. ESL) was treated as the “between” factor. Results from each of the analyses will be discussed in turn.

4.1.1 Standard English Pseudoword Repetition Task

In the case of the standard English pseudoword repetition task, the only statistically significant finding was a main effect of time, F(1, 82) = 92.24, p < .001. Examination of the relevant means shows that both EL1 and ESL subjects
improved over time, demonstrating similar growth patterns on this measure of phonological memory. The native language by time interaction was not significant.

4.1.2 Hebrew Pseudoword Repetition Task

Analysis of the Hebrew pseudoword repetition task revealed a different pattern of results. The ANOVA yielded significant main effects of native language, $F(1, 84) = 4.71, p < .05$, and time, $F(1, 84) = 57.79, p < .001$, and a significant native language by time interaction, $F(1, 84) = 4.20, p < .05$. Examination of the relevant means shows that although EL1 subjects outperformed their ESL counterparts at initial testing, by Time 2, ESL subjects were performing at a comparable level. Thus, while both groups of subjects improved over time, ESL children demonstrated the greatest improvement on this task from Time 1 to Time 2.

4.1.3 Auditory Analysis Task

ANOVA results for the phonological awareness task revealed only a significant main effect of time, $F(1, 83) = 74.75, p < .001$. Examination of the relevant means shows that EL1 and ESL subjects alike, improved on the auditory analysis measure from Time 1 to Time 2. The nonsignificant native language by time interaction suggests similar growth patterns for the two language groups.

4.1.4 Phonological Discrimination Task

Analysis of variance performed on the phonological discrimination task yielded significant main effects of native language, $F(1, 82) = 5.59, p < .05$, and time, $F(1, 82) = 50.50, p < .001$, and a significant native language by time interaction, $F(1, 82) = 7.79, p < .01$. Examination of the relevant means reveals
that while EL1 subjects outperformed their ESL counterparts at Time 1 testing, both EL1 and ESL subjects performed at a comparable level at Time 2. The rate of growth differed for the two language groups, with ESL subjects demonstrating the greatest improvement on this measure over time.

4.1.5 Vocabulary Tests

Analysis of the two vocabulary measures revealed comparable findings. With respect to the receptive measure of vocabulary, the ANOVA yielded significant main effects of native language, $F(1, 84) = 41.39, p < .001$, and time, $F(1, 84) = 359.75, p < .001$. The native language by time interaction was not significant. Analysis of the expressive measure of vocabulary also revealed significant main effects of native language, $F(1, 83) = 32.63, p < .001$, and time, $F(1, 83) = 179.08, p < .001$. As with the receptive measure, the native language by time interaction was not significant for the expressive measure of vocabulary. Examination of the relevant means for both vocabulary measures shows similar patterns of growth for EL1 and ESL subjects, and while both groups improved on these measures over time, EL1 subjects continued to outperform their ESL counterparts at Time 2.

4.1.6 Word Recognition Test

Finally, analysis of the word recognition measure yielded a significant main effect of time, $F(1, 83) = 499.67, p < .001$. Examination of the relevant means shows that EL1 and ESL subjects alike, improved significantly on this measure over time, with no group differences in the rate of growth from Time 1 to Time 2. The native language by time interaction was not significant.
4.2 Relation Between Phonological Processing Skills, Vocabulary, and Reading (Simple Correlations)

Correlation coefficients were computed for each pair of measures within and across the two times, on a pair-wise basis. Correlations between the nonverbal measure (MAT) and the outcome measures were also calculated. The resulting matrices are shown in Table 2 for EL1 subjects and Table 3 for ESL subjects. Only concurrent correlations for each pair of measures are considered. Of particular interest are those correlations which directly address the relation between phonological memory and phonological awareness on the one hand, and vocabulary and word recognition on the other hand. The relation between phonological discrimination and the measures of vocabulary and word recognition are also discussed. It is important to note, that the simple correlations reported here only serve to give an indication of the strength of the respective relations, without directly addressing the direction of these relations.

4.2.1 EL1 Findings

4.2.1.1 Phonological Memory, Vocabulary, and Reading

Concurrent correlations for EL1 subjects at both Time 1 and Time 2 are considered first. As can be seen in Table 2 (relevant correlations are shown in bold), with the exception of the standard English pseudoword repetition task at Time 2, within-time correlations between the two measures of phonological memory and both the receptive measure of vocabulary and the word recognition measure were positive and statistically significant, with coefficients ranging from .33 (p < .05) to .42 (p < .05). With respect to the expressive measure of vocabulary, only the correlation between the Hebrew pseudoword repetition task and the vocabulary measure at Time 1 was found to be statistically
Table 2

Simple Intercorrelations Among Measures of Phonological Memory, Phonological Awareness, Phonological Discrimination, Vocabulary, and Word Recognition for EL1 Subjects

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Note. Time 1 n = 40, Time 2 n = 28; * = testing time; ** p < .01, *** p < .001; Correlations shown in bold are discussed in text; AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Vocabulary Test-Revised; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; PDT = Phonological Discrimination Task; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3
Table 3

Simple Intercorrelations Among Measures of Phonological Memory, Phonological Awareness, Phonological Discrimination, Vocabulary, and Word Recognition for ESL Subjects

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<tr>
<td>13. PPVT (2)</td>
<td>.52***</td>
<td>.66**</td>
<td>.52**</td>
<td>.24</td>
<td>.77**</td>
<td>.65**</td>
<td>.50**</td>
<td>.48**</td>
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<tr>
<td>14. EOWPT (2)</td>
<td>.48**</td>
<td>.54**</td>
<td>.55**</td>
<td>.23</td>
<td>.68**</td>
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<td>.41**</td>
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<td>.33*</td>
<td>.83**</td>
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<td></td>
</tr>
<tr>
<td>15. WRAT (2)</td>
<td>.27*</td>
<td>.53**</td>
<td>.63**</td>
<td>.41**</td>
<td>.50**</td>
<td>.46**</td>
<td>.68**</td>
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<td>.24</td>
<td>.33*</td>
<td>.70**</td>
<td>.24</td>
<td>.48**</td>
<td>.57**</td>
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<td></td>
</tr>
<tr>
<td>16. MAT (2)</td>
<td>.37**</td>
<td>.36**</td>
<td>.49***</td>
<td>.10</td>
<td>.46**</td>
<td>.43**</td>
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<td>.59**</td>
<td>.58**</td>
<td>.21</td>
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</tr>
</tbody>
</table>

*Note. n = 58; * p < .05, ** p < .01, *** p < .001; Correlations shown in bold are discussed in text; AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Vocabulary Test-Revised; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; PDT = Phonological Discrimination Task; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test
significant \( (p < .05) \). With the exception of the relation between the Hebrew pseudoword repetition task and the receptive measure of vocabulary, the correlations between the phonological memory measures and vocabulary and word recognition were lower in magnitude at Time 2 than the corresponding correlations at Time 1. Differences between the correlations were not, however, statistically significant \( (EPR \text{ and PPVT}, t = .04, p > .05; EPR \text{ and EOWPT}, t = .08, p > .05; EPR \text{ and WRAT}, t = .18, p > .05; HPR \text{ and PPVT}, t = .23, p > .05; HPR \text{ and EOWPT}, t = .30, p > .05; HPR \text{ and WRAT}, t = .06, p > .05) \). It is interesting to note, that for EL1 subjects the correlations between the measures of phonological memory and vocabulary were very similar in magnitude to those found between phonological memory and word recognition.

4.2.1.2 Phonological Awareness, Vocabulary, and Reading

Phonological awareness was also found to correlate significantly with measures of vocabulary and word recognition. With the exception of the correlation between the auditory analysis task and the receptive measure of vocabulary at Time 1, within-time correlations were both positive and statistically significant, with coefficients ranging from .42 \( (p < .05) \) to .68 \( (p < .001) \). Comparisons across time revealed that the intercorrelations between the auditory analysis task and the two vocabulary measures and between the auditory analysis task and the word recognition measure increased in magnitude from Time 1 to Time 2. Again, analysis of the correlations did not reveal statistically significant differences in the magnitude of the correlations over time \( (AAT \text{ and PPVT}, t = .58, p > .05; AAT \text{ and EOWPT}, t = .15, p > .05; AAT \text{ and WRAT}, t = .81, p > .05) \). As might be expected, while not statistically significant \( (p > .05) \), the correlations between phonological awareness and word
recognition at each of the two times were found to be stronger than those between phonological awareness and vocabulary.

### 4.2.1.3 Phonological Discrimination, Vocabulary, and Reading

With respect to phonological discrimination, Table 2 shows that the within-time intercorrelations between the phonological discrimination task and the two vocabulary measures and between the phonological discrimination task and the word recognition measure were positive and statistically significant at Time 1, with coefficients ranging from .32 ($p < .05$) to .49 ($p < .01$), but failed to remain significant at Time 2 ($p > .05$). Comparisons across time revealed that the intercorrelations decreased in magnitude from Time 1 to Time 2. These changes were not, however, statistically significant (PDT and PPVT, $t = .46$, $p > .05$; PDT and EOWPT, $t = .18$, $p > .05$; PDT and WRAT, $t = 1.04$, $p > .05$). An important additional finding was the generally weak relation between measures of phonological discrimination and phonological memory.

### 4.2.2 ESL Findings

Within-time correlations for ESL subjects at both Time 1 and Time 2 are considered next. As shown in Table 3 (relevant correlations are shown in bold), the magnitude of the correlations between the various measures for ESL subjects, particularly in the case of the correlations between the measures of phonological memory and vocabulary, was considerably greater compared with that for EL1 subjects.

#### 4.2.2.1 Phonological Memory, Vocabulary, and Reading

With the exception of the correlation between the standard English pseudoword repetition task and the word recognition measure at Time 2, within-time correlations between measures of phonological memory and vocabulary
and between measures of phonological memory and word recognition were positive and statistically significant, with coefficients ranging from .33 ($p < .05$) to .63 ($p < .001$). Except in the case of the correlations between the standard English pseudoword repetition task and the receptive measure of vocabulary, the magnitude of the correlations decreased from Time 1 to Time 2. Analysis of the changes in magnitude did not, however, reveal statistically significant differences (EPR and PPVT, $t = .34$, $p > .05$; EPR and EOWPT, $t = .74$, $p > .05$; EPR and WRAT, $t = .88$, $p > .05$; HPR and PPVT, $t = 1.54$, $p > .05$; HPR and EOWPT, $t = .19$, $p > .05$; HPR and WRAT, $t = .24$, $p > .05$). It is important to note the stronger correlations found between phonological memory and vocabulary than between phonological memory and word recognition. While not statistically significant, this finding, noted with EL1 and ESL children alike, suggests the possible greater importance of phonological memory in vocabulary development than in reading development, an issue which will be addressed later.

### 4.2.2.2 Phonological Awareness, Vocabulary, and Reading

Phonological awareness was also found to relate significantly to early and later vocabulary and word recognition performance. Within-time intercorrelations between the auditory analysis task and vocabulary and between the auditory analysis task and word recognition were positive and statistically significant, with coefficients ranging from .40 ($p < .01$) to .70 ($p < .001$). With the exception of the relation between the auditory analysis task and the receptive measure of vocabulary in which there was no discernible change in the magnitude of the correlations from Time 1 to Time 2, the magnitude of the correlations between the other measures increased from Time 1 to Time 2. Again,
differences between the correlations across time were not statistically significant (AAT and PPVT, $t = .00, p > .05$; AAT and EOWPT, $t = .66, p > .05$; AAT and WRAT, $t = .57, p > .05$). As was noted for EL1 subjects, the correlations for ESL subjects between phonological awareness and word recognition were stronger than those between phonological awareness and vocabulary.

4.2.2.3 Phonological Discrimination, Vocabulary, and Reading

With respect to phonological discrimination, as Table 3 shows, with the exception of the relation between the phonological discrimination task and the expressive measure of vocabulary at Time 1 and between the phonological discrimination task and the word recognition measure at Time 2, the within-time intercorrelations between phonological discrimination and vocabulary and between phonological discrimination and word recognition were positive and statistically significant, with coefficients ranging from $.27 (p < .05)$ to $.39 (p < .01)$. While the intercorrelation between the phonological discrimination task and the word recognition measure decreased in magnitude from Time 1 to Time 2, the opposite pattern was found in the case of the two vocabulary measures. Differences between the correlations across time, were not, however, found to be statistically significant (PDT and PPVT, $t = .52, p > .05$; PDT and EOWPT, $t = .84, p > .05$; PDT and WRAT, $t = .88, p > .05$). Finally, it is interesting to note, that with the exception of the relation between the phonological discrimination task and the standard English pseudoword repetition task at Time 1, the magnitude of the correlations between phonological discrimination and phonological memory, particularly in the case of the Hebrew version of the pseudoword repetition test, was considerably greater for ESL children compared with their EL1 counterparts.
4.2.3 Summary

The results reported thus far support the notion that phonological memory and phonological awareness are related (to varying degrees) to vocabulary and reading performance in both EL1 and ESL subjects. The finding that phonological memory skills are associated with vocabulary and word recognition skills in EL1 subjects has been amply supported in the literature. Discovery of similar patterns of association in young ESL children, while not surprising, is an important result. With respect to phonological awareness, the present findings add to the existing body of literature by pointing to a strong association between children’s ability to manipulate the sound structure of the language and their reading competency. An interesting result, which supports Metsala’s (1999) data, is the finding of a strong relation between phonological awareness and vocabulary knowledge, in both EL1 and ESL children. Finally, while both EL1 and ESL’s children’s ability to discriminate among phonemes was related to their vocabulary knowledge and reading ability (although not consistently across the various measures and time), an interesting result is the stronger relation between phonological discrimination and phonological memory in ESL children compared with their EL1 counterparts. This latter finding lends support to the notion that at least in the case of ESL children, phonological discrimination may to some extent be influencing the relation between phonological memory and vocabulary.

The existence of co-relations does not, however, make clear the specific nature of the relations. While much is known about the reciprocal relation between phonological awareness and reading, considerably less is known about the causal links between phonological memory and vocabulary, phonological
memory and reading, and between phonological awareness and vocabulary. Data collected by Gathercole and her colleagues (1992) on native vocabulary development suggests that past age five, phonological memory ceases to be an important predictor of later vocabulary knowledge. Moreover, it has been posited that past age five, vocabulary knowledge becomes a key component in the subsequent development of phonological memory skills. What is of interest in the present context, is whether the causal structure between phonological memory and phonological awareness on the one hand and vocabulary and reading on the other hand, is comparable in EL1 and ESL children, or whether the developmental trajectories of these variables differ for the two language groups.

4.3 Relation Between Phonological Processing Skills, Vocabulary, and Reading (Cross-lagged Correlations)

To shed some light on this issue, cross-lagged correlations across Times 1 and 2 were examined between phonological memory and phonological awareness on the one hand and vocabulary and word recognition on the other hand. Figures 5 to 16 illustrate across-time correlations relating to measures of phonological memory, vocabulary, and word recognition for both EL1 and ESL subjects, while Figures 17 to 22 show comparable correlations for the phonological awareness measure. As was mentioned earlier, although no definitive causal statements can be offered on the basis of correlational findings, the method of cross-lagged correlations allows for the establishment of certain patterns of developmental association which lend greater or lesser support to a particular causal theory.
Figure 5. Cross-lagged correlations between EPR and PPVT for EL1 subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPR</td>
<td>.41*</td>
</tr>
<tr>
<td>PPVT</td>
<td>.15</td>
</tr>
</tbody>
</table>

Figure 6. Cross-lagged correlations between HPR and PPVT for EL1 subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPR</td>
<td>.41*</td>
</tr>
<tr>
<td>PPVT</td>
<td>.55**</td>
</tr>
</tbody>
</table>

Figure 7. Cross-lagged correlations between EPR and EOWPT for EL1 subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
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</thead>
<tbody>
<tr>
<td>EPR</td>
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</tr>
<tr>
<td>EOWPT</td>
<td>.16</td>
</tr>
</tbody>
</table>

Figure 8. Cross-lagged correlations between HPR and EOWPT for EL1 subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPR</td>
<td>.20</td>
</tr>
<tr>
<td>EOWPT</td>
<td>.51**</td>
</tr>
</tbody>
</table>

Figure 9. Cross-lagged correlations between EPR and WRAT for EL1 subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
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</thead>
<tbody>
<tr>
<td>EPR</td>
<td>.16</td>
</tr>
<tr>
<td>WRAT</td>
<td>.23</td>
</tr>
</tbody>
</table>

Figure 10. Cross-lagged correlations between HPR and WRAT for EL1 subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
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</thead>
<tbody>
<tr>
<td>HPR</td>
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</tr>
<tr>
<td>WRAT</td>
<td>.64***</td>
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</tbody>
</table>

Figure 11. Cross-lagged correlations between EPR and PPVT for ESL subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPR</td>
<td>.46***</td>
</tr>
<tr>
<td>PPVT</td>
<td>.52***</td>
</tr>
</tbody>
</table>

Figure 12. Cross-lagged correlations between HPR and PPVT for ESL subjects

<table>
<thead>
<tr>
<th>Time 1</th>
<th>Time 2</th>
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</thead>
<tbody>
<tr>
<td>HPR</td>
<td>.46***</td>
</tr>
<tr>
<td>PPVT</td>
<td>.66***</td>
</tr>
</tbody>
</table>

Note. * p < .05, ** p < .01, *** p < .001; Lines shown in bold represent correlations of greater magnitude than the respective cross-lagged correlation; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3.
Figure 13. Cross-lagged correlations between EPR and EOWPT for ESL subjects

Figure 14. Cross-lagged correlations between HPR and EOWPT for ESL subjects

Figure 15. Cross-lagged correlations between EPR and WRAT for ESL subjects

Figure 16. Cross-lagged correlations between HPR and WRAT for ESL subjects

Figure 17. Cross-lagged correlations between AAT and PPVT for EL1 subjects

Figure 18. Cross-lagged correlations between AAT and EOWPT for EL1 subjects

Figure 19. Cross-lagged correlations between AAT and WRAT for EL1 subjects

Figure 20. Cross-lagged correlations between AAT and PPVT for ESL subjects

Note. * p < .05, ** p < .01, *** p < .001; Lines shown in bold represent correlations of greater magnitude than the respective cross-lagged correlation; AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3
4.3.1 Relation Between Phonological Memory, Vocabulary, and Reading: EL1 Findings

Consider first the cross-lagged pairs of correlations between phonological memory and vocabulary and between phonological memory and word recognition for EL1 subjects. With respect to the receptive measure of vocabulary, a comparison of Figures 5 and 6 reveals a different causal dynamic between the standard English pseudoword repetition task and the receptive measure of vocabulary compared with that between the Hebrew pseudoword repetition task and the vocabulary measure. As the figures show, the correlation between the receptive measure of vocabulary at Time 1 and the standard English pseudoword repetition task at Time 2 was statistically significant ($p < .05$) and greater in magnitude than the converse nonsignificant correlation ($p > .05$) between the standard English pseudoword repetition task at Time 1 and the receptive measure of vocabulary at Time 2, while in the case of the Hebrew pseudoword repetition task, a different pattern emerged; the correlation between the Hebrew pseudoword repetition task at Time 1 and the receptive measure of vocabulary at Time 2 was statistically significant ($p < .01$) and greater in magnitude than the respective cross-lagged correlation; AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3.
magnitude than the corresponding significant correlation ($p < .05$) between the vocabulary measure at Time 1 and the Hebrew pseudoword repetition task at Time 2. In other words, the relation between the Hebrew pseudoword repetition task and the receptive measure of vocabulary appears to be bi-directional in nature, while this was not found to be the case with respect to the standard English pseudoword repetition task. It should be noted, however, that differences between the correlation coefficients were not statistically significant for either measure of phonological memory ($EPR, t = 1.01, p > .05; HPR, t = .65, p > .05$).

Analysis of the cross-lagged correlations between phonological memory and the expressive measure of vocabulary failed to reveal a comparable bi-directional relation between the variables. As Figures 7 and 8 illustrate, the only significant correlation was found between the Hebrew pseudoword repetition task at Time 1 and the expressive measure of vocabulary at Time 2 ($p < .01$). It should also be noted that while the relation between the Hebrew pseudoword repetition task and the two measures of vocabulary was similar in that early phonological memory was found to be a better predictor of later vocabulary knowledge than vice versa, the direction of greatest influence between the standard English pseudoword repetition task and the expressive measure of vocabulary and between the standard English pseudoword repetition task and receptive measure of vocabulary was found to differ. Although not statistically significant ($p > .05$), the correlation between the standard English pseudoword repetition task at Time 1 and the expressive measure of vocabulary at Time 2 was greater in magnitude than the converse relation between the expressive measure of vocabulary at Time 1 and the standard English pseudoword repetition task at
2. Differences between the correlations for either measure of phonological memory were not, however, statistically significant (EPR, \( t = .50, p > .05 \); HPR, \( t = 1.27, p > .05 \)).

A pattern of results similar to the one reported between the two measures of phonological memory and the expressive measure of vocabulary emerged between phonological memory and word recognition. As Figures 9 and 10 show, scores on both measures of phonological memory at Time 1 yielded higher correlations with word recognition scores at Time 2, than the corresponding correlations between word recognition scores at Time 1 and phonological memory scores at Time 2. Only the correlation between early Hebrew pseudoword repetition performance and later word recognition scores reached statistical significance \( (p < .001) \). Finally, while differences between the pairs of coefficients were found to be statistically significant for the Hebrew pseudoword repetition task \( (t = 2.11, p < .05) \), this was not the case for the standard English pseudoword repetition measure \( (t = .26, p > .05) \).

### 4.3.2 Relation Between Phonological Memory, Vocabulary, and Reading: ESL Findings

The ESL findings were similar to those reported for EL1 subjects with some notable exceptions. As Figures 11 through 16 show, the corresponding correlations between the English and the Hebrew pseudoword repetition tasks at Time 1 and vocabulary and word recognition performance at Time 2 were greater in magnitude than the converse correlations between the vocabulary and word recognition measures at Time 1 and English and Hebrew pseudoword repetition performance at Time 2. Differences between the respective correlations were not, however, statistically significant \( (EPR \text{ and PPVT}, t = .41, \)
HPR and PPVT, $t = 1.55, p > .05$; EPR and EOWPT, $t = 1.46, p > .05$; HPR and EOWPT, $t = 1.19, p > .05$; EPR and WRAT, $t = .33, p > .05$; HPR and WRAT, $t = 1.59, p > .05$). It is important to note, however, that with the exception of the relation between the standard English pseudoword repetition task and expressive measure of vocabulary and between the standard English pseudoword repetition task and the word recognition measure, the direction of causation between phonological memory and vocabulary and between phonological memory and word recognition appears to be bi-directional with correlations between early phonological memory and later vocabulary and word recognition and between early vocabulary and word recognition and later phonological memory all reaching statistical significance ($p < .05$). The finding that early English pseudoword repetition performance is significantly correlated with later vocabulary and word recognition scores is a result which is contrary to that reported for EL1 subjects.

4.3.3 Relation Between Phonological Awareness, Vocabulary, and Reading: EL1 Findings

Figures 17 through 19 show the cross-lagged correlations between phonological awareness and vocabulary and between phonological awareness and word recognition for EL1 subjects. Consider first the correlations between the auditory analysis task and the two measures of vocabulary. While not reaching statistical significance, the correlations between the receptive and expressive measures of vocabulary at Time 1 and the auditory analysis task at Time 2 were greater in magnitude than the corresponding correlations between the auditory analysis task at Time 1 and the two measures of vocabulary at Time 2 (PPVT, $t = .02, p > .05$; EOWPT, $t = .78, p > .05$). The only statistically
significant correlation was observed between early performance on the expressive vocabulary measure and later performance on the auditory analysis task (\(p < .05\)).

The pattern of results was markedly different between phonological awareness and word recognition. As would be predicted, there was a strong reciprocal relation between phonological awareness and word recognition with correlations between early performance on the auditory analysis task and later word recognition scores and between early word recognition performance and later auditory analysis scores reaching statistical significance (\(p < .01\) and \(p < .05\), respectively). Also, although not statistically significant, the correlation between early auditory analysis performance and later word recognition performance was greater in magnitude than the reverse correlation between early word recognition performance and later the auditory analysis scores (\(t = .71, p > .05\)).

4.3.4 Relation Between Phonological Awareness, Vocabulary, and Reading: ESL Findings

Finally, Figures 20 through 22 show the cross-lagged correlations between phonological awareness and vocabulary and between phonological awareness and word recognition for ESL subjects. The relation between phonological awareness and vocabulary differed from that observed for EL1 subjects. In the case of ESL subjects, the data suggest a strong bi-directional relation between phonological awareness and vocabulary with correlations between the auditory analysis task at Time 1 and the receptive and expressive measures of vocabulary at Time 2 and between the two vocabulary measures at Time 1 and the auditory analysis task at Time 2 reaching statistical significance
Further, the magnitude of the correlations was greatest in the direction of early auditory analysis performance correlating with later vocabulary scores. Differences between the correlations were not, however, statistically significant (PPVT, $t = .68$, $p > .05$; EOWPT, $t = .15$, $p > .05$).

The relation between phonological awareness and word recognition, on the other hand, paralleled that observed for EL1 subjects with strong correlations between early auditory analysis performance and later word recognition scores and between early word recognition performance and later auditory analysis scores ($p < .001$). The magnitude of the correlation between the auditory analysis task at Time 1 and the word recognition measure at Time 2 was greater than that of the corresponding correlation between word recognition performance at Time 1 and auditory analysis performance at Time 2. Again, differences between the correlations were not found to be statistically significant ($t = .65$, $p > .05$).

4.3.5 Summary

To sum up, results of the cross-lagged correlations suggest that phonological memory (in the case of EL1 subjects, depending on which measure of pseudoword repetition is used) plays a role in predicting later vocabulary and word recognition performance in EL1 and ESL subjects alike. The present findings also contribute to the existing literature which has found a strong reciprocal co-relation between phonological awareness and reading. Further, the data suggest that the relation between phonological awareness and vocabulary may be different for ESL children compared with EL1 children. Thus, while these correlational data specify the extent to which children’s ability to hold phonological sequences in memory and manipulate the sound structure
of the language explains individual differences in later vocabulary and reading performance, the present findings do not make clear whether these phonological processing skills are implicated in predicting vocabulary and reading development. To address this latter issue, hierarchical regression analyses with early vocabulary and reading knowledge accounted for, were performed.

4.4 Role of Phonological Processing Skills in Vocabulary and Reading Development (Hierarchical Regressions)

A series of hierarchical regression analyses were performed to assess the contributions of phonological memory and phonological awareness at age six (Time 1) to vocabulary and reading performance one-and-a-half years later (Time 2). The regression analyses were performed separately for the phonological memory and phonological awareness measures. In addition to partialling out early knowledge on the outcome measure (PPVT, EOWPT, or WRAT), variance accounted for by nonverbal ability was also taken into account.

Preliminary analyses revealed that for EL1 and ESL subjects alike, age (in months) was not a significant predictor of later vocabulary scores (variance explained in receptive vocabulary measure = 2% and 1%, respectively; variance explained in expressive vocabulary measure = 0% and 4%, respectively) or word recognition performance variance explained = 2% and 4%, respectively). Further, in a separate set of hierarchical regression analyses (see Appendix H), it was revealed that children's performance on the phonological discrimination

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Regression analyses aimed at assessing the contributions of vocabulary and word recognition to phonological memory and phonological awareness development were also performed (see Appendix G). Analyses were performed only on those variables which were found to correlate significantly in the cross-lagged analyses. Because the results do not directly address vocabulary and reading development, they are not discussed in the text.
measure, once nonverbal ability was accounted for, failed to explain any statistically significant amount of variance ($p > .05$) in vocabulary scores one-and-a-half years later. When both nonverbal ability and performance on the outcome measure at Time 1 were partialled out, phonological discrimination also failed to explain variability in later word recognition performance ($p > .05$). Children's age and performance on the phonological discrimination measure were thus not included in subsequent analyses examining the contributions made by phonological memory and phonological awareness to vocabulary and reading development.

Regression analyses were performed only on those variables which were found to correlate significantly in the cross-lagged analyses. In all regression equations, nonverbal ability (measured by the MAT) and early knowledge on the outcome measure (Time 1) were entered in steps 1 and 2, respectively. In the case of the ESL data in which both measures of phonological memory were found to correlate significantly with the outcome variable, the order in which the variables were entered into the regression equation was the Hebrew pseudoword repetition task first, the standard English pseudoword repetition task second. The rationale for entering the Hebrew measure of phonological memory prior to the English version was based on the stronger correlations between the Hebrew measure and vocabulary and between the Hebrew measure and word recognition compared with those between the standard English measure of phonological memory and the two criterion variables.
4.4.1 EL1 Findings

4.4.1.1 Role of Phonological Memory in Vocabulary and Reading Development

The findings for EL1 subjects are considered first. As Tables 4, 5, and 6a show, after nonverbal ability and early performance on the outcome measure were partialled out, the Hebrew pseudoword repetition task remained a significant predictor of vocabulary (receptive and expressive) and word recognition performance one-and-a-half years later, accounting for 11% (\(p < .05\)), 10% (\(p < .05\)), and 11% (\(p < .01\)) of the variance, respectively. Nonverbal ability and early vocabulary knowledge were also found to be highly significant predictors of subsequent vocabulary development (variance explained in receptive vocabulary measure = 21%, \(p < .05\) and 23%, \(p < .01\), respectively; variance explained in expressive vocabulary measure = 25%, \(p < .01\) and 15%, \(p < .05\), respectively). Likewise, nonverbal ability and early reading skills were significant predictors of individual differences in reading development (variance explained = 15%, \(p < .05\) and 47%, \(p < .001\), respectively).

4.4.1.2 Role of Phonological Awareness in Reading Development

Table 6b shows that when phonological awareness followed the word recognition Time 1 variable in the regression equation, it failed to account for any additional variance in the reading measure. This is not a surprising finding given the high correlation between word recognition and auditory analysis scores at Time 1 (\(r = .55, p < .001\)). When the auditory analysis variable preceded the word recognition Time 1 variable in the equation, it explained a significant amount of variance in the word recognition scores at Time 2 (variance explained = 19%, \(p < .05\)).
### Table 4

**Hierarchical Regression Analysis Predicting PPVT (Time 2) Performance in EL1 Subjects, with Phonological Memory (Time 1) as an Independent Variable**

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
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<th>$\Delta R^2$</th>
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<td>2.62*</td>
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<tr>
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<td>.23</td>
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</tr>
<tr>
<td>3.</td>
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</tbody>
</table>

*Note.* * = Time 1; *p < .05, **p < .01; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; PPVT = Peabody Picture Vocabulary Test-Revised

### Table 5

**Hierarchical Regression Analysis Predicting EOWPT (Time 2) Performance in EL1 Subjects, with Phonological Memory (Time 1) as an Independent Variable**

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>T</th>
<th>Partial r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.25</td>
<td></td>
<td>2.91**</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>EOWPT (T1)</td>
<td>.40</td>
<td>.15</td>
<td>2.53*</td>
<td>.45</td>
</tr>
<tr>
<td>3.</td>
<td>HPR</td>
<td>.50</td>
<td>.10</td>
<td>2.19*</td>
<td>.41</td>
</tr>
</tbody>
</table>

*Note.* * = Time 1; *p < .05, **p < .01; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test

### Table 6

**Hierarchical Regression Analyses Predicting WRAT (Time 2) Performance in EL1 Subjects, with Phonological Memory and Phonological Awareness (Time 1) as Independent Variables**

**Set a**

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>T</th>
<th>Partial r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.15</td>
<td></td>
<td>2.09*</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>WRAT (T1)</td>
<td>.62</td>
<td>.47</td>
<td>5.41***</td>
<td>.74</td>
</tr>
<tr>
<td>3.</td>
<td>HPR</td>
<td>.73</td>
<td>.11</td>
<td>3.16**</td>
<td>.55</td>
</tr>
</tbody>
</table>

**Set b**

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>T</th>
<th>Partial r</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>AAT</td>
<td>.62</td>
<td>.00</td>
<td>.61</td>
<td>.13</td>
</tr>
</tbody>
</table>

*Note.* * = Time 1; *p < .05, **p < .01, ***p < .001; AAT = Auditory Analysis Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; WRAT = Wide Range Achievement Test 3
4.4.2 ESL Findings

4.4.2.1 Role of Phonological Memory in Vocabulary and Reading Development

Results of the regression analyses for ESL subjects are shown in Tables 7 to 9. Tables 7a, 8a, and 9a show that in the prediction of vocabulary (both receptive and expressive) and word recognition scores at Time 2, the Hebrew pseudoword repetition task accounted for an additional 5% (p < .05) and 9% (p < .01) of the variance, respectively, above and beyond that of nonverbal ability and early performance on the outcome measure. When entered into the regression equation after the Hebrew pseudoword repetition task, the standard English pseudoword repetition task failed to contribute any unique variance to either the vocabulary or word recognition scores.

To assess whether the Hebrew pseudoword repetition task accounted for any unique variance in the regressions, a second set of hierarchical analyses in which the Hebrew pseudoword repetition task followed the standard English pseudoword repetition task in the equation, were performed (see Tables 7b, 8b, and 9b). Table 7b shows that when the standard English pseudoword repetition task preceded the Hebrew pseudoword repetition task in the regression equation, it significantly predicted receptive vocabulary performance (variance explained = 3%, p < .05). Moreover, the Hebrew pseudoword repetition task remained a significant predictor of later vocabulary knowledge, even after the other measures had been entered (unique variance explained = 4%, p < .05). A different pattern of results was revealed with respect to the expressive measure of vocabulary. Unlike the findings reported for the receptive measure of vocabulary, the standard English pseudoword repetition task, when entered into
Table 7

Hierarchical Regression Analyses Predicting PPVT (Time 2) Performance in ESL Subjects, with Phonological Memory and Phonological Awareness (Time 1) as Independent Variables

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>R²</th>
<th>AR²</th>
<th>T</th>
<th>Partial r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>PPVT (T1)³</td>
<td>.60</td>
<td>.37</td>
<td>6.99***</td>
<td>.69</td>
</tr>
<tr>
<td>3.</td>
<td>HPR</td>
<td>.65</td>
<td>.05</td>
<td>2.81**</td>
<td>.36</td>
</tr>
<tr>
<td>4.</td>
<td>EPR</td>
<td>.67</td>
<td>.02</td>
<td>1.65</td>
<td>.22</td>
</tr>
</tbody>
</table>

(Set b)

| 3.   | EPR          | .63    | .03    | 2.24*  | .29       |
| 4.   | HPR          | .67    | .04    | 2.33*  | .31       |

(Set c)

| 3.   | AAT          | .62    | .02    | 1.87   | .25       |

Note. ³ = Time 1; * p < .05, ** p < .01, *** p < .001; AAT = Auditory Analysis Task; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; PPVT = Peabody Picture Vocabulary Test-Revised
Table 8

Hierarchical Regression Analyses Predicting EOWPT (Time 2) Performance in ESL Subjects, with Phonological Memory and Phonological Awareness Measures (Time 1) as Independent Variables

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.16</td>
<td></td>
<td>3.21**</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>EOWPT (T1)*</td>
<td>.55</td>
<td>.39</td>
<td>6.95***</td>
<td>.69</td>
</tr>
<tr>
<td>3.</td>
<td>HPR</td>
<td>.60</td>
<td>.05</td>
<td>2.49*</td>
<td>.32</td>
</tr>
<tr>
<td>4.</td>
<td>EPR</td>
<td>.61</td>
<td>.01</td>
<td>.97</td>
<td>.13</td>
</tr>
</tbody>
</table>

(Set b)

| 3.   | EPR                            | .58   | .03          | 1.61      | .22         |
| 4.   | HPR                            | .61   | .03          | 2.09*     | .28         |

(Set c)

| 3.   | AAT                            | .63   | .08          | 3.18**    | .40         |

Note. * = Time 1; * $p < .05$, ** $p < .01$, *** $p < .001$; AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test
Table 9

Hierarchical Regression Analyses Predicting WRAT (Time 2) Performance in ESL Subjects, with Phonological Memory and Phonological Awareness Measures (Time 1) as Independent Variables

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>R²</th>
<th>AR²</th>
<th>T</th>
<th>Partial r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>WRAT (T1)*</td>
<td>.46</td>
<td>.42</td>
<td>6.54***</td>
<td>.66</td>
</tr>
<tr>
<td>3.</td>
<td>HPR</td>
<td>.55</td>
<td>.09</td>
<td>3.27**</td>
<td>.41</td>
</tr>
<tr>
<td>4.</td>
<td>EPR</td>
<td>.57</td>
<td>.02</td>
<td>-1.19b</td>
<td>-.16</td>
</tr>
</tbody>
</table>

(Set b)

| 3.   | EPR       | .46| .00 | -.11 | -.01 |
| 4.   | HPR       | .57| .11 | 3.49*** | .44 |

(Set c)

| 3.   | AAT       | .53| .07 | 2.67** | .34 |

Note. * = Time 1; b = negative values (which are relatively small in this data) indicate statistical suppression (see Cohen & Cohen, 1983); ** p < .01, *** p < .001; AAT = Auditory Analysis Task; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; WRAT = Wide Range Achievement Test 3

the regression equation prior to the Hebrew pseudoword repetition task, failed to explain any significant amount of variance in the dependent measure (p > .05). This nonsignificant finding may be explained by the high correlation between the standard English pseudoword repetition task and the expressive measure of vocabulary at Time 1 (r = .44, p < .001). In fact, when the standard English pseudoword repetition task was entered into the regression equation in step 2 (prior to the vocabulary Time 1 variable), it explained 14% (p < .001) of the variance in the vocabulary scores. It is also important to note, that the Hebrew pseudoword repetition task remained a significant predictor of expressive vocabulary performance, even after variance accounted for by the other three measures was partialled out (unique variance explained = 3%, p <
Finally, nonverbal ability and early vocabulary knowledge were significant predictors of both receptive vocabulary (variance explained = 23%, $p < .001$ and 37%, $p < .001$, respectively) and expressive vocabulary development (variance explained = 16%, $p < .01$ and 39%, $p < .001$, respectively).

In predicting scores on the word recognition measure (see Table 9b), the Hebrew pseudoword repetition task, when entered last into the regression equation, explained 11% unique variance ($p < .001$), while the standard English pseudoword repetition task, even when entered in step 3 of the equation, failed to explain any additional variance in the dependent measure ($p > .05$).

Children’s early word recognition performance was also found to significantly predict later reading skills (variance explained = 42%, $p < .001$). Nonverbal ability did not predict Time 2 scores on the reading measure ($p > .05$).

4.4.2.2 Role of Phonological Awareness in Vocabulary and Reading Development

Tables 7c, 8c, and 9c present the results of the regression analyses conducted on the vocabulary and word recognition measures with phonological awareness as the independent variable. Analysis of the two vocabulary measures revealed different patterns of results. As Table 7c shows, when the auditory analysis measure followed the receptive vocabulary Time 1 variable in the regression equation, it failed to account for any additional variance in the vocabulary measure at Time 2 ($p > .05$). Again, this nonsignificant finding is not surprising given the strong correlation between receptive vocabulary and auditory analysis scores at Time 1 ($r = .49, p < .001$). When the auditory analysis task preceded the receptive vocabulary Time 1 variable in the equation, it was
highly predictive of later vocabulary knowledge (variance explained = 17%, \( p < .001 \)).

Results for the expressive measure of vocabulary parallel those revealed for the reading measure. For both criterion variables, auditory analysis performance remained predictive of later expressive vocabulary and word recognition performance even after nonverbal ability and Time 1 performance on the outcome measure were partialled out, accounting for an additional 8% (\( p < .01 \)) and 7% (\( p < .01 \)) of the variance, respectively.

4.4.3 Summary

To briefly summarize, hierarchical regression analyses with Time 2 vocabulary and word recognition scores as criterion variables, revealed that for EL1 and ESL subjects alike, the Hebrew measure of phonological memory was a significant predictor of unique variance in later vocabulary and word recognition scores. The English version of the phonological memory measure, on the other hand, failed to account for any additional variance above and beyond that explained by the Hebrew measure. Finally, while phonological awareness was significantly predictive of individual differences in later reading scores for both EL1 and ESL children, it accounted for unique variance in vocabulary (specifically expressive vocabulary) knowledge only in the case of ESL children.

While the regression analyses reported thus far make clear the individual contributions made by phonological memory and phonological awareness to children’s later vocabulary and reading performance, they do not shed light on the covariance relations between these two phonological processing skills with respect to the development of vocabulary and reading. To further explore the
covariance relations between phonological memory and phonological awareness, commonality analyses were performed.

4.5 Relative Roles of Phonological Processing Skills in Vocabulary and Reading Development (Commonality Analyses)

The procedure of commonality analysis allows for closer examination of the unique and shared variances contributed by a number of independent variables to a predicted outcome measure (see Kerlinger & Pedhazur, 1973). In the present context, it is possible to make clear not only the proportion of the variance which is unique to each of the three phonological processing measures, namely the standard English pseudoword repetition task, the Hebrew pseudoword repetition task, and the auditory analysis task, but also the amount of variance shared by all possible combinations of these variables. In particular, it is of interest to assess to what extent phonological memory and phonological awareness are tapping the same underlying phonological processing skill.

Using the hierarchical regression method of analysis, the total amount of variance explained by each measure of phonological memory and phonological awareness was broken down into unique and shared components. Because the results of the regression analyses showed that nonverbal ability explained a significant amount of the variance in both vocabulary and word recognition performance (with the exception of ESL word recognition), it was incorporated into the commonality analysis. Early vocabulary and reading knowledge (Time 1) was not, however, considered in the analysis. As was shown earlier, in a number of hierarchical analyses, when phonological awareness followed the Time 1 vocabulary or word recognition variable in the regression equation, it was rendered nonsignificant because of its strong correlation with the preceding
variable. The purpose of the commonality analysis in the present context is to assess the overlapping variances between the three phonological measures in predicting vocabulary and reading performance, and not to ascertain if these variables are themselves significant predictors of vocabulary or reading development, an issue already addressed by the hierarchical regression analyses.

4.5.1 EL1 Findings

4.5.1.1 Relative Roles of Phonological Processing Skills in Vocabulary Development

Results of the commonality analysis for EL1 subjects are considered first. As Tables 10 and 11 show, the greatest amount of variance in the vocabulary measures was accounted for by the Hebrew pseudoword repetition task. With respect to the receptive measure of vocabulary, of the 22% variance in the vocabulary scores explained by the Hebrew pseudoword repetition task, only a fraction was shared variance (2% with the standard English pseudoword repetition task and 1% with the auditory analysis task). Neither the standard English pseudoword repetition task nor the auditory analysis task contributed any unique variance to the receptive measure of vocabulary, nor was there any evidence of any shared variance among all three phonological processing variables. Analysis of the expressive measure of vocabulary revealed a comparable pattern of results, with only a small percentage of the total amount of variance accounted for by the Hebrew pseudoword repetition task (17%) being variance shared with the other variables. Again, no unique variance in the expressive vocabulary scores was accounted for by either the standard English pseudoword repetition task or the auditory analysis task.
Table 10

Commonality Analysis Predicting EL1 PPVT (Time 2) Performance

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>EPR</th>
<th>HPR</th>
<th>AAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unique Variance</strong></td>
<td>.00</td>
<td>.19</td>
<td>.00</td>
</tr>
<tr>
<td><strong>Common Variance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPR, HPR</td>
<td>.02</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>EPR, AAT</td>
<td>.00</td>
<td></td>
<td>.00</td>
</tr>
<tr>
<td>HPR, AAT</td>
<td></td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>EPR, HPR, AAT</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td><strong>Total Unique and Common</strong></td>
<td>.02</td>
<td>.22</td>
<td>.01</td>
</tr>
</tbody>
</table>

*Note.* AAT = Auditory Analysis Task; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; PPVT = Peabody Picture Vocabulary Test-Revised

Table 11

Commonality Analysis Predicting EL1 EOWPT (Time 2) Performance

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>EPR</th>
<th>HPR</th>
<th>AAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unique Variance</strong></td>
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<td>.14</td>
<td>.00</td>
</tr>
<tr>
<td><strong>Common Variance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPR, HPR</td>
<td>.02</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>EPR, AAT</td>
<td>.00</td>
<td></td>
<td>.00</td>
</tr>
<tr>
<td>HPR, AAT</td>
<td></td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>EPR, HPR, AAT</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td><strong>Total Unique and Common</strong></td>
<td>.02</td>
<td>.17</td>
<td>.01</td>
</tr>
</tbody>
</table>

*Note.* AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task
4.5.1.2 Relative Roles of Phonological Processing Skills in Reading Development

A slightly different pattern of results was revealed for the word recognition measure. As can be seen in Table 12, both the Hebrew pseudoword repetition task and the auditory analysis task contributed unique amounts of variance to the outcome measure (25% and 13%, respectively). As was the case with the vocabulary measures, there was little overlapping variance among any two or all three of the phonological variables (ranging from 1% to 3%). The standard English pseudoword repetition task failed to account for any unique variance in the word recognition measure.

4.5.1.3 Summary

These data suggest that with respect to EL1 vocabulary development, phonological memory (i.e., the Hebrew pseudoword repetition task) but not phonological awareness, is a significant predictor. In the case of EL1 reading development, both phonological memory (again, only the Hebrew pseudoword repetition task) and phonological awareness explain unique variances, with negligible amounts of variance shared between them. This latter finding suggests that phonological memory and phonological awareness may be tapping unique phonological processing skills, both of which are important in the development of reading skills.

4.5.2 ESL Findings

4.5.2.1 Relative Roles of Phonological Processing Skills in Vocabulary Development

A different pattern of unique and shared variances was revealed for ESL subjects. Consider first the receptive measure of vocabulary. As shown in Table
Table 12

Commonality Analysis Predicting EL1 WRAT (Time 2) Performance

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>EPR</th>
<th>HPR</th>
<th>AAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Variance</td>
<td>.00</td>
<td>.25</td>
<td>.13</td>
</tr>
<tr>
<td>Common Variance</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>EPR, HPR</td>
<td>.03</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>EPR, AAT</td>
<td>.01</td>
<td></td>
<td>.01</td>
</tr>
<tr>
<td>HPR, AAT</td>
<td></td>
<td>.03</td>
<td>.03</td>
</tr>
<tr>
<td>EPR, HPR, AAT</td>
<td>.01</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>Total Unique and Common</td>
<td>.05</td>
<td>.32</td>
<td>.18</td>
</tr>
</tbody>
</table>

Note. AAT = Auditory Analysis Task; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; WRAT = Wide Range Achievement Test 3

13, the Hebrew pseudoword repetition task explained the greatest amount of variance in the vocabulary scores. Of the 27% accounted for by the Hebrew pseudoword repetition task, 10% was unique variance, while the remainder was common variance which can be decomposed into 4% shared variance with the standard English pseudoword repetition task, 7% shared variance with the auditory analysis task, and 6% shared variance with both the standard English pseudoword repetition task and the auditory analysis task. Of the variance in the vocabulary scores explained by the standard English pseudoword repetition task and the auditory analysis task, the majority was shared variance, with each variable accounting for only a small amount of unique variance.

Table 14 shows the results for the expressive measure of vocabulary. Unlike with the receptive measure of vocabulary, the greatest amount of unique variance in the expressive vocabulary scores was contributed by phonological
Table 13

Commonality Analysis Predicting ESL PPVT (Time 2) Performance

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>EPR</th>
<th>HPR</th>
<th>AAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Variance</td>
<td>.02</td>
<td>.10</td>
<td>.01</td>
</tr>
<tr>
<td>Common Variance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPR, HPR</td>
<td>.04</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>EPR, AAT</td>
<td>.02</td>
<td></td>
<td>.02</td>
</tr>
<tr>
<td>HPR, AAT</td>
<td></td>
<td>.07</td>
<td>.07</td>
</tr>
<tr>
<td>EPR, HPR, AAT</td>
<td>.06</td>
<td>.06</td>
<td>.06</td>
</tr>
<tr>
<td>Total Unique and Common</td>
<td>.14</td>
<td>.27</td>
<td>.16</td>
</tr>
</tbody>
</table>

Note. AAT = Auditory Analysis Task; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; PPVT = Peabody Picture Vocabulary Test-Revised

---

Table 14

Commonality Analysis Predicting ESL EOWPT (Time 2) Performance

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>EPR</th>
<th>HPR</th>
<th>AAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unique Variance</td>
<td>.02</td>
<td>.03</td>
<td>.06</td>
</tr>
<tr>
<td>Common Variance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPR, HPR</td>
<td>.02</td>
<td>.02</td>
<td></td>
</tr>
<tr>
<td>EPR, AAT</td>
<td>.03</td>
<td></td>
<td>.03</td>
</tr>
<tr>
<td>HPR, AAT</td>
<td></td>
<td>.06</td>
<td>.06</td>
</tr>
<tr>
<td>EPR, HPR, AAT</td>
<td>.06</td>
<td>.06</td>
<td>.06</td>
</tr>
<tr>
<td>Total Unique and Common</td>
<td>.13</td>
<td>.17</td>
<td>.21</td>
</tr>
</tbody>
</table>

Note. AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task
awareness (6%). A large proportion of the total amount of variance explained by the auditory analysis task was, however, common variance, the majority of which was variance shared with the standard English pseudoword repetition task (3%), the Hebrew pseudoword repetition task (6%), and both the standard English pseudoword repetition task and the Hebrew pseudoword repetition task (6%). While the total amount of variance contributed by the standard English pseudoword repetition task and the Hebrew pseudoword repetition task was substantial (13% and 17%, respectively), the majority of it was shared variance, with only a small percentage of the total variance accounting for any unique contribution (2% and 3%, respectively).

4.5.2.2 Relative Roles of Phonological Processing Skills in Reading Development

The most significant predictor of later ESL word recognition performance was phonological awareness (see Table 15). Of the total amount of variance accounted for by the auditory analysis task (36%), approximately half was unique variance while the other half was common variance, most notably shared with the Hebrew pseudoword repetition task (15%) and with both the standard English pseudoword repetition task and the Hebrew pseudoword repetition task (4%). The Hebrew pseudoword repetition task contributed an additional 5% unique variance to the word recognition measure, while the standard English pseudoword repetition task failed to contribute any unique variance.

4.5.2.3 Summary

The results of the commonality analysis confirm that phonological memory, as measured by the Hebrew pseudoword repetition task, is the strongest unique predictor of receptive vocabulary development in ESL.
Table 15

**Commonality Analysis Predicting ESL WRAT (Time 2) Performance**

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>EPR</th>
<th>HPR</th>
<th>AAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unique Variance</strong></td>
<td>.00</td>
<td>.05</td>
<td>.17</td>
</tr>
<tr>
<td><strong>Common Variance</strong></td>
<td>.00</td>
<td>.00</td>
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<td>Total Unique and Common</td>
<td>.04</td>
<td>.24</td>
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*Note.* AAT = Auditory Analysis Task; EPR = Standard English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; WRAT = Wide Range Achievement Test 3

Children. Results for the expressive measure of vocabulary, on the other hand, suggest a somewhat greater unique role for phonological awareness than phonological memory. Finally, ESL reading development can be predicted first and foremost by phonological awareness. It is important to note, however, that in addition to phonological awareness, phonological memory also explains a unique amount of variance in the development of reading skills. In the ESL data, unlike in the EL1 data, a large proportion of the explained variance in both the vocabulary and word recognition measures is variance common to the Hebrew pseudoword repetition task and the auditory analysis task, or to all three phonological measures. This latter finding suggests that while phonological memory and phonological awareness may make unique contributions to ESL vocabulary and reading development, they also appear to be tapping a similar underlying phonological processing skill.
Chapter 5: Discussion

5.1 Phonological Memory as a Longitudinal Predictor of Vocabulary Development

5.1.1 Native Vocabulary Development

The first important finding of the present study is a replication of the now well-established association between pseudoword repetition skills and vocabulary knowledge in native language development (see Baddeley et al., 1998 for a review of the literature). EL1 children’s ability to repeat back pseudowords was significantly correlated with vocabulary size, both at age 6 and 7.5. A trend towards a reduction in the strength of the correlation across time, which was found by Gathercole and her colleagues (Gathercole et al., 1992), was also observed.

The present study provides further evidence of a robust causal relation between phonological memory skills and vocabulary development. Long-term learning of new words is thought to depend in part on the ability to construct and maintain phonological representations in short-term memory (see Baddeley, 1986). It should be acknowledged that while the present study was not designed to distinguish encoding and storage processes in phonological memory, this distinction is important and must be addressed in future research.

A significant causal relation in the forward direction between phonological memory skills and later vocabulary knowledge was observed in EL1 and ESL children alike. Consider first native vocabulary development. Children’s pseudoword repetition performance explained a significant proportion of the variance in the vocabulary scores 1.5 years later. This positive relation was maintained even after nonverbal ability and vocabulary
performance at age 6 were accounted for. Partialling out nonverbal ability reduces the possibility that the relation between pseudoword repetition and vocabulary is simply a reflection of individual differences in general intelligence. The conservative procedure of controlling for prior vocabulary knowledge makes it less likely that it is the influence of early vocabulary knowledge on subsequent vocabulary knowledge which is mediating the observed association between pseudoword repetition skills and vocabulary. Moreover, controlling for prior vocabulary knowledge allows for a more accurate measure of the relation between phonological memory and the change or growth in vocabulary knowledge over time.

5.1.1.1 Role of Phonological Memory Beyond Age 5

This statistically significant correlation between early pseudoword repetition skills and later vocabulary knowledge in children older than 5, is inconsistent with earlier findings reported by Gathercole and her colleagues (Gathercole et al., 1992). Their data suggest that beyond age 5, phonological memory skills cease to place any major constraints on native vocabulary development. The primary pacemaker in the developmental relation between pseudoword repetition skills and vocabulary knowledge is thought to shift from the ability to hold in temporary memory unfamiliar phonological sequences to the ability to use existing knowledge of language structure (Gathercole et al., 1992).

The favoured explanation for these discrepant findings is the use of a different more sensitive measure of pseudoword repetition in the present study. In their longitudinal study, Gathercole et al. (1992) correlated children's ability to repeat English-sounding pseudowords (nonwords which follow the rules of
English phonology, morphology, and prosody) with subsequent vocabulary knowledge. In the present study, phonological memory was measured using two different pseudoword repetition tasks, one consisting of Hebrew-sounding pseudowords and the other consisting of English-sounding pseudowords. While the cross-lagged relation between early phonological memory skills, as measured by the Hebrew pseudoword repetition task, and later vocabulary knowledge is inconsistent with that reported by Gathercole and her colleagues, the correlation between the standard English pseudoword repetition task and vocabulary knowledge is not.

In both studies, at age 6, children's ability to repeat English pseudowords failed to significantly predict vocabulary development once nonverbal ability and earlier vocabulary knowledge had been controlled. (In the present study, this relation failed to reach statistical significance even before nonverbal ability and performance on the outcome measure 1.5 years earlier had been partialled out.) Moreover, the finding that the correlation between children's early receptive vocabulary knowledge and their later English pseudoword repetition skills was greater in magnitude than the converse correlation between their early pseudoword repetition skills and their later receptive vocabulary knowledge, is also consistent with Gathercole et al.'s data. This latter association between early vocabulary knowledge and later pseudoword repetition performance was not maintained, however, after nonverbal ability and earlier performance on the pseudoword repetition measure was accounted for.

The present findings thus suggest that in situations where children are confronted with novel phonological sequences which "activate" few existing lexical representations with similar phonological codes (e.g., Hebrew
pseudowords), phonological memory skills continue to constrain vocabulary development. In situations where children are able to make use of their existing lexical knowledge to support unfamiliar phonological information (e.g., English pseudowords) in short-term memory, phonological memory skills are thought to be less critical.

5.1.2 Second-Language Vocabulary Development

Analysis of the ESL data, in addition to showing a relation between phonological memory and second-language vocabulary development, provides additional evidence that phonological memory skills can continue to contribute to individual differences in vocabulary development beyond age 5. Analysis of the association between ESL children’s pseudoword repetition performance and their vocabulary knowledge 1.5 years later, suggests a similarly robust causal relation to that observed in native language learning. This statistically significant relation was maintained even after nonverbal ability and earlier vocabulary knowledge was partialled out.

The finding of a significant predictive relation between early phonological memory skills and later vocabulary knowledge is consistent with results reported by Service in her studies of Finnish children learning English (Service, 1992; Service & Kohonen, 1995). Recall that in her first study, Service (1992) found that 9- and 10-year-old children’s ability to repeat English-sounding pseudowords was significantly predictive of their English grade 2.5 years later. A subsequent study provided evidence of a specific link between children’s pseudoword repetition performance and their English vocabulary knowledge close to 4 years later (Service & Kohonen, 1995).
5.1.2.1 Role of Second-Language Proficiency in Task Performance

What role did ESL children’s proficiency in English play in the principal finding yielded by the present study, namely that children’s phonological memory skills are a potent predictor of second language vocabulary development? This question is an important one and can be addressed from a number of different perspectives.

First, as was mentioned previously, ESL children in the present study had a minimum of 1 year of exposure to English in a school setting (kindergarten or preschool). As the analysis of variance of the phonological awareness measure shows, ESL children had adequate knowledge of the sounds of the English language so that even at initial testing, their ability to delete target phonemes in the auditory analysis task was comparable to that of EL1 children. Similarly, there was no statistically significant difference in the performance on the word recognition measure for the two language groups. By Time 2 of testing, ESL children’s performance on all measures with the exception of the vocabulary tests, was comparable to that of their EL1 counterparts.

Further, the analyses performed in the present study (with the exception of the analyses of variance), were aimed at addressing the question of the predictive value of phonological memory skills in accounting for individual differences (not group differences) in vocabulary development. The fact that there was variability on the phonological memory tasks suggests that even for ESL children, these tasks were sensitive enough to detect individual differences in ability.

Given the children’s significant exposure to English and the nature of the questions posed by the present study, it is contended that their level of
proficiency in their second language minimally affected the results yielded by the study. It is acknowledged, however, that in situations where children have had no significant exposure to the target language, the appropriateness and feasibility of administering tasks based on a language other than the native language needs to be considered.

5.1.3 Relation Between Phonological Memory, Long-Term Phonological Knowledge, and Pseudoword Repetition: Contributions of the English and Hebrew Pseudoword Repetition Tasks

In ESL children, unlike EL1 children, the causal relation between early pseudoword repetition skills and later vocabulary knowledge was preserved irrespective of the phonological memory measure used in the analysis (English or Hebrew pseudowords). These results, along with the presence of a positive causal relation between Hebrew pseudoword repetition skills and vocabulary development and the absence of a comparable association between English pseudoword repetition skills and vocabulary development in EL1 children, are entirely consistent with the notion of an interactive or reciprocal association between phonological memory, long-term phonological knowledge, and pseudoword repetition (see Baddeley et al., 1998 for a review of the relevant literature). This interactive interpretation modifies the more simplistic view that the causal relation between phonological memory skills and long-term phonological knowledge is uni-directional in nature.

There is converging evidence to suggest that the traditional pseudoword repetition task, involving the repetition of English-sounding pseudowords, in addition to tapping phonological memory skills, also accesses long-term phonological knowledge. In a number of studies, Gathercole and her colleagues
(e.g., Gathercole, 1995; Gathercole, Willis, Emslie, et al., 1991) found that young children were better able to repeat pseudowords with higher “wordlikeness” ratings than pseudowords with comparably lower “wordlikeness” ratings. It is thought that existing lexical knowledge facilitates pseudoword repetition by making available familiar phonological structures similar to those that might appear in novel words, or by providing the learner with more generalized knowledge about the statistical probabilities associated with the occurrence of various phonological combinations (Baddeley et al., 1998).

A series of other studies involving paired-associate learning paradigms provide additional support for a lexically-mediated relation between phonological memory skills and word learning. In examining both normal adult populations and individuals with specific short-term memory impairments, Papagno and his colleagues (Baddeley et al., 1988; Papagno et al., 1991; Papagno & Vallar, 1992; Vallar & Baddeley, 1984) found that the ease with which word-pseudoword but not word-word associations were learned, was negatively affected by experimental manipulations known to disrupt operation of the phonological loop. Finally, other evidence from word-learning studies involving children suggests that children with superior pseudoword repetition skills learn unfamiliar toy names with greater ease than children with comparably lower pseudoword repetition skills (Gathercole & Baddeley, 1990b). This study found no difference in the learning rates for familiar toy names. Children’s level of vocabulary knowledge has also been found to be positively related to their performance on a paired-associate learning task involving word-pseudoword pairs (Gathercole et al., 1997).
Results of the present study are consistent with the notion that both phonological memory and long-term phonological knowledge are implicated in the association between pseudoword repetition performance and vocabulary knowledge. Assuming a high or at least sufficient level of lexical-phonological knowledge in their native language, EL1 children's performance on the standard English pseudoword repetition task should be better supported by long-term phonological knowledge than their performance on the Hebrew pseudoword repetition task. In the case of the English pseudoword repetition task, it can be argued that EL1 children's use of existing lexical knowledge reduced or offset the phonological memory load involved in repeating English-like pseudowords. The consequence of this was that children's ability to repeat back English-sounding pseudowords would be less predictive of later vocabulary knowledge.

Children's strategy for repeating pseudowords, it could be argued, changes across development. Young children encode and maintain the unfamiliar phonological sequence in temporary memory, processes thought to be involved in the long-term learning of new words. Older children, on the other hand, identify subunits of stored words to facilitate repetition. It is only in situations where the to-be-repeated stimuli fail to "activate" any existing lexical representations that older children revert to the earlier strategy. Accordingly, it could be argued that the Hebrew pseudoword repetition task is a purer measure of phonological memory, because it calls on children to construct and maintain in memory new phonological sequences.

For ESL children, however, the ability to hold English pseudowords in temporary memory significantly predicted subsequent vocabulary development. It can be argued that ESL children in the present study, whose knowledge of
the English language was significantly lower than that of their EL1 counterparts, did not hold sufficient knowledge of the component phonological sequences in the English language to use this knowledge to support unfamiliar sequences in short-term memory. With fewer lexical entries and consequently fewer phonological sequences for the purposes of comparing the phonological structure of stored words to that of the unfamiliar pseudoword, ESL children would be less able to employ a lexical mediation strategy for the purposes of supplementing the phonological representations in memory. For these subjects then, pseudoword repetition of English-sounding nonwords was a sufficiently sensitive measure of their phonological memory skills.

Analysis of the relation between the Hebrew pseudoword repetition task and vocabulary in EL1 children suggests that the increased support from children’s lexical knowledge in the case of the standard English pseudoword repetition task may have overshadowed or masked the role played by phonological memory skills. For EL1 and ESL children alike, access to lexical knowledge in the Hebrew task, both in terms of the phonological structures available to support novel phonological information in temporary memory, as well as knowledge about likely phonological combinations in the language, would be minimized, making the Hebrew measure of pseudoword repetition a more sensitive measure of phonological memory skills (for children who do not speak Hebrew). Existing lexical knowledge is thus thought to be less relevant when the to-be-repeated pseudowords differ greatly from words already stored in long-term memory (see also Dollaghan, Biber, & Campbell, 1995; Gathercole, 1995). This explanation is in line with research which has shown a differential
pattern of association between vocabulary and repetition performance of high and low wordlike pseudowords (Gathercole, 1995).

It should be noted that although the relation between Hebrew pseudoword repetition performance and vocabulary knowledge observed in EL1 and ESL children can best be explained in terms of a causal relation in the forward direction between early repetition skills and later vocabulary knowledge, children’s existing lexical knowledge did contribute to later repetition performance, at least with respect to the receptive measure of vocabulary. The correlation between early vocabulary knowledge and later pseudoword repetition performance just failed to reach statistical significance once nonverbal ability and earlier performance on the repetition measure were controlled. This trend suggests, however, that children were able to use their existing phonological knowledge to some extent to support even the Hebrew-sounding words in short-term memory. With respect to their performance on the standard English pseudoword repetition task, ESL children were also able to use their existing lexical knowledge to support the English-sounding pseudowords in phonological memory. This relation was maintained even after nonverbal ability and earlier performance on the repetition task were accounted for. These findings suggest that as children’s vocabulary grows, the tendency to use existing lexical knowledge to support unfamiliar phonological sequences in temporary memory increases.

5.1.4 Role of Other Non-Memory Factors in Vocabulary Development

The present findings do not preclude the possibility that in addition to the role played by phonological memory in children’s native and second-language vocabulary development in the early elementary school years, other factors are
also critical in vocabulary learning. It has been suggested elsewhere that as children acquire more abstract vocabulary knowledge, skills related to semantic and conceptual knowledge may place increasingly greater constraints on vocabulary development compared with phonological memory (see Gathercole et al., 1992). The role of reading is also thought to play an increasingly important role in vocabulary development in the early school years. Cunningham and Stanovich (1991) found, for example, that individual differences in children’s vocabulary knowledge could be explained, in part, by their familiarity with book titles. Finally, Stanovich’s Matthew Effect in reading (1986) may also be applicable in vocabulary development. Children with larger vocabularies have more phonological structures available for building analogies with to-be-learned words (Gathercole et al., 1992). Children with smaller vocabularies, on the other hand, are more limited in the number and kinds of phonological analogies they can generate. Support for such a Matthew Effect in vocabulary development has been reported elsewhere (Robbins & Ehri, 1994; Senechal, Thomas, & Monker, 1995). The present study also provides support for this notion--while phonological memory skills significantly predicted later vocabulary knowledge, previous vocabulary knowledge explained the greatest amount of variance in later vocabulary scores.

5.1.5 Summary

In summary, the present study was able to replicate the well-established relation between pseudoword repetition skills and native vocabulary development. Moreover, it provides new evidence which suggests a continuing role for phonological memory skills in vocabulary learning at least into the early school years. The latter finding highlights the need to employ measures with
sufficient sensitivity to ensure accurate assessment of a given skill, in this case the construction and temporary maintenance of novel representations in memory. As well, along with the findings reported by Service (1992; Service & Kohonen, 1995), the present study provides evidence of an equally robust causal relation between phonological memory skills and vocabulary development in a second language. These findings suggest that phonological memory is critical for the long-term learning of novel phonological forms in situations, such as foreign-language learning, where lexically-mediated strategies are less likely.

5.2 Phonological Memory as a Longitudinal Predictor of Reading Development

Another area in which phonological memory has been heavily implicated is early reading skills. The present study contributes to the copious body of evidence pointing to phonological memory as an important contributor to early reading skills (for reviews of the literature see Jorm, 1983; Wagner & Torgesen, 1987). Phonological memory skills are thought to place constraints on phonological recoding processes (Baddeley, 1986; see also Gathercole, Willis, & Baddeley, 1991) by affecting the ease with which the grapheme-phoneme correspondences necessary for applying the alphabetic strategy are learned, as well as impacting the efficiency with which segments of unfamiliar words can be encoded and maintained during the decoding process.

It should be acknowledged that while the present findings are important in and of themselves, they serve a greater purpose in illustrating parallels with the vocabulary data, particularly with respect to the interrelatedness between phonological memory and phonological awareness in vocabulary development.
The association between phonological memory and word recognition performance will thus be only briefly discussed here. For EL1 and ESL children alike, the ability to hold unfamiliar phonological sequences in temporary memory was significantly related to performance on a word recognition measure, both at age 6 and 7.5. As was the case with vocabulary knowledge, there was a trend towards a decrease in the strength of the correlations over time. This was particularly the case when the phonological memory measure was the standard English pseudoword repetition task. This is consistent with the view that phonological memory skills are most critical during the very early stages of reading development when children are learning letter-sound correspondences (Torgesen, 1988).

The cross-lagged analysis revealed that the observed association between phonological memory and word recognition could best be explained in terms of a causal relation in the forward direction between early pseudoword repetition skills and later word recognition performance. This was found to be the case for both EL1 and ESL children. This positive relation was maintained even after nonverbal ability and earlier performance on the word recognition measure were partialled out. The conservative procedure of controlling for earlier word recognition skills rules out the possibility that it is in fact the influence of early word recognition skills on subsequent word recognition skills which is explaining the observed association between early pseudoword repetition skills and later reading performance.

An important finding is the stronger causal relation between the Hebrew measure of pseudoword repetition and word recognition compared with that between the standard English pseudoword repetition task and word
recognition. For EL1 children, the ability to repeat English-sounding pseudowords was not significantly associated with their later performance on the word recognition measure. The finding of a positive causal relation between early Hebrew pseudoword repetition skills and later word recognition performance suggests that the increased support from children’s lexical knowledge in the case of the English task may have overshadowed or masked the contributions made by phonological memory. For EL1 children then, the Hebrew task provided a more sensitive measure of phonological memory capacity. This divergent relation between word recognition and the two repetition tasks parallels that observed for vocabulary development.

For ESL children, both measures of phonological memory significantly predicted word recognition performance 1.5 years later. Once nonverbal ability and earlier performance on the outcome measure were considered, however, the positive association was maintained only in the case of the Hebrew measure. As was the case for EL1 children, it appears that the Hebrew measure was the more sensitive measure of phonological memory, presumably because it minimized children’s ability to use existing lexical-phonological knowledge to support information in short-term memory.

Finally, it is interesting to note that children’s word recognition knowledge did not significantly predict later performance on the pseudoword repetition measure. This provides additional evidence that the well-established association between phonological memory skills and reading development is not the result of reading achievement itself stimulating phonological memory development. Children in the present study were just beginning to learn how to read, leaving open the possibility that once children’s reading skills become
more developed, that these skills may in fact impact performance on phonological memory tasks. The notion that more developed decoding skills could play a role in phonological memory performance is consistent with the view that children’s ability to represent items in a more segmented phonemic form, a skill highly related to reading, may also be contributing to performance on the pseudoword repetition task (see Metsala, 1999).

In sum, the ability to hold unfamiliar phonological sequences in temporary memory is predictive of EL1 and ESL children’s later word recognition performance. Again, similar to the findings relating to vocabulary development, the Hebrew measure of pseudoword repetition is a more sensitive measure of phonological memory because it minimizes children’s reliance on lexical knowledge to support information in the phonological loop.

5.3 Alternative Non-Memory Explanations for the Observed Relation Between Pseudoword Repetition and Vocabulary

The findings reported thus far are entirely consistent with the large body of research showing a significant positive relation between young children’s ability to repeat back pseudowords and their performance on measures of vocabulary and reading. What is considerably less clear, however, is what is mediating this relation. While Gathercole and her colleagues adhere to the position that it is phonological memory which is mediating the observed association between pseudoword repetition and these language subskills, they do concede that other cognitive processes may also contribute to individual differences in pseudoword repetition performance.

Repeating pseudowords clearly necessitates the operation of a number of different cognitive skills. These include perceiving and discriminating the initial
acoustic signal, encoding the acoustic information into a phonological code or representation, holding the representation in memory, segmenting the phonological representation, and finally planning and executing the response which further involves assembly of articulatory instructions and articulation (see Bowey, 1996; Edwards & Lahey, 1998; Gathercole et al., 1994; Snowling et al., 1991). It is possible that deficits in any one or a combination of these cognitive skills can affect repetition accuracy. As was discussed earlier, matters are complicated further by the role that existing lexical knowledge plays in influencing repetition performance (see Gathercole 1995; Gathercole, Willis, Emslie, et al., 1991). The next step in providing evidence in support of the phonological memory hypothesis then is to show that the association between pseudoword repetition and vocabulary and between pseudoword repetition and reading is maintained when other non-memory factors are controlled. There have been recent efforts to do just that, with the majority of work focusing on the roles played by speech perception and articulation.

5.3.1 Role of Speech Perception

Gathercole and Baddeley (1990a), for example, found that language-impaired children with depressed pseudoword repetition skills failed to show the presence of any speech perception deficits. Similar findings were reported in a recent study by Edwards and Lahey (1998). The present study offers additional support—normally developing EL1 and ESL children’s performance on a minimal pairs discrimination task, a measure of phoneme discrimination, failed to significantly predict vocabulary development.
5.3.2 Role of Articulation Processes

The mediating role of articulation processes has also received some attention. Deficits in response processes can impact repetition accuracy in several different ways. Consider first the skills involved in planning and executing phonologically complex sequences. While Gathercole and Adams (1993) concede that articulatory planning and execution skills may exert some influence on repetition accuracy in very young children, they appear to be less of a contributor in older children who are thought to have acquired the necessary skills to reproduce complex sequences. Gathercole and Baddeley (1989a) found that repetition performance of 4-year-olds with depressed vocabulary was poorer for pseudowords containing clustered than single consonants. For 5-years-olds as well as for 4-year-olds with good vocabulary skills, no such sensitivity to the complexity of stimuli was observed. In another study, Gathercole and Baddeley (1990a) found that language impaired children were no worse at repeating pseudowords with consonant clusters than either younger-aged children matched on verbal abilities or children of comparable age matched on nonverbal intelligence. Clustered consonants clearly require more elaborate and complex output procedures than do sequences containing single clusters. Failure to find differences in repetition accuracy relative to stimuli complexity suggests that articulatory output procedures at least past age 5 are not important for explaining individual differences in repetition performance.

Articulation processes may also be implicated in terms of specific production skills. It may be that children who perform poorly on pseudoword repetition tasks do so because they have difficulties articulating certain
phonemes. The evidence so far seems to suggest that this is likely not the case. Kamhi, Catts, Mauer, Apel, and Gentry (1988), for example, failed to find any consistent articulation errors in the group of language and reading-impaired children they studied. Michas and Henry (1994) found associations of comparable strength between vocabulary and a number of phonological memory measures varying in the degree to which they depend on articulation (and segmentation) skills. The present study also took measures to control for any articulatory problems which might affect repetition performance. In scoring repetition accuracy, consistent articulatory errors were taken into account and were not considered incorrect. Individual differences in repetition performance can, therefore, not be attributed to differences in the ability to articulate certain phonemes.

Additional evidence that pseudoword repetition contributes to language learning independent of perception and articulation skills comes from a study by Service (1992). In her study about the role of phonological memory in second-language development, she compared the relation between two phonological memory tasks and overall English Grade several years later. One phonological memory task paralleled that of the standard pseudoword repetition task while the other involved delayed copying of visually-presented pseudowords. The latter measure, with no auditory perception or spoken output component, is thought to invoke an articulatory recoding component resulting in the formation of a representation in the phonological memory store (see Baddeley, 1986). Analysis of the data showed that the correlation between the oral repetition task and English proficiency was of the same order of magnitude as that between the delayed copying task and English proficiency.
5.3.3 Summary

This brief review of the literature suggests that perception and articulation processes do not appear to contribute significantly to performance on the pseudoword repetition task. Rather, there is strong evidence to suggest that it is phonological memory processes that are being tapped by this measure. The finding that pseudoword repetition tasks are highly correlated with more traditional indices of phonological memory such as digit span, word span and sentence repetition (see Brady, Poggie, & Rapala, 1989; Gathercole, 1995; Gathercole & Adams, 1993; Michas & Henry, 1994) clearly supports this view.

While the pseudoword repetition task may not be a pure measure of phonological memory (if indeed there is such a thing), it certainly taps a memory component. Gathercole, Willis, Emslie, et al.’s (1991) finding that children’s accuracy rate on a pseudoword repetition task was affected by word length, even after “wordlikeness” ratings were covaried, is also consistent with this hypothesis. Similar findings have been reported elsewhere (Gathercole & Baddeley, 1990a; Montgomery, 1995).

While there has been some effort to isolate the role of phonological memory from that of other cognitive skills such as speech perception and articulation, there has been considerably less work directed at assessing the contributions made by phonological awareness skills. Repetition of an unfamiliar word or pseudoword is thought to involve accurate segmentation of the phonological sequence (Snowling et al., 1991). There have been suggestions that it is, in fact, individual differences in children’s awareness of the structure of language (i.e., phonological awareness), and not phonological memory which underlies the association between pseudoword repetition performance and
vocabulary knowledge (Metsala, 1999; Snowling et al., 1991). In the present study the independence of these two abilities in relation to vocabulary and reading development was examined, and the results appear to support the position of a specific and independent relation between phonological memory and both vocabulary and reading.

5.4 Specificity of the Role of Phonological Memory in Vocabulary and Reading Development

In the area of reading development, researchers have gone beyond simply confirming the existence of relations between various phonological processing skills and reading and have instead focused their attention on studying the specificity of the relations between the various phonological processing skills and reading. In the area of vocabulary development, this type of research, primarily cross-sectional in design, is just beginning to emerge. The present study represents one of the first attempts to assess the uniqueness of the relation between phonological memory and vocabulary development in a longitudinal analysis.

5.4.1 Vocabulary Development

In the present study, a series of commonality analyses were performed in order to assess the unique and shared variances contributed by phonological memory and another phonological processing skill, phonological awareness, to vocabulary development in EL1 and ESL children. While there are no published studies to date in the area of second-language learning looking at the uniqueness of the relation between phonological memory and vocabulary in relation to other phonological processing skills, there are a number of studies in
the area of vocabulary development in native language learning which have considered this question.

These studies have to a large extent yielded conflicting results. Gathercole, Willis, and Baddeley (1991) in their study of 4- and 5-year-olds found that phonological memory but not phonological awareness significantly predicted vocabulary knowledge, this despite both measures loading onto a single phonological processing factor. Metsala’s findings (1999), on the other hand, lend support to the notion that it is not components of phonological memory but rather phonological awareness which is uniquely related to vocabulary development (see Chapter 2 for more details). A recent longitudinal study by Avons, Wragg, Cupples, and Lovegrove (1998) found that even after age, IQ and vocabulary knowledge at age 5 were partialled out, word span remained a good predictor of vocabulary knowledge one year later. Due to the limited statistical power of the study (reflected in the fact that large amounts of additional variation failed to reach statistical significance), nonword repetition and rhyme detection were not found to be significant predictors of later vocabulary knowledge. These findings, nonetheless, suggest that both phonological memory and phonological awareness contribute to vocabulary development.

5.4.1.1 Native Vocabulary Development

Results of the present study are more or less consistent with those reported by Gathercole, Willis, and Baddeley (1991), at least in the case of the EL1 group. In what follows, because of the low correlation between the standard English pseudoword repetition task and vocabulary, only the Hebrew version of the repetition task is considered. Only the pseudoword repetition
measure was found to explain any unique variance in vocabulary knowledge 1.5 years later. This was true for both the receptive and the expressive measures of vocabulary. Moreover, most of the variance explained by the repetition measure was unique variance, with only a minimal amount being variance shared with phonological awareness. These findings suggest that the observed association between pseudoword repetition skills and vocabulary is not due to a general phonological processing ability tapped by both phonological memory and phonological awareness, but rather due to something specific to the components of phonological memory. These findings further suggest that phoneme segmentation, as measured by the phonological awareness measure, while necessary (but not sufficient) to perform the pseudoword repetition task, did not account for the positive relation between phonological memory and vocabulary development.

This unique relation between phonological memory and vocabulary, independent of phonological awareness, contrasts with results reported by Metsala (1999). Metsala found that phonological awareness and not phonological memory was a significant independent predictor of vocabulary knowledge. She contends that it is children’s ability to represent phonological sequences in a less holistic and more segmented phonemic form in short-term memory, an ability directly accessed by phonological awareness tasks, which is mediating the observed relation between pseudoword repetition and vocabulary. This ever-increasing need for finer discriminations between words in long-term memory is thought to be the direct result of growth in spoken vocabulary. Metsala proposes that it is this ability to represent speech units in a more segmented form and not phonological memory processes per se, which
accounts for individual differences in children’s performance on the pseudoword repetition task.

One important difference between Metsala’s study and the present investigation is that Metsala’s study examined concurrent relations in 4- and 5-years-olds, while the present study examined predictive relations from age 6 to 7.5. It may be that individual differences in the way in which speech units are represented place greater constraints on repetition performance before age 6, than they do subsequently. There is an extreme growth spurt in vocabulary knowledge during the early schools years (see Anglin, 1989, 1993; Biemiller & Slonim, 1999). Relatedly, in line with Metsala’s claim that the ability to represent speech in a segmented form is the direct result of vocabulary growth, it is possible that children in the present study were able to represent the to-be-repeated pseudowords sufficiently enough so as to not impair their performance. As well, the fact that Metsala’s study examined concurrent relations while the present study examined predictive relations makes direct comparisons of the results exceedingly difficult. In fact, analysis of the simple correlations in the present study reveals a statistically significant relation between phonological awareness and vocabulary both at age 6 and 7.5. Without the appropriate commonality analyses, however, the specificity of that relation remains unclear.

5.4.1.2 Second-Language Vocabulary Development

Results of the ESL data are slightly more complex. Consider first the receptive measure of vocabulary. Cross-lagged correlational analyses showed that performance on the phonological awareness measure was highly related to later vocabulary knowledge, with the order of magnitude closely resembling that observed between the phonological memory measures and vocabulary. Analysis
of the pattern of unique and overlapping variances of the two phonological processing skills, however, suggests that the variance explained by phonological awareness is variance shared with phonological memory. In other words, the positive relation between phonological awareness and vocabulary development had little specificity, and arose simply as an artifact of the association between phonological memory and phonological awareness. On the other hand, while much of the contribution of phonological memory to vocabulary was shared variance, phonological memory also explained a significant amount of unique variance. Phonological awareness and phonological memory are thus not equal independent predictors of vocabulary development. Rather, in line with Gathercole, Willis, and Baddeley’s (1991) interpretation of their data, the present results suggest that while phonological memory and phonological awareness may to some extent tap a general phonological processing ability important in vocabulary development, components of phonological memory are particularly potent predictors of later vocabulary knowledge.

Analysis of the expressive measure of vocabulary revealed a different pattern of results. It should be noted that with the exception of one or two studies (e.g., Gathercole et al., 1997), researchers examining the relation between phonological memory and vocabulary have limited their assessment of vocabulary to that of receptive knowledge, presumably to control for individual differences in expressive ability. The present study included the expressive measure in order to employ a broader range of methods to measure vocabulary knowledge.

Analysis of the ESL data revealed that after nonverbal ability and vocabulary performance 1.5 years earlier had been partialled out, phonological
memory accounted for comparable amounts of additional variance in both the receptive and expressive vocabulary measures. Gathercole et al. (1997) also report (concurrent) correlations of comparable magnitude between phonological memory and receptive and expressive vocabulary.

Results yielded by the commonality analysis, however, suggest that of the two phonological processing skills, phonological awareness and not phonological memory is the most potent predictor of expressive vocabulary knowledge. Phonological memory contributed only a minimal amount of unique variance. While both phonological processing skills contributed some unique variance, the majority was variance shared between the two. This degree of specificity between phonological awareness and the expressive measure of vocabulary is noteworthy. The greater variance explained by phonological awareness appears to be related to processes unique to the expressive aspects of language. It may be that some aspect of phonological processing, tapped more directly by the phonological awareness measure, is critical for speech production in young ESL learners. Processes related to motor planning and execution are one such candidate. These processes would presumably be more critical in the production of unfamiliar phonological sequences (i.e., phonological memory) than in the analysis of familiar words (i.e., phonological awareness as measured in the present study). Furthermore, as was discussed earlier, there is little data suggesting a deciding role for such motor planning and execution-related processes in other phonological processing tasks such as pseudoword repetition (e.g., Edwards & Lahey, 1998; Kamhi et al., 1988; Service, 1992). Another possibility is that ESL children’s phoneme segmentation skills, tapped by the phonological awareness task, are more heavily implicated in the expressive
measure of vocabulary than in the receptive measure. Given ESL children's limited exposure to the phonological components of the English language compared with their EL1 counterparts, the expression of words for which the concepts may already be known, places greater demands on other phonological processing skills such as the ability to segment sounds in the language. Before any conclusions can be reached on the specificity between phonological awareness and expressive vocabulary in ESL children, this result needs to be replicated.

5.4.1.2.1 Implications for a Theory of Second-Language Vocabulary Development

The finding that phonological memory skills play a specific role in vocabulary development in both ESL and EL1 children suggests that a single theoretical framework could be used to explain this predictive relation. The present findings do indeed suggest that the constraints placed on second-language vocabulary development by phonological memory skills closely resemble those placed on vocabulary development in native language learners. Evidence of comparable developmental sequences in other areas of first- and second-language development such as grammatical morphemes, negation, and word order (see Hecht & Mulford, 1982, for a brief review of the literature), have also been reported.

Although not directly examined in the present study, it is important to consider the role that language transfer may play in the relation between phonological memory and second-language vocabulary development. As was discussed earlier, existing lexical knowledge is thought to play an important role in the extent to which children rely on their phonological memory skills to
repeat English-sounding pseudowords. In the case of second-language learners, it is conceivable that phonological knowledge of the first language could impact the extent to which phonological memory skills constrain vocabulary development in the second language. The degree of structural overlap (e.g., phonological and morphological features) between the first and second language may thus be critical. Future research may show that the relation between phonological memory and second-language vocabulary development can in fact be best explained in terms of an interaction between developmental processes present in both the first and second language and transfer of phonological knowledge from the first language.

5.4.2 Reading Development

Commonality analyses examining the respective roles of phonological memory and phonological awareness in reading development suggest that for EL1 and ESL children alike, both phonological processing skills are significant predictors.

5.4.2.1 Native Language Reading Development

Consider first reading skills in EL1 children. The finding that phonological awareness and phonological memory, when analyzed separately, explain significant amounts of variance in reading performance, as revealed by the cross-lagged correlations, is consistent with previous studies (for reviews of the literature see Adams, 1990; Blachman, 1997b; Jorm, 1983; Wagner & Torgesen, 1987). There is a body of evidence, however, which suggests that much of the variance in reading explained by phonological memory is in fact variance shared with phonological awareness, and that only the latter explains any unique variance (see e.g., Torgesen et al., 1994; Wagner et al., 1994; Wagner et al.,
There are a number of other studies which have found that both phonological memory and phonological awareness are independent, albeit not equal, predictors of reading skills (e.g., Gottardo et al., 1996; Hansen & Bowey, 1994; Mann & Liberman, 1984). In the majority of these studies, phonological awareness is clearly the most potent predictor of word-level reading skills, while phonological memory's contribution is relatively small in comparison.

The present study suggests that phonological memory's contribution to early word-level reading may in fact be much larger. The commonality analysis revealed that both phonological awareness and phonological memory showed specificity with respect to their relation to word recognition. In contrast to many other studies, phonological memory and not phonological awareness contributed the greatest amount of additional unique variance.\(^\text{20}\) It is also interesting to note that the two measures shared minimal amounts of variance. The absence of a unique relation between word recognition and the standard English pseudoword repetition task is more consistent with the majority of the previous studies. Yet, phonological memory was a potent predictor of later word recognition skills. The stronger role played by phonological memory in the present study may be related to the fact that a more sensitive measure of phonological memory was used in the present study. In particular, as was discussed earlier in the context of vocabulary development, children's ability to hold in temporary memory Hebrew-sounding pseudowords is less likely to be supported by their lexical knowledge because of the incongruity between the phonological sequences of existing words in their lexicon and those of the to-

\(^{20}\)There is also evidence to suggest that phonological memory is a strong predictor of reading comprehension (Gottardo et al., 1996).
be-repeated pseudowords.

5.4.2.2 Second-Language Reading Development

Analysis of the ESL data revealed a slightly different pattern of results. Similar to EL1 children, ESL children's performance on both phonological processing measures significantly predicted scores on word recognition 1.5 years later. Unlike EL1 children, however, the greatest amount of variance was explained by phonological awareness and not by phonological memory. As well, the majority of the variance explained by both measures was variance they shared. It thus appears that while both measures have some specificity as predictors of word recognition in the case of ESL children, they also appear to be tapping a common underlying phonological processing component. In sum, it is interesting to note that although EL1 and ESL children's word recognition performance was not significantly different, the dominant phonological processing skill underlying word recognition skills differed for the two language groups.

5.4.3. Summary

Taken as a whole, these data suggest that phonological memory is a potent predictor of vocabulary and reading development in EL1 and ESL children alike. Moreover, phonological memory predicts significant amounts of variance above and beyond that explained by phonological awareness. The selective contribution of phonological awareness skills to expressive vocabulary in ESL children deserves further study. While not having any specificity as a predictor of vocabulary development, phonological awareness did explain unique variance in word recognition scores, for both EL1 and ESL children. It thus appears that the interrelatedness between phonological memory and
phonological awareness is different for vocabulary and reading development. Finally, the finding that in ESL children phonological memory and phonological awareness share greater amounts of variance in predicting vocabulary and reading development than in EL1 children is also noteworthy.

This latter point deserves further consideration. The present study was not designed to provide answers as to why it is the case that for ESL children but not EL1 children, phonological memory and phonological awareness share a considerable amount of variance in both vocabulary and word recognition scores. One possibility is that for ESL children, the phonological awareness measure used in the present study had a particularly heavy memory component, thus resulting in the significant overlap. Because ESL children have less vocabulary knowledge, their use of long-term lexical knowledge to support stimuli manipulated in the phonological awareness task in temporary memory, is limited. EL1 children, on the other hand, are able to use their extensive lexicons to support the phonological items in memory, thereby taxing fewer memory resources. Given that this type of detailed analysis of the phonological processing skills underlying second-language development is just beginning to emerge, this hypothesis requires further substantiation. It is unclear if the significant overlap between the two phonological processing measures is simply due to the greater memory demands of the phonological awareness task in the case of ESL children, or if the interrelatedness between phonological memory and phonological awareness is different when learning a first and second language.

Assessing whether or not phonological memory and phonological awareness are independent predictors of vocabulary and word recognition is
clearly complicated by the fact that a given task invariably measures more than its targeted construct. Because there is evidence to suggest that all phonological awareness tasks tap phonological memory (see Yopp, 1988), the critical question then becomes to what extent. Clearly, there are some phonological awareness tasks which have inherently larger memory components. For example, Bradley and Bryant's (1983) rhyme awareness task requires more memory resources than, say, a phoneme identification task. It is interesting to note that the phonological awareness tasks most predictive of reading ability tend to place greater demands on the phonological memory component (Brady, 1991; Yopp, 1988). Although phonological awareness tasks such as the one used in the present study have been amply studied in terms of their construct validity (e.g., McBride-Chang, 1995; Stanovich, Cunningham, & Cramer, 1984; Yopp, 1988) it is clear that they too tap phonological memory processes. The problem in using tasks which require fewer memory resources is that they may also be less sensitive to variability in the processes thought to be critical in phonological awareness. The task of separating contributions made by phonological memory and phonological awareness to such language skills as vocabulary and reading remains a challenge. Nevertheless, an interesting finding revealed by the present study is that the phonological awareness task may be placing different demands on memory resources in ESL and EL1 children.

5.5 General Summary

To briefly summarize, the present study provides evidence which points to a continuing role for phonological memory skills in vocabulary development in native language learners in the early school years. Further, the results suggest an equally robust causal relation between early phonological memory skills and
vocabulary development in a second language to that observed in native language development. This degree of generality provides additional support for the role of the phonological loop in language development. Finally, the present study indicates that this positive association between phonological memory skills and vocabulary in EL1 and ESL children alike is independent of a more general phonological processing component. While phonological memory skills appear to play an important role in vocabulary development and early reading skills of EL1 and ESL children, they contribute only a small percentage of the overall variance in vocabulary and reading scores. Clearly more research is called for to ascertain what other variables are critical for these aspects of language development.

5.6 Future Research Directions

The study of the cognitive processes underlying vocabulary development be it in a first or second language is an important endeavour for a number of reasons. First, the acquisition of vocabulary is critical for all modes of communication, spoken and written, and is a necessary component of early language development. As well, word learning is a developmental process that spans the lifetime. Finally, vocabulary knowledge is often used as a measure of verbal intelligence. While there is a burgeoning field of research concentrated on delineating the cognitive underpinnings of the semantic and conceptual components of vocabulary development, it has only been recently that efforts have been made to examine the phonological side of vocabulary learning. Given that much of the research in second language learning stems from examining the developmental processes common to first and second languages, this area in second language learning has not received much attention.
The findings of the present study along with those reported by Service (1992; Service & Kohonen, 1995) represent the beginning of what will hopefully become a viable field of study aimed at examining the role of specific phonological processing skills in second- and foreign-language development. Second-language research is not only a necessary and fruitful endeavour in and of itself, but also manages to shed light on the nature of processes under study in native language development. For example, the claim that the role of the phonological loop is to foster acquisition of new words (see e.g., Baddeley et al., 1998), would certainly be strengthened if research showed that phonological memory processes are critical in the learning of new words, irrespective of the specific language being learned. It is of course conceivable that a learner's phonological knowledge of his or her first language would influence the degree to which their phonological memory skills would constrain word learning in the second language. The extent of overlap between the two languages in terms of language structure (e.g., phonological, morphological, phonotactic, and prosodic features), may be critical, given evidence of an interactive association between long-term phonological knowledge and phonological memory (see e.g., Gathercole, Willis, Emslie, et al., 1991). The need thus exists to extend this research program to include the study of other languages besides English.

As is discussed in greater detail below, future research endeavours should also attempt to address some of the limitations evident in the present study as well as make use of existing bodies of literature on the relation between phonological memory and vocabulary to inform educational practices (e.g., developing strategies aimed at improving phonological memory function in children with depressed language skills).
5.6.1 Limitations of Study

As is the case with any study, the present study suffers from a number of limitations. It is important to distinguish, however, between limitations which if addressed would serve to increase our knowledge about a certain construct and those which directly impact the kinds of theoretical conclusions which can be offered in light of the findings. It is the latter which will be addressed here.

5.6.1.1 Correlational Nature of Study

The most serious limitation is the correlational nature of the results. Basic statistical reasoning dictates that causal statements cannot be based on results yielded by correlational analyses. Issues relating to directionality and third variable influences necessarily preclude causal interpretations. While steps were taken to minimize the impact of any confounding variables, it must be acknowledged that in the absence of more stringent controls, causality cannot be unambiguously established. The findings yielded by the present study are not any less valid in light of their correlational nature, because they converge on a theory that is supported by studies which employ a host of diverse research methods (e.g., paired-associate learning paradigms).

5.6.1.2 Sample Size

In a similar vein, there is the issue of sample size and attrition over time. This is particularly relevant in the case of the EL1 sample. It would have been preferable if the sample sizes at the beginning of the study had approximated 100 subjects, making the loss of 30% of the sample over time, less of an issue. As such, with respect to the EL1 sample in particular, there are correlation coefficients which would have reached statistical significance if the sample size
had been larger. Analysis of the differences between correlations would surely also have yielded statistically significant results had the samples been larger.

Furthermore, larger sample sizes would have afforded more flexibility in the kinds of statistical analyses which could have been performed. For example, in the present situation, structural equation modeling would have been a more sophisticated alternative to the simple cross-lagged correlation and regression analyses. Moreover, results yielded from such an analysis would have been considered more robust given that predictor variables would have been derived from a factorial score rather than a score yielded by a single measure. Results yielded by the present study should thus be seen as representing trends in the data. Further empirical work is called for to ensure the reliability of these findings.

5.6.2 Educational Implications

As illustrated by the findings of the present study and the existing bodies of literature, there is ample reason to believe that individual differences in phonological memory skills are related to a young child’s ability to learn new vocabulary and acquire necessary reading skills. Given the importance of both vocabulary and reading skills to general language development, the effects of inadequate phonological memory processes could be serious and far-reaching. The educational implications are clear: remediation of poor phonological memory skills in children already diagnosed with developmental language impairments and prevention of future language problems by children who have been deemed “at risk” because of their depressed phonological memory capacity. The finding that phonological memory skills may continue to place constraints on
vocabulary development even into the early school years suggests an even greater need for intervention.

5.6.2.1 Training for Children with Depressed Phonological Memory Skills

To date, there has been little effort to test the effectiveness of training programs aimed directly at improving children's phonological memory skills. Future research should ascertain whether the mere practice of maintaining novel phonological sequences in temporary memory is sufficient to ameliorate depressed memory skills or whether more intensive strategies such as increasing articulation speed (thought to be directly tied to rehearsal speed in the phonological loop) are called for. Children's rehearsal strategies have in fact been found to improve as a result of specific training efforts (Johnson, Johnson, & Gray, 1987).

With respect to vocabulary acquisition, Gathercole (1993) has suggested that children with poor phonological memory skills may benefit from training which focuses on use of existing lexical knowledge to facilitate learning. There is support for the notion that children access existing phonological structures to support representations in short-term memory (e.g., Gathercole, Willis, Emslie, et al., 1991). Direct instruction in using such an analogy approach to word learning may work to lessen the demands of phonological memory processes. This approach may only be possible, however, with older children who have more developed lexicons.

An alternate intervention strategy considers the role played by phonological awareness skills. Given that phonological memory and phonological awareness, may, to some extent, be tapping a common phonological processing component thought to be critical for phonological
coding (in the present study this was found to be true only in the case of ESL children), it could be argued that direct training of phonological awareness skills could affect phonological memory skills by providing children with practice in phonological coding. Preliminary evidence supports this proposal. In a recent study by Gillam and van Kleeck (1996), language-disordered preschoolers were trained on a program consisting of a variety of phonological awareness tasks. The results suggest that phonological awareness training can improve phonological coding—pseudoword repetition, considered to be a sensitive index of phonological coding ability, improved after training while this was not found to be the case for real word repetition. Given the voluminous data pointing to the benefits of phonological awareness training on reading (see e.g., Ball & Blachman, 1991; Byrne & Fielding-Barnsley, 1991; Bradley & Bryant, 1985), further investigation of the possible benefits of phonological awareness training on other language skills such as vocabulary may be fruitful.

5.6.2.2 Phonological Memory Skills as an Indicator of Foreign-Language Aptitude

The results of the present study along with those reported by Service and Kohonen (1995) also contribute to on-going research aimed at identifying psychological variables consistent with foreign-language learning success and failure (see Sparks et al., 1995). Assessment of a learner's phonological memory capacity not only helps to explain why some individuals are so-called "foreign-language underachievers" (Pimsleur, Sundland, & McIntyre, 1964), but may also be used as one of a number of indices of foreign-language aptitude. In fact, in a recent paper, Ganschow, Sparks, and Javorsky (1998), while not directly addressing the role of phonological memory, make the case that it is the learner's
linguistic adeptness, in terms of mastering the phonological, orthographic, and syntactic aspects of the language, and not their level of intelligence or attitude towards the learning process, which best predicts the ease with which they will acquire a foreign language.
References


## Appendix A

### Demographic Profile (Reported in Percentages) of EL1 and ESL Subject Samples

<table>
<thead>
<tr>
<th>Demographic Indices</th>
<th>EL1 Sample</th>
<th>ESL Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>47.5%</td>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
<td>52.5%</td>
<td>Female</td>
</tr>
<tr>
<td><strong>Country of Birth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>90.0%</td>
<td>Canada</td>
</tr>
<tr>
<td>Jamaica</td>
<td>7.5%</td>
<td>India</td>
</tr>
<tr>
<td>England</td>
<td>2.5%</td>
<td></td>
</tr>
<tr>
<td><strong>Number of Siblings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>12.5%</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>65.0%</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>12.5%</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>5.0%</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5.0%</td>
<td>4</td>
</tr>
<tr>
<td><strong>Birth Order</strong></td>
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<td></td>
</tr>
<tr>
<td>Youngest</td>
<td>50.0%</td>
<td>Youngest</td>
</tr>
<tr>
<td>Middle Child</td>
<td>17.5%</td>
<td>Middle Child</td>
</tr>
<tr>
<td>Oldest</td>
<td>20.0%</td>
<td>Oldest</td>
</tr>
<tr>
<td>Only Child</td>
<td>12.5%</td>
<td>Only Child</td>
</tr>
<tr>
<td><strong>Previous School Years(^a)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>10.0%</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>62.5%</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>27.5%</td>
<td>2</td>
</tr>
<tr>
<td><strong>Remediation(^b)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>82.5%</td>
<td>0</td>
</tr>
<tr>
<td>Speech</td>
<td>12.5%</td>
<td>Speech</td>
</tr>
<tr>
<td>Therapy</td>
<td></td>
<td>Therapy</td>
</tr>
<tr>
<td>Referred(^c)</td>
<td>5.0%</td>
<td>Referred</td>
</tr>
</tbody>
</table>

\(^a\)Previous School Years = number of years of schooling with English instruction prior to testing at Time 1 (i.e., preschool, junior kindergarten, senior kindergarten); \(^b\)Remediation = type of special education received by child at Time 1 of testing; \(^c\)Referred = child has been referred to school psychologist at Time 1 of testing
# Appendix B

Standard English Pseudoword Repetition Task

<table>
<thead>
<tr>
<th>2-syllable</th>
<th>3-syllable</th>
<th>4-syllable</th>
<th>5-syllable</th>
</tr>
</thead>
<tbody>
<tr>
<td>kabbit</td>
<td>doppetate</td>
<td>wooganamic</td>
<td>consamponita</td>
</tr>
<tr>
<td>megole</td>
<td>bannifet</td>
<td>fennegiser</td>
<td>penpisonkerous</td>
</tr>
<tr>
<td>seebus</td>
<td>backazon</td>
<td>commeecitate</td>
<td>bonsemtapinger</td>
</tr>
<tr>
<td>popkum</td>
<td>commeazine</td>
<td>koddenapish</td>
<td>suppogaticine</td>
</tr>
<tr>
<td>gotty</td>
<td>tickeny</td>
<td>pennedifut</td>
<td>epifoventy</td>
</tr>
<tr>
<td>pennem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bannop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>subid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dillet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bannow</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix C

**Hebrew Pseudoword Repetition Task**

<table>
<thead>
<tr>
<th>2-syllable</th>
<th>3-syllable</th>
<th>4-syllable</th>
<th>5-syllable</th>
</tr>
</thead>
<tbody>
<tr>
<td>eckla</td>
<td>kamasher</td>
<td>batahpoofeem</td>
<td>efroloteihem</td>
</tr>
<tr>
<td>doogut</td>
<td>maldaira</td>
<td>nitparsegeem</td>
<td>meihatavikot</td>
</tr>
<tr>
<td>palake</td>
<td>pashmaloot</td>
<td>hitnavalooot</td>
<td>makataforum</td>
</tr>
<tr>
<td>lived</td>
<td>hadgasa</td>
<td>mitargenill</td>
<td>beitahasoofum</td>
</tr>
<tr>
<td>boshen</td>
<td>nitbaseem</td>
<td>betipooshug</td>
<td>lesharneigoleem</td>
</tr>
<tr>
<td>kamuff</td>
<td>tolabeem</td>
<td>histargebut</td>
<td></td>
</tr>
<tr>
<td>kisroo</td>
<td>kilaton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pofek</td>
<td>mudbeitok</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix D
Phonological Awareness Task

1. Say sunshine Now say it again but don’t say shine
2. Say baseball Now say it again but don’t say base
3. Say seesaw Now say it again but don’t say see
4. Say picnic Now say it again but don’t say nic

5. Say leg Now say it again but don’t say l/
6. Say meat Now say it again but don’t say h\n/ 
7. Say hand Now say it again but don’t say h/ 

8. Say pain Now say it again but don’t say h/ 
9. Say keep Now say it again but don’t say p/ 
10. Say like Now say it again but don’t say k/ 

11. Say train Now say it again but don’t say h/ 
12. Say clap Now say it again but don’t say k/ 
13. Say stop Now say it again but don’t say s/ 

14. Say left Now say it again but don’t say l/ 
15. Say west Now say it again but don’t say s/ 
16. Say belt Now say it again but don’t say l/
Appendix D continued

17. Say stand  Now say it again but don’t say /t/  
18. Say spit   Now say it again but don’t say /p/  
19. Say grow   Now say it again but don’t say /θ/  
20. Say tree   Now say it again but don’t say /θ/  

*21. Say split Now say it again but don’t say /p/  
*22. Say string Now say it again but don’t say /θ/  
*23. Say splash Now say it again but don’t say /p/  

*24. Say bunch Now say it again but don’t say /ch/  

*25. Say munch Now say it again but don’t say /n/  

* Only administered at Time 2
Appendix E
Phonological Discrimination Task

1. thonn-von
2. shen-sen
3. sen-fen
4. togg-togg
5. tep-tet
6. nush-nush
7. keathe-keev
8. tekk-tekk
9. noff-noss
10. poth-poth
11. konn-komm
12. meathe-meez
13. monn-monn
14. boz-boz
15. joof-joof
16. bish-biss
17. lenn-lenn
18. tonn-tonn
19. ting-tig
20. thop-zop
21. mak-mag
22. jekk-jekk
23. noz-nov
24. noove-noove
25. nesh-neff
26. zeem-zeem
27. lup-lut
28. seak-seak
29. tas-tas
30. foom-shoom
31. tass-tass
32. zam-vam
33. theak-theak
34. nim-nin
Appendix F

Effects of Native Language and Time on EPR\textsuperscript{a} Performance: Analysis of Variance Summary Table

<table>
<thead>
<tr>
<th>Effect</th>
<th>MSE</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language</td>
<td>918.22</td>
<td>1, 82</td>
<td>3.38</td>
<td>.070</td>
</tr>
<tr>
<td>Time</td>
<td>12302.98</td>
<td>1, 82</td>
<td>92.24</td>
<td>.000</td>
</tr>
<tr>
<td>Native Language × Time</td>
<td>413.84</td>
<td>1, 82</td>
<td>3.10</td>
<td>.082</td>
</tr>
</tbody>
</table>

Note. \( n = 84; \) \( ^{a} = \) Standard English Pseudoword Repetition Task

Effects of Native Language and Time on HPR\textsuperscript{a} Performance: Analysis of Variance Summary Table

<table>
<thead>
<tr>
<th>Effect</th>
<th>MSE</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language</td>
<td>1436.25</td>
<td>1, 84</td>
<td>4.71</td>
<td>.033</td>
</tr>
<tr>
<td>Time</td>
<td>6068.13</td>
<td>1, 84</td>
<td>57.79</td>
<td>.000</td>
</tr>
<tr>
<td>Native Language × Time</td>
<td>440.80</td>
<td>1, 84</td>
<td>4.20</td>
<td>.044</td>
</tr>
</tbody>
</table>

Note. \( n = 86; \) \( ^{a} = \) Hebrew Pseudoword Repetition Task

Effects of Native Language and Time on AAT\textsuperscript{a} Performance: Analysis of Variance Summary Table

<table>
<thead>
<tr>
<th>Effect</th>
<th>MSE</th>
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<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language</td>
<td>278.14</td>
<td>1, 83</td>
<td>.33</td>
<td>.565</td>
</tr>
<tr>
<td>Time</td>
<td>15879.69</td>
<td>1, 83</td>
<td>74.75</td>
<td>.000</td>
</tr>
<tr>
<td>Native Language × Time</td>
<td>412.33</td>
<td>1, 83</td>
<td>1.94</td>
<td>.167</td>
</tr>
</tbody>
</table>

Note. \( n = 85; \) \( ^{a} = \) Auditory Analysis Task
### Appendix F continued

**Effects of Native Language and Time on PDT\(^a\) Performance: Analysis of Variance Summary Table**

<table>
<thead>
<tr>
<th>Effect</th>
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<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language</td>
<td>95.34</td>
<td>1, 82</td>
<td>5.59</td>
<td>.020</td>
</tr>
<tr>
<td>Time</td>
<td>442.90</td>
<td>1, 82</td>
<td>50.50</td>
<td>.000</td>
</tr>
<tr>
<td>Native Language × Time</td>
<td>68.32</td>
<td>1, 82</td>
<td>7.79</td>
<td>.007</td>
</tr>
</tbody>
</table>

Note. \(n = 84\); \(^a\) = Phonological Discrimination Task

**Effects of Native Language and Time on PPVT\(^a\) Performance: Analysis of Variance Summary Table**

<table>
<thead>
<tr>
<th>Effect</th>
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<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language</td>
<td>5469.17</td>
<td>1, 84</td>
<td>41.39</td>
<td>.000</td>
</tr>
<tr>
<td>Time</td>
<td>7500.98</td>
<td>1, 84</td>
<td>359.75</td>
<td>.000</td>
</tr>
<tr>
<td>Native Language × Time</td>
<td>37.08</td>
<td>1, 84</td>
<td>1.78</td>
<td>.186</td>
</tr>
</tbody>
</table>

Note. \(n = 86\); \(^a\) = Peabody Picture Vocabulary Test-Revised

**Effects of Native Language and Time on EOWPT\(^a\) Performance: Analysis of Variance Summary Table**

<table>
<thead>
<tr>
<th>Effect</th>
<th>MSE</th>
<th>df</th>
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<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language</td>
<td>9000.23</td>
<td>1, 83</td>
<td>32.63</td>
<td>.000</td>
</tr>
<tr>
<td>Time</td>
<td>9112.77</td>
<td>1, 83</td>
<td>179.08</td>
<td>.000</td>
</tr>
<tr>
<td>Native Language × Time</td>
<td>111.17</td>
<td>1, 83</td>
<td>2.18</td>
<td>.143</td>
</tr>
</tbody>
</table>

Note. \(n = 85\); \(^a\) = Expressive One-Word Picture Vocabulary Test-Revised
Appendix F continued

Effects of Native Language and Time on WRAT\textsuperscript{a} Performance: Analysis of Variance Summary Table

<table>
<thead>
<tr>
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<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Language</td>
<td>52.60</td>
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<td>.48</td>
<td>.492</td>
</tr>
<tr>
<td>Time</td>
<td>10362.97</td>
<td>1, 83</td>
<td>499.67</td>
<td>.000</td>
</tr>
<tr>
<td>Native Language × Time</td>
<td>18.50</td>
<td>1, 83</td>
<td>.89</td>
<td>.348</td>
</tr>
</tbody>
</table>

Note, $n = 85$; \textsuperscript{a} = Wide Range Achievement Test 3
Appendix G

Hierarchical Regression Analysis Predicting EPR Performance (Time 2) in EL1 Subjects, with Receptive Vocabulary (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.00</td>
<td></td>
<td>.14</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>EPR (T1)*</td>
<td>.17</td>
<td>.17</td>
<td>2.19*</td>
<td>.41</td>
</tr>
<tr>
<td>3.</td>
<td>PPVT</td>
<td>.26</td>
<td>.09</td>
<td>1.70</td>
<td>.33</td>
</tr>
</tbody>
</table>

Note. * = Time 1; * $p < .05$

Hierarchical Regression Analysis Predicting HPR Performance (Time 2) in EL1 Subjects, with Receptive Vocabulary (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.02</td>
<td></td>
<td>.81</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>HPR (T1)*</td>
<td>.43</td>
<td>.41</td>
<td>4.20***</td>
<td>.64</td>
</tr>
<tr>
<td>3.</td>
<td>PPVT</td>
<td>.46</td>
<td>.03</td>
<td>1.22</td>
<td>.24</td>
</tr>
</tbody>
</table>

Note. * = Time 1; *** $p < .001$

Hierarchical Regression Analysis Predicting AAT Performance (Time 2) in EL1 Subjects, with Expressive Vocabulary (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.27</td>
<td></td>
<td>3.14**</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>AAT (T1)*</td>
<td>.50</td>
<td>.23</td>
<td>3.40**</td>
<td>.56</td>
</tr>
<tr>
<td>3.</td>
<td>EOWPT</td>
<td>.50</td>
<td>.00</td>
<td>-.08</td>
<td>-.02</td>
</tr>
</tbody>
</table>

Note. * = Time 1; ** $p < .01$

AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Vocabulary Test-Revised; EPR = English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; PPVT = Peabody Picture Vocabulary Test-Revised
Appendix G continued

### Hierarchical Regression Analysis Predicting AAT Performance (Time 2) in EL1 Subjects, with Word Recognition (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.27</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>AAT (T1)*</td>
<td>.50</td>
<td>.23</td>
<td>3.08**</td>
<td>.56</td>
</tr>
<tr>
<td>3.</td>
<td>WRAT</td>
<td>.51</td>
<td>.01</td>
<td>.32</td>
<td>.07</td>
</tr>
</tbody>
</table>

Note. * = Time 1; ** $p < .01$

### Hierarchical Regression Analysis Predicting EPR Performance (Time 2) in ESL Subjects, with Receptive Vocabulary (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>.09</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>EPR (T1)*</td>
<td>.15</td>
<td>.06</td>
<td>1.90</td>
<td>.25</td>
</tr>
<tr>
<td>3.</td>
<td>PPVT</td>
<td>.23</td>
<td>.08</td>
<td>2.38*</td>
<td>.31</td>
</tr>
</tbody>
</table>

Note. * = Time 1; * $p < .05$

### Hierarchical Regression Analysis Predicting HPR Performance (Time 2) in ESL Subjects, with Vocabulary and Word Recognition (Time 1) as Independent Variables

#### (Set a)

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>.05</td>
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</tr>
<tr>
<td>2.</td>
<td>HPR (T1)*</td>
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<td>.13</td>
<td>2.97**</td>
<td>.37</td>
</tr>
<tr>
<td>3.</td>
<td>PPVT</td>
<td>.24</td>
<td>.06</td>
<td>1.96</td>
<td>.26</td>
</tr>
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</table>

#### (Set b)

3. EOWPT  .22  .04  1.47  .20

#### (Set c)

3. WRAT  .20  .02  1.03  .14

Note. * = Time 1; ** $p < .01$

AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; EPR = English Pseudoword Repetition Task; HPR = Hebrew Pseudoword Repetition Task; MAT = Matrix Analogies Test; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3
Hierarchical Regression Analysis Predicting AAT Performance (Time 2) in ESL Subjects, with Vocabulary and Word Recognition (Time 1) as Independent Variables

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.04</td>
<td></td>
<td>1.52</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>AAT (T1)*</td>
<td>.36</td>
<td>.32</td>
<td>5.17***</td>
<td>.58</td>
</tr>
<tr>
<td>3.</td>
<td>PPVT</td>
<td>.38</td>
<td>.02</td>
<td>1.28</td>
<td>.17</td>
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(Set b)

<table>
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<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>EOWPT</td>
<td>.47</td>
<td>.11</td>
<td>3.25**</td>
<td>.41</td>
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(Set c)

<table>
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<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>WRAT</td>
<td>.41</td>
<td>.05</td>
<td>2.08*</td>
<td>.27</td>
</tr>
</tbody>
</table>

Note. * = Time 1; * $p < .05$, ** $p < .01$, *** $p < .001$; AAT = Auditory Analysis Task; EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; MAT = Matrix Analogies Test; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3
Appendix H

Hierarchical Regression Analysis Predicting PPVT Performance (Time 2) in EL1 Subjects, with Phonological Discrimination (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.21</td>
<td></td>
<td>2.62*</td>
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</tr>
<tr>
<td>2.</td>
<td>PDT</td>
<td>.28</td>
<td>.07</td>
<td>1.57</td>
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Set (b)

<table>
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<th>Variable</th>
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<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.21</td>
<td></td>
<td>2.62*</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>PPVT (T1)$^a$</td>
<td>.44</td>
<td>.23</td>
<td>3.17**</td>
<td>.53</td>
</tr>
<tr>
<td>3.</td>
<td>PDT</td>
<td>.46</td>
<td>.02</td>
<td>.93</td>
<td>.19</td>
</tr>
</tbody>
</table>

Note. $^a$ = Time 1; * $p < .05$, ** $p < .01$

Hierarchical Regression Analysis Predicting EOWPT Performance (Time 2) in EL1 Subjects, with Phonological Discrimination (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
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<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.25</td>
<td></td>
<td>2.91**</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>PDT</td>
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<td>.07</td>
<td>1.71</td>
<td>.32</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.25</td>
<td></td>
<td>2.91**</td>
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</tr>
<tr>
<td>2.</td>
<td>PPVT (T1)$^a$</td>
<td>.40</td>
<td>.15</td>
<td>2.53*</td>
<td>.45</td>
</tr>
<tr>
<td>3.</td>
<td>PDT</td>
<td>.43</td>
<td>.03</td>
<td>1.06</td>
<td>.21</td>
</tr>
</tbody>
</table>

Note. $^a$ = Time 1; * $p < .05$, ** $p < .01$

EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; MAT = Matrix Analogies Test; PDT = Phonological Discrimination Task; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3
Appendix H continued

Hierarchical Regression Analysis Predicting WRAT Performance (Time 2) in EL1 Subjects, with Phonological Discrimination (Time 1) as an Independent Variable

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.15</td>
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<td></td>
</tr>
<tr>
<td>2.</td>
<td>PDT</td>
<td>.37</td>
<td>.22</td>
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<td>.51</td>
</tr>
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</table>

(Set b)

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial r</th>
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<tbody>
<tr>
<td>1.</td>
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<td>2.09*</td>
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</tr>
<tr>
<td>2.</td>
<td>WRAT (T1)$^a$</td>
<td>.62</td>
<td>.47</td>
<td>5.41***</td>
<td>.74</td>
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<tr>
<td>3.</td>
<td>PDT</td>
<td>.65</td>
<td>.03</td>
<td>1.41</td>
<td>.28</td>
</tr>
</tbody>
</table>

Note: $^a$ = Time 1; * $p < .05$, *** $p < .001$

Hierarchical Regression Analysis Predicting PPVT Performance (Time 2) in ESL Subjects, with Phonological Discrimination (Time 1) as an Independent Variable

<table>
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<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial r</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.23</td>
<td></td>
<td>4.09***</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>PDT</td>
<td>.28</td>
<td>.05</td>
<td>1.84</td>
<td>.24</td>
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</table>

(Set b)

<table>
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<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.23</td>
<td></td>
<td>4.09***</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>PPVT (T1)$^a$</td>
<td>.60</td>
<td>.37</td>
<td>6.99***</td>
<td>.69</td>
</tr>
<tr>
<td>3.</td>
<td>PDT</td>
<td>.60</td>
<td>.00</td>
<td>.49</td>
<td>.07</td>
</tr>
</tbody>
</table>

Note: $^a$ = Time 1; *** $p < .001$

EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; MAT = Matrix Analogies Test; PDT = Phonological Discrimination Task; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement Test 3
Appendix H continued

Hierarchical Regression Analysis Predicting EOWPT Performance (Time 2) in ESL Subjects, with Phonological Discrimination (Time 1) as an Independent Variable

(Set a)

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>MAT</td>
<td>.16</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>PDT</td>
<td>.20</td>
<td>.04</td>
<td>1.72</td>
<td>.23</td>
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</tbody>
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(Set b)

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>$T$</th>
<th>Partial $r$</th>
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<td>1.</td>
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<td></td>
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<tr>
<td>2.</td>
<td>EOWPT (T1)*</td>
<td>.56</td>
<td>.40</td>
<td>6.95***</td>
<td>.69</td>
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<td>3.</td>
<td>PDT</td>
<td>.57</td>
<td>.01</td>
<td>1.11</td>
<td>.15</td>
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</table>

Note. * = Time 1; ** $p < .01$, *** $p < .001$

Hierarchical Regression Analysis Predicting WRAT Performance (Time 2) in ESL Subjects, with Phonological Discrimination (Time 1) as an Independent Variable

(Set a)

<table>
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(Set b)

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</thead>
<tbody>
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</table>

Note. * = Time 1; ** $p < .01$, *** $p < .001$

EOWPT = Expressive One-Word Picture Vocabulary Test-Revised; MAT = Matrix Analogies Test; PDT = Phonological Discrimination Task; PPVT = Peabody Picture Vocabulary Test-Revised; WRAT = Wide Range Achievement