SPOKEN WORD RECOGNITION BY CHILDREN
WITH AND WITHOUT SPECIFIC LANGUAGE IMPAIRMENT:
AN EXAMINATION OF LEXICAL CHARACTERISTICS
by
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Abstract

The current study had three aims: 1) To examine spoken word recognition by children with and without specific language impairment (SLI), 2) To investigate the effects of two lexical characteristics, age of acquisition and neighbourhood density, on spoken word recognition, and 3) To explore possible links between spoken word recognition and phonological short-term memory or semantic knowledge.

Eight school-aged children with SLI and nine typically developing children matched for comprehension vocabulary completed three experimental tasks. First, they listened to 28 common nouns presented in a gating paradigm. The 28 words varied along the dimensions of age of acquisition (early- versus late-acquired) and neighbourhood density (words from sparse versus dense phonological neighbourhoods) so that there were four types of words: early/sparse, early/dense, late/sparse and late/dense. Participants were asked to identify the word being presented. Second, participants completed a word-picture matching task (from a choice of four pictures) that measured the depth of their semantic knowledge of the same 28 words. Third, children repeated nonsense words that varied from one to four syllables in length as a measure of their phonological short-term memory.

Results from the gating task found no significant difference between groups. For both groups, children recognized early-acquired words from sparse neighbourhoods more quickly than early-acquired words from dense neighbourhoods and late-acquired words from both sparse and dense neighbourhoods. A significant correlation was found between the gating task and the nonsense word repetition task for all participants. The longer the phonological short-term memory span, the more quickly words were recognized for all children. A strong and marginally significant correlation was found between the gating task
and the word-picture matching task for the children with SLI only: the higher the number of words they could correctly match to a picture the more quickly words were recognized in the gating task.

These results suggest that children with SLI do not have a deficit relative to vocabulary-matched peers in the recognition of single, spoken, words. Furthermore, the current findings provide some degree of support for a relationship between spoken word recognition and both phonological short-term memory and depth of semantic knowledge.
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1 Introduction

1.1 Why study spoken word recognition in Specific Language Impairment?

Do deficits at the basic level of word recognition underlie higher-level language difficulties in specific language impairment (SLI)? Research on SLI has tended to focus on low-level auditory impairments (e.g., tone discrimination), or higher-level language difficulties such as the production and comprehension of grammatical morphology and complex sentences. The widely known work of Tallal and colleagues in the 1970s and 80s, revealed that children with SLI have an impaired ability to process non-linguistic auditory information; specifically, they have difficulty discriminating and sequencing short sounds presented at a quick rate (Tallal, Miller, et al., 1996; Tallal, Stark & Mellits, 1985). The list of linguistic deficits of children with SLI is long and diverse (these children demonstrate difficulties in virtually all areas of language: phonological, lexical, semantic, syntactic, morpho-syntactic, and pragmatic); however, it is not clear how auditory difficulties relate to these language impairments (Leonard, 1998).

Words, arguably, are the basic meaningful units of spoken language, and they form the central layer of the cognitive faculty we call language. Words are abstract entities that provide the crucial link between arbitrary sound patterns (e.g., /kat/) and meaning (e.g., small carnivorous domestic mammal). In children with SLI, difficulty in spoken word recognition could have an incremental impact on the comprehension of larger units of language, providing a link between the low-level auditory impairments these children have and their disordered higher-level language. This study compared children with SLI and typically developing children matched for vocabulary comprehension level in their ability to recognize
spoken words. In addition, possible links between spoken word recognition and phonological short-term memory or semantic knowledge were explored.

In this chapter, I will review an interactive-activation connectionist model of lexical access as it applies to spoken word recognition. This model will provide the framework for discussion of lexical access in typically developing children and those with SLI. Three lexical characteristics: neighbourhood density, age of acquisition and frequency, will be considered as will their impact on lexical access by adults and children. This will be followed by a discussion of specific language impairment and evidence for lexical abilities and deficits. This chapter will close with a brief overview of the current project and the research questions it set out to address.

1.2 Lexical access in spoken word recognition: A model and characteristics

1.2.1 Introduction: Interactive-activation model

Understanding a spoken word involves mapping sound onto meaning. Common to all models of spoken word recognition are two levels of information: the phonological level where sounds are represented as phonemes or phonetic features, and the word level, where words are represented in an abstract manner (Jusczyk & Luce, 2002). Some models also include a third semantic level, where information about the meaning of lexical items is stored. This section will summarize Dell et al.'s (1997) connectionist model of lexical access. While Dell et al. discuss the model as it applies to word retrieval, it is equally applicable to word recognition; both processes involve the same levels of representation, though the starting point differs (for a connectionist model specific to speech perception, see Protopapas, 1999). Although there are many models of spoken word recognition (see Jusczyk

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1 Technically, word recognition begins with the input of auditory information via the auditory system. For the purposes of this discussion, we will discuss word recognition from the point where auditory information meets the phonological system, or abstract, encoded information about speech sounds.
& Luce, 2002, for a review), for the purposes of the current study, Dell’s connectionist model provides a useful way to think about spoken word recognition and SLI as it attends to both the processing resources a listener brings to the task of word recognition as well as the effects of the characteristics of the words themselves. The intention of this study was not to provide an empirical test of different models of spoken word recognition, hence a thorough comparison of the various models would go beyond the scope of this study. On the other hand, where results from the current study do not find a ready explanation in the interactive-activation model, alternative theoretical accounts will be considered (in the discussion section, see chapter four).

In the Dell model, word recognition involves processing at three interconnected levels of representation: the phonological level (where units correspond to phonemes), the lexical level (units represent abstract lexical items or *lemmas*) and the semantic level (where units correspond to semantic features). (See Figure 1 for a pictorial representation of the model.) Activation flows to units at each level via many connections between units at different levels. Two aspects regarding activation are key to this model. First is the notion that activation flows between levels in both directions (feed forward/backward) and hence the model is a form of interactive activation model. Second, levels of representation are processed in parallel, such that semantic information and phonological information contribute simultaneously to the process of word recognition (though with different temporal features).

The connections between units have weights (e.g., between the phoneme /t/ at the phonological level and the lexical level unit for *cat*), and these weights are modified through learning and experience (although, the Dell model used fixed weights for convenience, assuming a stable adult state). Stronger weights represent stronger connections and increased
activation passed between levels. In addition, each unit has an activation level, like a threshold, which has to be reached for the unit to be selected as a target.

Figure 1. Illustration of three-level interactive-activation lexical network from Dell et al. (1997).

In connectionist terms, the act of recognizing a word entails activating the phonological units that correspond to the target (e.g., the phonemes that correspond to cat).

This activation spreads to the corresponding lexical node for cat. Lexical nodes that share phonological units with cat also receive some activation (for example, rat and mat).

Activation from the lexical nodes that have been activated (including the lexical node for cat) also spreads to the semantic level. The lexical level activates the semantic units (e.g., animal, furry, feline) in proportion to lexical level activity. Importantly, activation spreads backward as well as forward allowing for mutually constraining activation from different levels of representation. While processing begins with the phonological level, it spreads to other levels quickly so that all levels are processing virtually simultaneously. Ultimately, the model
chooses the lexical unit with the highest activation (which has spread forward from the phonological nodes and backwards from the semantic nodes) for recognition. In this example, activation would spread from the semantic units that correspond to *cat* back to all units at the lexical level that the semantic units are connected to (e.g., to *rat* which shares several semantic features with *cat*), and also from the lexical units back to the phonological units that are shared (e.g., to /a/ and to /t/). Some interactive-activation models also include lateral inhibition which allow for activated units at one level to inhibit other units at the same level (e.g., /a/ might inhibit /i/).

According to this connectionist model, lexical knowledge is stored in representations that are distributed across the three levels (phonological, lexical and semantic). Recognition of a spoken word entails the spread of bottom-up information from the auditory system to the phonological level and then to the lexical and semantic levels, top-down information from the semantic level to the lexical level and feedback from the lexical level to both the semantic and phonological levels. Lexical access is achieved (in both word recognition and name retrieval) when the lemma with the highest level of activation is selected. This, in Dell’s account, normally happens when a word is needed to fill a syntactic slot in a sentence.

Research has demonstrated that lexical access is also affected by stored information beyond phonological and semantic representation, including sentence context, pragmatics and prosody. In addition, several lexical properties have been found to affect both production and comprehension; the effect of these lexical characteristics emerges from the way in which the network processes and represents phonological and semantic information.
1.2.2 Lexical characteristics

The next three sections focus on three lexical characteristics: age-of-acquisition, neighbourhood density and word frequency, and each section defines the characteristic under consideration and discusses its effect on spoken word recognition. Each section will include a brief précis of the results of research on the effect of the relevant lexical characteristic on word recognition by adults. This will be followed by a section that considers the results of research on all three characteristics (ND, AOA and WF) on spoken word recognition by children.

1.2.2.1 Neighbourhood Density and the Neighbourhood Activation Model

The connectionist model above described how lexical nodes (lemmas, or abstract word forms) that share sounds with a given stimulus are activated in addition to the target lemma during word recognition. The target lemma and similar-sounding lemmas form a neighbourhood according to Luce and Pisoni’s (1998) Neighbourhood Activation Model (NAM). According to this account, the mental lexicon is organized into phonological similarity neighbourhoods, and neighbours are defined as any word that differs by one phoneme from the target (e.g., target: cat, neighbours: mat, cot, can, at, etc.). In connectionist terms, a neighbour would be a word that has connections to all but one of the phonemes that the target item has connections to. Research by Luce and colleagues over the past several years has provided strong evidence in favour of this model (Luce & Pisoni, 1998).

According to Luce and colleagues, neighbourhood density refers to the number of neighbours, or phonologically similar words, there are in the lexicon for a particular target word. In an interactive activation model, such as Dell’s model, neighbourhood density is explained as the automatic and unconscious activation of lexical items that share
phonological units with a target word. Some words share phonological units with many lexical items, forming a dense neighbourhood, and some share phonological units with just a few lexical items forming a sparse neighbourhood.

Research with adults has demonstrated a robust effect of neighbourhood density (for a review see Jusczyk & Luce, 2002). Words from denser neighbourhoods (usually defined as more than nine neighbours) are recognized less accurately and more slowly than words from sparser neighbourhoods (Luce & Pisoni, 1998). Researchers have interpreted these results as reflecting a "competition effect" whereby phonological neighbours that are also activated during recognition compete for selection; as a result the system must select the correct lexical item from a number of competing possible lexical candidates. In dense neighbourhoods many lexical items map on to the phonological string and hence it takes more time to activate the target lexical item above threshold, compared to sparse neighbourhoods where few lexical items map onto the phonological string.

In the Neighbourhood Activation Model, word frequency (of target words and their neighbours) also figures into the probability of word recognition during the activation, competition and selection process. The next section defines word frequency, and describes its effect on lexical access in adults.

1.2.2.2 Frequency

Word frequency refers to the number of times a word is produced or encountered in a given chunk of text or discourse (e.g., per million words). Along with age-of-acquisition (see below), frequency reflects word familiarity, and research has shown AOA and word

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2 Another construct that affects word recognition in NAM is neighbourhood frequency, which is usually measured as the average of the frequency of each word in a neighbourhood. In some studies neighbourhood density and frequency are combined into one measure: frequency-weighted neighbourhood density (Luce & Pisoni, 1998).
frequency to be distinct even though they are correlated (see Garlock, Walley & Metsala, 2001, for a review). Word frequency has been measured objectively in both spoken and written corpora (Carroll & White, 1973). The most commonly used corpus of word frequencies is the norms from written American English published by Kucera and Francis in 1967.

Findings from research into the effect of word frequency on spoken word recognition by adults have been inconsistent for different tasks (e.g., gating, word repetition, auditory lexical decision; see Garlock, Walley & Metsala, 2001, for a review). In general, results have shown that high-frequency words have processing advantages over low-frequency words (Luce & Pisoni, 1998). Researchers are still debating the nature of the mechanism that underlies this phenomenon. From a connectionist perspective, high frequency of exposure to a word would result in stronger connection weights between the lemma level and the phonological and semantic units for the word resulting in faster arrival to threshold for high frequency words.

The interaction between word frequency and neighbourhood density in spoken word recognition has produced inconsistent results in adults. On the one hand, Dirks, Takayanagi, Moshfegh, Douglas Noffsinger and Fausti (2001) found the expected results: adults recognized high frequency words better than low frequency words overall, and for both high frequency and low frequency words, those from sparse neighbourhoods were recognized better than those from dense neighbourhoods. However, other studies have found that high frequency words are recognized best from sparse neighbourhoods compared to dense neighbourhoods, but that low frequency words experience an advantage in high density compared to low density neighbourhoods (see Luce & Pisoni, 1998 for results from a lexical...
decision task and Metsala 1997a for a gating task and further discussion in chapter four). These conflicting results are likely due to the use of different tasks.

1.2.2.3 Age of Acquisition

The average age at which a typical individual can understand and produce a specific word is defined as the age-of-acquisition for that word. Like word frequency, age of acquisition affects connection weights activating words above their thresholds, since individuals typically have more experience with words acquired at a younger age. Evidence is mounting in favour of AOA as a more sensitive index of lexical familiarity than word frequency, especially for children (Garlock, Walley & Metsala, 2001). This sensitivity is easy to understand given that a one-year difference in age-of-acquisition is proportionately longer for someone who is only seven years old compared to someone who is 30 years old.

AOA is typically measured through subjective estimates from adults (and sometimes children), which have shown to be reliable predictors of word recognition (Walley & Metsala, 1992). Like word frequency, AOA has a robust effect on word recognition by adults, such that early-acquired words experience an advantage over late-acquired words (Garlock, Walley & Metsala, 2001; see also Morrison & Ellis, 1995, for results from written word recognition).

In sum, recognition of all words is not equally easy or quick; some words are harder to recognize than others (e.g., those of late AOA, low frequency or high neighbourhood density). In the next section, I will consider research that has examined the effect of these lexical characteristics on lexical access in children.
1.2.3 The development of spoken word recognition

The limited research on the effects of AOA, ND and WF on children of different ages suggests that changes in spoken word recognition occur throughout early childhood, until about age seven when children’s responses become similar to adult responses (Garlock, Walley & Metsala, 2001). According to the “emergent view of lexical development” (supported by Garlock, Walley & Metsala, 2001, amongst others), during childhood lexical-phonological representations become more completely specified and/or more segmentally structured. This re-structuring occurs with vocabulary growth, perhaps as a result of pressure to distinguish between an increasing number of words in the lexicon, many of which have overlapping phonological representations. So as phonological-similarity neighbourhoods become denser, phonological representations of words must become more detailed.

According to the emergent view, in addition to neighbourhood density growth, another factor that affects the phonological specification of a word is experience with a word over time (either because it was acquired early or because it is experienced frequently). That is, through experience, connection weights become strengthened between units at different levels leading to greater unit to unit ‘sensitivity’. Therefore, both neighbourhood density and word familiarity (AOA and/or WF) may facilitate increasingly detailed and segmental lexical representations in language acquisition (Metsala, 1997b).

The emergent view claims that young children’s lexical-phonological representations are less specified, or “underspecified” compared to older children and adults (Garlock, Walley, & Metsala, 2001). Does underspecification mean that young children do not have the full phonological form (e.g., each segment in a word, or all the phonological features for each phoneme in a word) of words stored in their mental lexicon? Not necessarily. It is possible
that the phonological form is stored but that it is harder to access the full form of words that have a late age of acquisition (AOA) due to weak connections. Limited experience with a word (either due to its low frequency or because it was only recently acquired) would be associated with weak connections to some or all phonemes. If a child had a weaker network (fewer and/or weaker connections) due to their young developmental state or to delayed language development, then access to phonological forms that are weakly connected to lexical and/or semantic nodes would be even slower and more error prone. Given that neighborhood density effects reflect both processing demands and representation, access to representations should not be dismissed from the discussion of developmental changes in spoken word recognition.

Recent research by Metsala (1997a) and others (e.g., Garlock et al., 2001) on spoken word recognition by children has produced findings in support of the emergent view of lexical development. Metsala (1997a) used a gating task to examine word recognition by children of different ages (7, 9 and 11 years old) and adults and, in particular the effects of word frequency and neighbourhood density. In the gating task, listeners hear successive increments (or gates) of an acoustic signal of a word, starting with the onset, until the whole word has been presented (Grosjean, 1980). After each gate, listeners guess what the target word is. Metsala found that with increasing age, listeners recognized target words using less acoustic information. All subjects (children and adults) identified high frequency words from low density neighbourhoods at an earlier gate compared to high density neighbourhoods. By contrast, low frequency words were identified more quickly from high density than low density neighbourhoods by all groups.

3 From a connectionist perspective, access and representation are interdependent and determined by connection strength. For example, neighbourhood density affects representation through the number of competitors, whereas it impacts access through the demands placed on resources for lateral inhibition of competitors.
Metsala’s results parallel the results found for the interaction of word frequency and neighbourhood density in adults in an auditory lexical decision task (Luce & Pisoni, 1998). An explanation of this interaction is that high frequency words are activated quickly and that the system can select the correct lexical item more quickly when there are fewer candidates, which map onto the phonological string. Low frequency targets, on the other hand, are activated more slowly, but in dense neighbourhoods they benefit from the high frequency of the shared phonological pattern compared to sparse neighbourhoods (Metsala, 1997a). However, different results found in other studies may be due to the variety of tasks used, developmental level of participants or familiarity level of stimuli used. Where density has had the same effect on low and high frequency targets, (i.e., sparse easier than dense) researchers have interpreted this as the competition effect (Dirks et al., 2001).

Garlock, et al. (2001) looked at changes in the effects of ND, WF and AOA on word recognition by children at different ages and adults by comparing the performance across groups on a gating task and a word repetition task (young children in preschool and kindergarten, mean age 5;6; older children in grades one and two, mean age 7;6; and adults, mean age 25;6). The authors found that AOA had a significant impact on word identification, such that children and adults were much faster in identifying (or more accurate in repeating) early-acquired words compared to later-acquired words. In addition, for the young children, neighbourhood density only had an effect on early-acquired words, such that sparse words were repeated more accurately than dense words, whereas sparse and dense late-acquired words were repeated equally accurately. By contrast, ND affected repetition accuracy of both early- and late-acquired words in older children and adults in the expected way (words from sparse neighbourhoods were repeated more accurately than words from dense
neighbourhoods). There was no main effect of ND on the gating task for the very young children, however there was for the older children and adults.

Garlock et al.'s finding that the greatest differences between the three age groups were for late words and those from sparse neighbourhoods, was interpreted as evidence for the emergent view: changes in the lexical representations of late words over the course of childhood account for developmental differences in spoken word recognition. Since young children have more experience with early words, their representations of these words have become more segmental, and as a result, neighbourhood density affects recognition. For late words, neighbourhood density does not affect recognition speed since the representations are more holistic and most or all of the word needs to be heard to identify it. For example, for a young child both a late word from a sparse neighbourhood (e.g., *yam*) and a late word from a dense neighbourhood (e.g., *kit*) would be recognized after hearing the whole word, and therefore, with the same speed because words of both neighbourhood densities are not represented in a segmental manner. For early-acquired words, on the other hand, a word from a sparse neighbourhood (such as *bar*) could be recognized after hearing a little bit of the word—just enough of the word to distinguish it from others – but a child would take longer to recognize an early-acquired word from a dense neighbourhood (such as *mop*) because even though its representation is segmental they would need to hear more of the word in order to distinguish it from competing neighbours.

Alternatively, it is possible that late-acquired words have weak connections overall, but that late-acquired words from dense neighbourhoods have relatively stronger connections (compared to sparse neighbourhoods) due to the increased frequency of exposure (see the discussion on phonotactic probability in chapter four). If this was the case, then word
recognition would actually be faster for late-acquired (or low frequency) words from dense compared to sparse neighbourhoods.

In sum, recent research on spoken word recognition has provided support for the claim that lexical-phonological representations of words become increasingly segmentally specified throughout childhood. The finding that older subjects need less acoustic information to recognize a word than younger subjects (Metsala, 1997a) and that young children only show effects of neighbourhood density when recognizing early-acquired words (Garlock et al., 2001) challenge the more traditional view that lexical representations are phonemic in nature but not consciously accessible until later in development.

1.3 Specific Language Impairment

1.3.1 Definition and characteristics of SLI

As defined by Leonard (1998), SLI is a "significant limitation in language ability, yet the factors usually accompanying language learning problems – such as hearing impairment, low non-verbal intelligence test scores and neurological damage – are not evident" (p.3). As such, children are often diagnosed through exclusionary as much as inclusionary criteria. Children with SLI are a heterogeneous group; some exhibit deficits in language production only, while others have deficits in both production and comprehension (Bishop, 1997). One of the most conspicuous deficits in English-speaking children with SLI is their variable use of grammatical morphemes (see Leonard, 1998, for a review). While some researchers believe that language deficits underlie SLI, for example Gopnik and Crago (1991), evidence is mounting that suggests deficits extend to domains beyond language (see Leonard, 1998, for a review).
An early symptom of SLI is lexical difficulty: parents often report that children later identified with SLI were late to acquire their first words (Leonard, 1998). Difficulties in word production are widespread in SLI. These children are slow to name pictured objects (Lahey & Edwards, 1996) and exhibit subtle but important difficulties in learning new words (Ellis Weismer & Hesketh, 1996). Overall, however, there are mixed findings as to whether children with SLI have difficulty learning words (Leonard, 1998). In word recognition tasks, children with SLI also have difficulties. For example, Montgomery, Scudder and Moore (1990) found that children with SLI were slower to push a button in response to hearing a common noun embedded in a sentence compared to younger, language-matched controls.

Various explanations of the lexical deficits of children with SLI have been proposed, including difficulties in perceptual encoding, lexical processing (phonological and/or semantic), and nonlexical response processing (such as a generalized slowing; see Lahey & Edwards, 1996 for a brief review of sources of naming difficulty, and Bishop, 1997, for a thorough review of comprehension deficits). In the next two sections, I will briefly review the evidence for auditory-perceptual deficits, and the evidence for generalized processing deficits. This will be followed by a review of the few studies that have directly examined spoken word recognition by children with SLI. I will conclude this section with evidence for deficits in the areas of phonology and semantics, which could underlie difficulty with lexical access in SLI.

1.3.2 Auditory-perceptual deficits

Early research documented that children with SLI have difficulty compared to age-matched controls discriminating brief nonverbal auditory stimuli and adjacent stimuli

\[\text{Participants with SLI in the current study also reflect these mixed findings: half performed below normal limits on the standardized measure of vocabulary comprehension and half performed within normal limits.}\]
separated by brief intervals, as well as difficulty with synthesized verbal stimuli when the
task demands identification as well as discrimination (see Leonard, 1998, for a review).
Nevertheless, even with these auditory deficits children with SLI do manage to acquire the
very speech contrasts they have difficulty discriminating and identifying in experimental
studies. However, recent work by Trehub and Henderson (1996) and Benasich and Tallal
(2002) suggests there is a link between performance on auditory processing tasks in infancy
and language outcomes in the toddler years (for both children with and without a family
history of language difficulty).

In a recent study Marler, Champlin and Gillam (2002) argued that children with SLI
had difficulty not in the perception of brief auditory information but rather incomplete
processing (encoding into memory) due to the speed of information being presented and the
demand to process multiple pieces of auditory information. Using both psychoacoustic-
behavioural methods and electrophysiological methods, the authors demonstrated a temporal
processing deficit in children with SLI through their performance on a backward masking
task. Unlike typical controls, children with SLI did not have lower detection thresholds for a
signal presented in a backward masking condition compared to a signal presented in a
simultaneous masking condition. Both the behavioural and electrophysiological results
indicated that the deficit was due to a memory component rather than a sensory component
(problems in basic perception) or attention component. In particular, children with SLI had
difficulty holding onto auditory information while processing further incoming information.
These findings suggest that the auditory-perceptual difficulties found in children with SLI
might be due to capacity limitations. This account of SLI is the focus of the next section.
1.3.3 Capacity limitations

The findings of Trehub & Henderson (1996) and Benasich and Tallal (2002) provide support for the link between auditory processing in infancy and language development in early childhood. But what aspect of language development do auditory processing deficiencies impact, and how? Leonard and colleagues (as reviewed in Leonard, 1998) have hypothesized that difficulty processing successive brief sounds leads to the grammatical morpheme difficulties that are so typical of English-speaking children with SLI. Many of the English morphemes that children with SLI have difficulty with are of a short duration (e.g., past tense -ed, articles, copula and infinitival to). Findings from studies by Leonard and others, in English and other languages have provided general support for the hypothesis of capacity limitations in SLI. Researchers believe that, as in the auditory perception studies reviewed above, it is not perception of the morphemes that is the problem but rather incomplete processing (encoding into memory) due to their brief duration and the amount of adjacent auditory information that must also be processed. Leonard’s research provided support for the idea that ultimately, limitations in memory capacity or speed of processing, seem to be behind auditory and grammatical difficulties in SLI. Taken together with research demonstrating limited capacity of working memory and phonological short-term memory in children with SLI (see Montgomery, 2003, for a review), this suggests that children with SLI may have difficulty in spoken word recognition because it also involves processing a stream of brief auditory information that could exceed their capacity.

Some researchers believe that children with SLI have limitations in rate (as opposed to capacity) of information processing, and that this domain-general slowing underlies the language difficulties of children with SLI. According to this view, deficits will appear in the
performance of complex tasks, and therefore arise during language processing tasks, which
tend to be complex by nature. This explanation of SLI is attractive as it could provide a
parsimonious account of the diverse findings from children with SLI. However, one study
found that not all children with SLI show general deficits in speed of processing (Miller,
Kail, Leonard & Tomblin, 2001), and a recent meta-analysis has raised significant doubts
about the general nature of the slowing (as reviewed in Windsor, 2002).

1.3.4 Spoken word recognition by children with SLI

The finding of impaired lexical abilities in some children with specific language
impairment, combined with the evidence of auditory processing impairments, provides good
reason to believe that children with SLI may recognize spoken words differently than
typically developing children. However, few studies have investigated word recognition by
children and even fewer in children with language disorders. In what follows, I will review
several studies that have examined spoken word recognition by children with SLI. Then I
will review research that has attempted to uncover whether children with SLI might have less
detailed lexical-phonological representations and/or less detailed lexical-semantic
representations – two possible sources of difficulty in spoken word recognition.

Two studies have examined word recognition by children with specific language
found that children with specific language impairment (SLI; n = 10) and chronological age-
matched peers (CA; n = 10) ranging in age from 6;9 to 10;11 performed equivalently in
identifying familiar words (selected from a list of words in the productive lexicon of children
under age 3). However, the children with SLI required more of the acoustic-phonetic signal
than CA peers to recognize less familiar (newly learnt) nonsense words. In addition, the
children with SLI were less successful in identifying initial consonants for both familiar and unfamiliar words (responses by children with SLI were less likely than control children to begin with the same phoneme as the target at early gates). Dollaghan interpreted these results as suggesting that in SLI "word recognition processes are vulnerable when processing demands are increased" (p. 203). If the connections to new words are weaker, more resources could be required to activate the representations, and representations of phonologically-similar words could cause strong competition. Unfortunately, without a receptive vocabulary matched control group we do not know if the performance of the children with SLI is a result of their level of language development (and therefore simply a developmental delay) or unique to children with SLI (and therefore deviant development).

In the second study on spoken word recognition by children with SLI, Montgomery (1999) compared lexical access in an SLI group (n = 21, mean age 8;9), a chronological age matched group (n = 21) and 21 children matched for vocabulary comprehension (mean age 7;1). He found that all three groups performed equivalently on a gating task: they identified target words with similar amounts of acoustic input, and they identified the initial phoneme of target words equally quickly. However, since Montgomery only used very familiar words, his results do not speak to performance on later acquired words or words that vary in neighbourhood density.

In sum, these findings demonstrate that children with SLI are as accurate and as quick to recognize highly familiar words as typically developing children (both age-matched and vocabulary-matched). However the findings are in conflict regarding their identification of word-initial phonemes, though this may be due to methodological differences in how the data were analysed between the two studies. Montgomery measured this by calculating the mean
amount of acoustic information needed to guess from among candidate words having the same initial consonant as the target, whereas Dollaghan looked at the percentage of children in each group at each gate who guessed a word that began with the same initial consonant as the target. Furthermore, neither study speaks to the question of whether SLI children differ from vocabulary-matched peers on their ability to recognize ‘harder’ (late AOA or high ND) words.

If SLI children do differ from age-matched peers in identifying “harder” words, what might be the source of this difficulty? It is possible that there are weak connections between the lexical level and the phonological level (as in the emergent view suggested by Metsala and others) or between the lexical level and the semantic level (see below), or weak connections among all levels. Alternatively, low-level deficits in auditory processing could cause differences in spoken word recognition. In the next two sections, I will review the evidence for phonological deficits and semantic deficits in SLI, respectively, and their relationship to difficulties in lexical access.

1.3.5 Phonological representation deficits

Two recent studies have suggested that children with SLI may have underspecified lexical-phonological representations (representations that are missing some phonemic or phonetic feature information). Crosbie, Howard and Dodd (2004) examined lexical access in 15 children with SLI (mean age 8;11) and two control groups (15 in the age-matched, or AM, group, and 15 in the receptive vocabulary-matched, or RV group, mean age 6;10) using an auditory lexical decision task. Children listened to a word and had to decide whether it was a real word by answering yes or no. The stimuli included high frequency/highly imageable real words, nonwords and illegal nonwords (that violated English phonotactic constraints). The
dependent variables were reaction time and accuracy. The study found no significant differences between the groups for reaction time, suggesting no group difference in processing speed. However, the SLI group was less accurate than the AM control group.\(^5\)

Post-hoc analyses revealed that the group difference in accuracy resulted from the extremely poor performance of five SLI subjects. The other ten children with SLI performed within normal limits when compared with receptive vocabulary matched peers. The children in the SLI subgroup that performed poorly were significantly less accurate and found it harder to reject nonwords than the RV controls. The authors interpreted these results as evidence that this subgroup of children with SLI had underspecified phonological representations so that the “information from acoustic-phonetic analysis of a non-word may provide enough activation to select the representation of a real word” and as a result the subject judges the similar-sounding nonword to be real (p.117).

Maillart, Schelstraete and Hupet (2004) also used a lexical decision task to examine lexical-phonological representations in French-speaking children with SLI (age 6;4 to 12;3) and typically developing children matched for receptive vocabulary level. They found that the children with SLI had particular difficulty rejecting pseudowords that were slightly modified (e.g., real words with a single phoneme deletion/addition) compared to pseudowords that were significantly modified (e.g., real words with a whole syllable deleted or added). In addition, subjects with SLI performed poorest when the slight modification was located at the beginning or end of a word. The authors interpreted these findings as evidence of underspecified lexical-phonological representations in children with SLI.

\(^5\) The possibility of a speed accuracy trade-off was examined by correlating response time and accuracy for each type of stimulus but no evidence for this trade-off was found.
Based on these findings, it is not clear whether all children with SLI, or just a subset, have less specified lexical-phonological representations compared to typically developing peers. The authors of both studies interpreted their findings as evidence that children with SLI maintain less detailed phonological representations of words longer than typically developing children, and longer than they should given their vocabulary size. However, these results must be interpreted cautiously as a response bias could be at work in auditory lexical decision tasks. For example, participants may be biased towards responding ‘yes’ to all stimuli and this could account for the difficulty the SLI subjects had in rejecting the nonwords. However, the fact that the children with SLI experienced more difficulty with the nonwords that were only slightly modified compared to those that were modified in a larger way (Maillart et al., 2004) provides evidence that more than just a response bias is responsible for the group difference. Given the low ecological validity of the auditory-lexical decision task, the heavy demands on meta-linguistic processes, which depend on strong language development (Paul, 2001), and the conflicting results from the two studies above, further examination of lexical-phonological representations in children with SLI using other paradigms is warranted.

1.3.6 Semantic deficits

Another possible source of difficulty in lexical access (either in comprehension or production) is access to or representations at the semantic level. Several studies have shown that the most frequent type of error in picture naming made by young children with SLI is semantic (e.g., hawk for owl), followed by phonological errors (e.g., water for walker) (Leonard, 1998, McGregor, 1994, McGregor & Waxman, 1998). While this data suggests that children with SLI may have difficulties at the semantic level which affect naming, there
is little empirical evidence regarding the quality of semantic representations in children with SLI. Recent research by McGregor and colleagues, however, has recently begun to explore this possibility (McGregor, Newman, Reily & Capone, 2002). McGregor et al. (2002) had children with and without SLI (aged 5–8) complete three tasks: name 20 pictures of objects that were low in frequency but age-appropriate (mean AOA = 4.09 years), then draw and define the same 20 words. As predicted, the SLI group made more naming errors, and for both groups the majority of errors were semantically related to the target. Results from the drawing and defining tasks indicated that both the SLI and the typically developing control group had less information in the pictures and definitions of items they named incorrectly, suggesting that a limited semantic representation contributes to name retrieval failure.

The results of McGregor et al. provide initial evidence that constraints in semantic processing (during word learning and/or lexical access) contribute to naming difficulty for children with and without SLI. Similar research into word comprehension has not been conducted. Given that word recognition and picture naming depend on the same semantic representations and the same levels of processing, it would be worthwhile to examine the contribution of semantic processing to word recognition by children with and without SLI. If a child with SLI is slower to recognize or does not recognize a spoken word, it could be due to weak connections between the lexical level and the relevant feature nodes at the semantic level. Although it is possible that there are weak connections at all levels of lexical processing in SLI (phonological to lexical and lexical to semantic), weak connections between the lexical and semantic levels could lead to underactivation of the phonological form of the word, given the interactive nature of lexical processing (rather than weak connections between the lexical and phonological level, per se).
1.3.7 Summary of deficits in children with SLI

This section began with a brief description of SLI, with a particular focus on the lexical deficits these children experience. Four possible explanations for their lexical deficits were reviewed: auditory-perceptual impairments, processing capacity limitations, underspecified lexical-phonological representations and limited semantic representations. Two studies that examined the way children with SLI recognize spoken words were reviewed. These studies demonstrate that children with SLI recognize highly familiar words as readily as age-matched and vocabulary-matched typically developing children; however, questions regarding the ability of children with SLI to recognize less familiar words, relative to age-matched peers, remain. Difficulty in recognizing less familiar words could stem from auditory-perceptual difficulties, processing speed limitations, and/or limited semantic and phonological representations. In the next section, I will describe how the current study attempts to address these outstanding questions.

1.4 The present project

It is clear that lexical characteristics (such as AOA and neighbourhood density) affect word recognition by children and adults. Their effect on word recognition by children with SLI is less clear. The results of both Dollaghan (1998) and Montgomery (1999) suggest that children with SLI recognize highly familiar\(^6\) words as quickly as their peers (age and vocabulary comprehension matched) and that children with SLI are slower to recognize newly learnt words (than age-matched peers). We do not know if children with SLI have more difficulty recognizing ‘hard’ words (late AOA and/or from dense neighbourhoods) compared to typically developing children at the same level of vocabulary development. It is likely that weak connections between levels of representation would lead to differences in the

\(^6\) Familiarity encompasses both word frequency and age of acquisition.
ease of word recognition when processing demands are increased (i.e., between easy and hard words). Results of studies employing the lexical decision task with children with SLI suggest that their lexical-phonological representations are underspecified. On the other hand, the gating studies that have examined recognition of highly familiar words by children with SLI find no difference from their typically developing peers. This raises several questions: Do children with SLI have underspecified phonological representations of words (i.e., weak connections between lexical and phonological nodes)? Or does limited semantic knowledge contribute to difficulty recognizing ‘hard’ words? Finally, do general processing limitations or deficits in auditory perception or phonological memory lead to word recognition difficulty in specific language impairment?

The current project examined spoken word recognition by children with and without specific language impairment, using the gating paradigm. The effect of lexical characteristics (AOA and ND) on spoken word recognition were examined. In addition, the relationship between spoken word recognition and the quality of participants’ semantic representations and their phonological processing abilities was considered by examining correlations between the gating task, a picture-word matching task, and a nonsense word repetition task. Results from this study will increase our understanding about the underlying deficits in lexical access in children with SLI. In the following pages, I present the research questions that the current study set out to address.

1.5 Research questions and predictions

1. Do children with SLI need more of the acoustic-phonetic signal to recognize spoken words than receptive vocabulary (RV) matched controls? If so, this suggests that their lexical-phonological and/or lexical-semantic representations are less specified than RV
matched controls' representations. In connectionist terms, this means that the children with SLI have weaker connections between the units at the phonological, lexical and/or semantic levels for the words in their lexicon.

2. Are children in both groups slower to recognize later-acquired words compared to early-acquired words? When neighbourhood density is held constant, I predict that children with SLI and their RV matched controls will require more of the acoustic-phonetic signal to recognize late-acquired words compared to early-acquired words. This is because the children have had more opportunity to hear words learned early than words recently acquired (all other factors held equal), and therefore, early-acquired words have developed stronger connections between the lexical and phonological levels and between the semantic and lexical levels. Unlike past gating studies with children with SLI, the words used in this study will include both highly familiar and less familiar words.

3. Does neighbourhood density affect word recognition by children with SLI and RV-matched typically developing children? I predict that there will be a main effect of neighbourhood density such that participants will recognize words from sparse neighbourhoods more quickly than words from dense neighbourhoods. These findings will provide further support for the neighbourhood activation model (Luce & Pisoni, 1998) and further evidence that neighbourhood density also affects spoken word recognition by children. Previous research has not explored the effect of neighbourhood density on lexical access in children with Specific Language Impairment and this study will address this issue.

4. Compared to RV-matched controls, do children with SLI require more of the acoustic signal to recognize later acquired words? Receptive vocabulary level will be held constant by comparing children with SLI and their receptive vocabulary matched peers. If
children with SLI perform more poorly in a word recognition task on later-acquired words, then this would suggest that their lexical-phonological representations of late-acquired words are underspecified (i.e., weak connection strengths between the lexical node and phonological units). One possible reason could be that children with SLI put more resources into learning the meaning of new words and less into the phonological representations such that for more recently learned words they know the meaning but have less detailed phonological representations. In other words, children with SLI have weaker connections between the lexical level and the phonological level than typically developing children. This could be due to general resource limitations in SLI as discussed above (see also Dollaghan, 1998 and Leonard, 1998). Alternatively, weak connections at the semantic level could lead to difficulties in recognizing late-acquired words, given the interactive nature of the system.

By contrast, for early-acquired words, I predict there will be no group difference in performance. That is, participants with SLI and RV matched participants will require similar amounts of the acoustic-phonetic signal to recognize early-acquired words. This result will replicate the results of Dollaghan (1998) and Montgomery (1999) and provide evidence that when processing demands are low (i.e., with more familiar words), the children with SLI can activate their lexical-phonological representations of words. However, even recently acquired words could have weaker connection strengths in children with SLI than typically developing children, leading to difficulty in activating these lexical items.

5. Do children with SLI require more of the acoustic signal to recognize words from dense neighbourhoods compared to RV matched controls? If there is greater competition between words in dense neighbourhoods, and if children with SLI have weaker connections between levels, then they will take longer to resolve the competition between
lexical items, and therefore, take longer to recognize words from dense neighbourhoods compared to RV matched controls.

6. **Do the effects of neighbourhood density interact with the effects of age-of-acquisition?** Given the results of past research on school-age children (Garlock et al., 2001), I predict no interaction such that ND will affect recognition of both early and late words, with sparse being easier for both.

7. **Does neighbourhood density affect word recognition of late- versus early-acquired words differently for children with SLI and RV matched controls?** I predict that neighbourhood density will have an impact on word recognition for the RV group for both later-acquired and earlier-acquired words such that less input is needed to recognize words from sparse neighbourhoods compared to words from dense neighbourhoods, and less input is needed to recognize early words compared to late words. For the children with SLI, on the other hand, I predict that there will be an effect of neighbourhood density only for the early-acquired words. Like the control group, early-acquired words from sparse neighbourhoods will be recognized more quickly than early-acquired words from dense neighbourhoods. However, late-acquired words from sparse neighbourhoods will be recognized with the same amount of input as late-acquired words from dense neighbourhoods. If children with SLI recognize later acquired words from sparse neighbourhoods as slowly as they do from dense neighbourhoods, this would suggest that they are experiencing as much competition in the sparse condition as they are in the dense condition. What would cause this competition? If the children’s connections to the phonological representations of later acquired target words were weaker, then a less specified form would be activated and each word would have a larger number of neighbours than if it
had normal connection strength. As a result, there would be greater competition during a speech perception/word recognition task. Therefore, any differences in speed of recognition for words from sparse neighbourhoods compared with dense neighbourhoods (for late AOA words) would be minimal because all words would have large neighbourhoods.

Alternatively, for late-acquired words, those from dense neighbourhoods might be recognized as quickly as those from sparse because of phonotactic facilitation in the dense neighbourhoods. It is possible that individuals process recently-learnt words in a similar way to nonsense words and low frequency words, where the facilitatory effects of phonotactic probability outweigh competition at the lexical level.

8. Do limited semantic representations and/or phonological memory limitations contribute to slower word recognition? In an interactive lexical system, weak connections at one level (e.g., between the semantic and the lexical level) will affect activation at other levels (e.g., the phonological level). It is possible that the semantic representations of the words that children recognize more slowly are less detailed than the semantic representations of the words that are recognized more quickly. If so, sparse semantic representations (or difficulty accessing all relevant semantic features due to weak connections) could be contributing to spoken word recognition difficulty, and this could be evidenced by correlations between performance on a picture-word matching task (where children must discriminate between items that are semantically very similar) and the spoken word recognition task.

Alternatively, primary deficits at the phonological level (in encoding and storing phonological information) in children with SLI could lead to difficulties in spoken word recognition. Nonword repetition tasks (such as Gathercole and Baddeley, 1998) have been
used extensively to measure the capacity of an individual’s phonological short-term memory store (or phonological loop). It is possible that limits in the phonological loop lead to impoverished phonological representations of words (weak connections) and contribute to difficulty recognizing spoken words. This would be evidenced by a correlation between results from the nonword task and the gating task.
2 Method

2.1 Overview

This chapter discusses the methods used in conducting the experiment, which involved three tasks: a gating task, a picture pointing task and a nonword repetition task. The first section will present a description of the participants, followed by sections describing the experimental stimuli, tasks and procedures.

2.2 Participants

Seventeen English speaking children between the ages of 6;4 (76 months) and 10;10 (130 months) were included in this study ($M = 100.4$ months, SD = 16.9). Nine were typically developing and 8 had specific language impairment; the two groups were matched for receptive vocabulary level. An additional eight children were tested but were not included in the analysis because they failed to meet inclusion criteria. All children were attending schools in three school districts in British Columbia: Vancouver, Surrey and Salmon Arm. The eight children with specific language impairment (SLI) ranged in age from 100 months (8 years, 4 months) to 130 months (10 years, 10 months) ($M = 114.88$, SD = 9.78). The nine normally developing children in the receptive vocabulary matched group (RV) ranged in age from 76 months (6 years, 4 months) to 107 months (8 years, 11 months) ($M = 87.56$ months, SD = 9.62).

The children with SLI were compared with vocabulary-matched typically developing children in the current study because past research has shown that vocabulary size impacts spoken word recognition (Garlock, Walley & Metsala, 2001; Metsala, 1997a). In order to reveal any deficits that are due to language impairment rather than language level (in this case vocabulary size) it was necessary to hold vocabulary comprehension level constant.
between the two groups. Thus, the two groups were matched for mean receptive vocabulary level as indicated by their raw score on the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1981). PPVT raw scores for the SLI group ranged from 74 to 122 (M = 104.5, SD = 18.29). Half of the SLI group’s PPVT standard scores were more than 1 standard deviation below the mean (below normal limits), and the other half were 1 standard deviation below the mean or higher (within normal limits). All control subjects performed within the normal range (1 SD below the mean or higher) on the PPVT, with raw scores ranging from 71 to 131 (M = 106.0, SD = 19.98). There was no significant group difference in PPVT score, t(15) = - .170, p = .867. The RV group included 7 boys and 2 girls, and the SLI group included 7 boys and 1 girl.

Hearing ability of all participants was tested with a portable screening audiometer at 20 dB HL at 1000, 2000 and 4000 Hz and at 25 dB at 500 Hz. All but two participants had normal-range hearing sensitivity (ANSI, 1989). Of the two participants who failed the hearing screening, one had a mild high frequency hearing loss in the left ear (above 2000 Hz) and the other failed the screening in one ear at 500 Hz. Both participants were included because they were able to complete the experimental tasks satisfactorily and stimuli were presented binaurally. Participants received the hearing screening during the second session with the gating task. Due to time constraints and technical malfunctions, a small number of participants received the hearing screening during the first or third session, which occurred within two weeks of the second session.

To be included in this study, all children were required to obtain nonverbal IQ scores of 85 (1 SD below the mean) or higher on the Test of Nonverbal Intelligence7 (TONI)

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7 Most participants completed version A of the TONI. Two completed version B more than one week after having completed version A because the results from version A were considered unreliable – the TONI was
(Brown, Sherbenou & Johnsen, 1997); SLI (\(M = 93.75, SD = 3.54\)), RV (\(M = 98.22, SD = 7.97\)). There was no significant group difference on TONI scores, \(t(11) = -1.524, p = .155\).

Participants had no oral structural or motor impairments that would affect speech or nonspeech movements of the articulators\(^8\) and had articulation abilities within the normal range for their chronological age. Articulation was screened using the Computerized Articulation and Phonology Examination System (CAPES; Masterson & Bernhardt, 2001), a non-standardized phonology and articulation test).\(^9\) All children had normal or corrected vision. Parent report confirmed that all children were monolingual native English speakers, with limited exposure to other languages and had no history of frank neurological impairment or psychological/emotional disturbance.\(^10\)

A positive relationship between level of maternal education and speech and language skills of 3-year-olds was found by Dollaghan et al. (1999). Thus, we collected data on maternal education, measured in number of years (e.g., high school completion = 12, bachelor’s degree = 16). Data was unavailable for one SLI child.\(^11\) A small but significant group difference in level of maternal education was found for the 16 children for which there was data, SLI (\(M = 12.86, SD = 1.07\)), RV (\(M = 14.67, SD = 2.00\)), \(t(14) = -2.155, p = .049\).

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\(^8\) One SLI participant had a history of a cleft soft palate, which was successfully repaired before 12 months of age and did not affect his speech at the time of the study.

\(^9\) Several children in the SLI and RV groups had frontal lisps.

\(^10\) One child in the SLI group was diagnosed with attention deficit disorder at a young age (4 years) but was never medicated and the parents reported that he had improved significantly since the time of diagnosis.

\(^11\) Parents were asked for the highest level of education attained by the child’s mother. Most responded with ‘high school’ or ‘bachelor’s degree” and were easily translated into a numerical value. Several responses were difficult to categorize in terms of years of education (i.e., “college” or “two college diplomas”). A value of 14 years was given to these responses since they have more than high school but less than a full bachelor’s education.
2.2.1 Language criteria: CELF - 4

The children with SLI were recruited through speech language pathologists, communication class teachers and principals from the involved school districts. All SLI participants were receiving treatment or were on a waitlist for treatment, or had received it in the past. Scores on the Clinical Evaluation of Language Fundamentals – Fourth Edition (CELF-4) (Semel, Wiig & Secord, 2003) were used to discriminate between the SLI and RV groups. All participants completed an expressive subtest (Recalling Sentences) and one or two receptive subtests (Concepts and Following Directions and Understanding Spoken Paragraphs) from the CELF-4. Both subtests were administered to all children. To be included, participants with SLI had to score at least 1.5 SD or more below the mean (a scaled score of 6 or less) on the expressive subtest of the CELF-4 and on at least one of the two receptive subtests. All control participants obtained a score above the mean (a scaled score of nine or higher) on both subtests. Table 1 outlines the language and cognitive test scores for the two groups.

Table 1. Mean (SD) scores for language and cognitive testing for the SLI and RV group

<table>
<thead>
<tr>
<th></th>
<th>Age in months M, (SD)</th>
<th>Maternal Education Level, M (SD)</th>
<th>CELF-4 Recalling Sentences M, (SD)</th>
<th>CELF-4 Concepts and Following Directions M, (SD)</th>
<th>PPVT M, (SD)</th>
<th>TONI M, (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Language Impairment</td>
<td>114.88* (9.78)</td>
<td>12.86* (1.07)</td>
<td>3.5* (2.20)</td>
<td>4.50* (3.82)</td>
<td>104.5 (18.29)</td>
<td>93.75 (3.54)</td>
</tr>
<tr>
<td>Receptive Vocabulary Match</td>
<td>87.56 (9.62)</td>
<td>14.67 (2.00)</td>
<td>11.22 (1.48)</td>
<td>11.89 (2.26)</td>
<td>106.0 (17.98)</td>
<td>98.22 (7.97)</td>
</tr>
</tbody>
</table>

Note. * = p < .05 (all comparisons are between groups)

As expected, t-tests indicated a significant difference in expressive language scores and receptive language scores between the two groups on the CELF-4 subtests (Recalling
Sentences subtest $t(15) = -8.572, p < .05$, Concepts and Following Directions subtest $t(15) = -4.927, p < .05$.

2.3 Experimental tasks

All children completed three experimental tasks: 1) a gating task, as a measure of lexical access, 2) a picture pointing task, as a measure of semantic representation, and 3) a nonsense word (or nonword) repetition task, as a measure of phonological short-term memory. All children completed the gating task in their second session and the semantic and nonword repetition tasks in the third session. The gating task and the nonword repetition task were presented using E-Prime software (Schneider, Eschman & Zuccolotto, 2002a, 2002b) on a laptop computer (Hewlett Packard Pavilion N5270 Notebook, Dell Notebook or Toshiba Satellite 2450). All auditory information was presented using headphones (either JVC HA-G33 or Maxell HP2000) at a loudness level each participant considered comfortable.

2.3.1 Gating task

Grosjean (1980) introduced the forward gating task as a means of exposing the automatic, real-time processes that take place during word recognition. For this reason, the task is well suited to explorations of the effects of lexical characteristics on processing in the word recognition network. In the gating task, the listener hears successive increments (or gates) of an acoustic signal of a word, starting with the onset, until the whole word has been presented. After each gate, listeners guess what the target word is and also rate how confident they feel about their response. Responses reflect the lexical items that were activated by the acoustic input (i.e., members of the target word’s neighbourhood). For example, a listener might hear /bi/ on an early gate and guess any word that shares the same onset such as beet, beak, bead, beef, etc.
The gating task is not a true on-line task as the amount of acoustic input is controlled by the examiner and there is no response deadline for the listener. However, this is precisely what makes the task well suited to the study of spoken word recognition by young children (Walley, Michela, & Wood, 1995). Children can respond at their own pace and do not need to have higher metalinguistic abilities such as phonological awareness. The potential limitation of the gating task is that it may introduce word search strategies that do not accurately reflect normal spoken word recognition. For example, if a listener does not immediately think of a word after presentation of a gate, then in order to answer he must consciously try to categorize the acoustic information he heard and then come up with a word that begins with the same phoneme(s).

Researchers have used different dependent variables in the gating task to measure lexical access. The most commonly used dependent variable is the Isolation Point (IP), which is the “size of the segment (measured in milliseconds or % of stimulus [or number of gates] needed to identify the stimulus (without any change in response thereafter)” (Grosjean, 1996, p.598). The IP reflects the point at which the listener has discriminated the target from competing words with no subsequent change. Confidence is typically low at the isolation point. Responses from the confidence rating are used to define the second common variable, which is the Total Acceptance Point (TAP), or point at which the listener has confidently identified the correct word. Studies vary in how strict a criterion they use to define the TAP: some have demanded a perfect confidence rating while others just require a score above the median (Grosjean, 1996). A third variable was used by Dollaghan (1998), who measured participant responses in terms of an Activation Point (AP). She defined the AP as the first gate at which the target word is correctly named even if the participant subsequently changes...
to an incorrect guess. Another popular measurement point is the Phoneme Identification
Point (PIP), which is the first gate at which the participant identifies the word-initial
phoneme of the target, by guessing another word (or nonword) that begins with the same
phoneme as the target (Montgomery, 1999). The PIP provides information about word-initial
phoneme perception, and speaks more to the auditory-perceptual aspect of lexical access.
Finally, some studies have also measured the point at which the target word is recognized
(with a certain confidence level) and have called this the ‘recognition point’; however
researchers disagree as to whether or not this point truly reflects a word’s actual recognition
point (Grosjean, 1996).

In the current project four dependent variables were examined: first, the PIP was
measured because it provides information about phoneme perception and insight into the
lower-level auditory perceptual abilities of participants (e.g., listening to a little bit of
acoustic information and discriminating and identifying the initial phoneme). This measure
also provides additional evidence about phoneme perception in SLI given conflicting
phoneme identification results in past gating studies with this population. Second, the IP was
calculated in order to compare the results of this study with previous research (Montgomery,
1999; Garlock et al., 2001; Metsala, 1997a, 1997b). Third, the TAP was calculated because it
represents the most conservative estimate of word recognition and also for the purposes of
comparison with past research. Fourth, the AP was measured in order to facilitate direct
comparisons with Dollaghan (1998), and in contrast to the TAP, the AP is a more generous
estimate of lexical access, providing an estimate of the amount of time required to contact the
target in the lexicon, regardless of subsequent guesses or confidence ratings which may
reflect task variables or more conscious processing.
2.3.1.1 Stimuli description

The stimuli used in the gating task comprised 28\textsuperscript{12} monosyllabic nouns (see Appendix A) chosen from lists of words for which neighbourhood density measures based on a child’s lexicon were available (Garlock, Walley & Metsala, 2001 and Metsala, 1997a). The words were chosen to vary on two major dimensions: age of acquisition, or AOA (early-acquired versus later-acquired), and neighbourhood density, or ND (sparse versus dense). When stimuli were chosen there were seven words in each condition. Due to incorrect age of acquisition information, one word\textsuperscript{13} was moved to a different category, resulting in an unequal number of words in each category (early/sparse \( N = 8 \), early/dense \( N = 7 \), late/sparse \( N = 6 \), and late/dense \( N = 7 \)). Subjective AOA ratings were available from previous research (Metsala, 1997a). Fifteen of the words were considered “early” and had subjective age of acquisition ratings of 2.81 or less on a 9-point scale (Carroll & White, 1973), where 1 means acquired at 0-2 years, 2 by age 3, and 3 by age 4. The words in the early category are therefore typically acquired before age four. There were 13 “late” words, which are typically acquired between the ages of approximately 4;11 and 6;8, as indicated by a subjective AOA ratings of 3.94 to 5.63 on the same scale. Words from this range of AOA ratings were used so that the effect of age-of-acquisition could be explored and yet all words would be in the receptive lexicons of children participating in the study.

Neighbourhood density measures based on a child’s lexicon were available from two previously published studies (Garlock et al., 2001 and Metsala, 1997a). Fourteen of the

\textsuperscript{12} Initially, there were 32 stimuli, 8 per condition. 4 (1 per condition) were ultimately discarded due to difficulty finding an adequate image for the semantic task or due to poor audio recordings for the gating task.

\textsuperscript{13} The stimuli was ‘sky’ and it was moved from the late AOA/sparse neighbourhood group to early AOA/sparse neighbourhood group.
words were from sparse neighbourhoods (3-9 neighbours, $M = 6.5$) and 14 were from dense
neighbourhoods (11-22 neighbours; $M = 14.7$).

Word frequency was based on Kucera and Francis (1967), which is an adult count
from a written corpus of American English. Frequency values ranged from 1-103$^{14}$, where
values of 70 or higher indicate high frequency. Words with extremely high frequency values
(e.g. over 150) were excluded. The four lists were constructed with an attempt to control the
average frequency of the stimuli in each condition; however, this was not possible in the end.
The words in both early conditions (early/sparse and early/dense) had higher mean frequency
values. This is not surprising given that common words are learned early; AOA and word
frequency both contribute to word familiarity and are correlated (Carroll & White, 1973).
The average frequency of the words in each condition was as follows: early/sparse, $M =
55.75$, $SD = 35.15$; early/dense, $M = 31.43$, $SD = 38.57$, late/sparse, $M = 10.67$, $SD = 16.84$
and late/dense, $M = 19.14$, $SD = 28.84$. T-tests indicated a significant difference in frequency
between early and late words $t(24) = 2.494$, $p < .05$ but no significant difference in frequency
between sparse and dense words $t(26) = .847$, $p = .405$. These results indicate that AOA is
confounded with word frequency.

Words were chosen so that the place and manner of articulation of word-initial
consonants was balanced in each condition as much as possible. In the final list, 4
early/sparse words began with continuants and 4 with non-continuants, 4 early/dense words
began with continuants and 3 with non-continuants, 2 late/sparse words began with
continuants and 4 with non-continuants and 6 late/dense words began with continuants and 1
with a non-continuant. In word-final position, early/sparse had 4 continuants and 4 non-

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$^{14}$ These values represent occurrences per million words. The number of high frequency words in each condition
is as follows: early/sparse = 4/8, early/dense = 2/7, late/sparse = 0/6, late/dense = 1/7.
continuants, early/dense words had 4 continuants and 3 non-continuants, late/sparse words had 5 continuants and 1 non-continuant, and late/dense words had 2 continuants and 5 non-continuants. Table 2 lists AOA, frequency, neighbourhood density and duration values for the stimuli in the four conditions.

Table 2. Mean (SD) values for AOA, ND, frequency and duration for the four conditions.

<table>
<thead>
<tr>
<th>Age of Acquisition</th>
<th>Neighbourhood Density</th>
<th>Number of Neighbours M (SD)</th>
<th>AOA M (SD)</th>
<th>Duration of word (ms.) M (SD)</th>
<th>Frequency M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Sparse</td>
<td></td>
<td>6.25</td>
<td>2.13 (0.43)</td>
<td>464.88 (77.01)</td>
<td>55.75 (35.15)</td>
</tr>
<tr>
<td>Early Dense</td>
<td></td>
<td>16.0</td>
<td>2.59 (0.60)</td>
<td>459.43 (63.60)</td>
<td>31.43 (38.57)</td>
</tr>
<tr>
<td>Late Sparse</td>
<td></td>
<td>6.17</td>
<td>4.64 (0.62)</td>
<td>464.67 (19.19)</td>
<td>10.67 (16.84)</td>
</tr>
<tr>
<td>Late Dense</td>
<td></td>
<td>14.0</td>
<td>4.58 (0.55)</td>
<td>460.00 (65.83)</td>
<td>19.14 (28.84)</td>
</tr>
</tbody>
</table>

All words were fairly imageable given that they needed to be represented in picture format for the semantic task; however, imageability ratings for each word are not known.

2.3.1.2 Stimuli preparation

2.3.1.3 Recording the stimuli

The stimulus words were recorded by an adult female native speaker of English (not the experimenter) in the carrier phrase “I will say the word ______ now.” The speaker used natural prosody and spoke at a normal volume and rate. The stimuli were recorded using Cool Edit 2000 software (2000) in .wav format using a sampling rate of 44,100 Hz. The recordings were made in a double-walled, sound attenuating booth, using a Creative low-impedance microphone positioned about four inches from the speaker’s mouth. Stimuli were recorded directly onto the hard drive of a Toshiba Satellite 2450 computer.

15 If the target word had a word-final /n/, the same as the word-initial sound in ‘now,’ then the word ‘today’ was used instead of ‘now’. This procedure was used so that the stimulus words would be easily separable from the preceding and following words in the phrase.
Several tokens of each stimulus word were recorded to ensure that a clear token with minimal effects of co-articulation was captured. The experimenter gave the speaker feedback about her rate so that words with 2 nonstops (affricates, fricatives, nasals, liquids and glides) had the longest acoustic duration (around 540 ms), words with one stop and one nonstop had a shorter acoustic duration (around 450 ms) and words with two stops had the shortest duration (around 370 ms). These durations are in-line with similar words from previous studies (see Montgomery 1999). T-tests indicated that there was no significant difference in duration between early and late AOA words $t(26) = .008, p = .994$, nor between sparse and dense words $t(26) = .224, p = .825$. See Table 2 for the mean duration of words in each condition.

2.3.1.4 Editing the stimuli

The recordings were edited in the Cool Edit 2000 (2000) computer software program to delete the carrier phrase and isolate the target word. Deletions were made at zero crossings at points judged by the experimenter to contain the entire target word. The auditory stimulus and the visual representation of the waveform were used to make decisions regarding deletion points.

The experimenter listened to the isolated tokens of each word and chose the token that had no audible clicks or artifacts from the recording process and that approximated the target length for the type of word (stop/nonstop).\footnote{One word, bun, was judged to have an unusually long coda and so the last 160 ms of the word were faded out.} Next, each word was normalized for peak amplitude using the normalize function in Cool Edit (2000). Most words were normalized to 90 percent of their peak amplitude. The waveforms of each word were visually and auditorally examined by the experimenter to make sure that they had similar amplitudes, and
those that were judged to have smaller amplitudes (that were quieter) were normalized higher (up to 99 percent of their peak amplitude) so that all stimuli were subjectively judged by the experimenter to be of similar loudness, based on both the auditory stimulus and the visual representation of the waveform.

2.3.1.5 Subjective judgments of the stimuli

To ensure that the recordings were sufficiently intelligible to be included as experimental stimuli, three naïve adult listeners listened to the isolated words and wrote down or repeated what they heard. The words were presented through headphones in a quiet room. Recordings were included in the experiment if the word was correctly identified by two out of three listeners.17

2.3.1.6 Preparation of the gates

The next stage of stimulus preparation was gating. Each stimulus item was individually edited into gates using Cool Edit (2000), so that the first gate was 120 milliseconds, and each gate thereafter increased incrementally in duration by 50 ms (e.g., gate 1 = first 120 ms of the word, gate 2 = first 170 ms of the word, gate 3 = first 220 ms of the word, etc.). The cut point for each gate was the nearest zero crossing using the visual representation of the waveform in order to avoid audible clicks. As a result, each gate is the target duration +/- 1 millisecond. Most words had durations that were not evenly divisible by 50 ms. If the difference between the duration of the last gate and the entire waveform was 25 ms or less (half the length of a gate or less) then the final gate was not used and the total duration was used instead (the resulting gate is up to 75 ms longer than the preceding gate). If the difference between the duration of the last gate and the entire waveform was between 26

17 Twenty-three out of twenty-eight words were correctly identified by all three listeners and the remaining five words were correctly identified by two out of three listeners.
and 50 ms then a final gate was created (the resulting final gate would be 26-50 ms longer than the second to last gate). Words ranged in duration from 359 ms to 580 ms. The mean duration was 462.25 ms. The number of gates per word ranged from 6 to 10. The mean number of gates was 7.78

Each gate was saved as an individual sound file on the computer hard drive. CD ROMs and floppy disks were used to transfer the files onto the hard drives of the laptop computers used to present the task. The 28 words were arranged into a fixed random order using a random numbers table with the following conditions: no more than two consecutive stimuli from the same condition, and no two consecutive stimuli with the same word-initial onset.

2.3.1.7 Gating task procedure

In this task children listened to a series of trials of gated words, with increasing amounts of acoustic information from word onset. After each gate, children were asked to guess “what word they thought it might be.” On each trial, listeners also rated how confident they felt about their guess on a 7-point scale. The scale had the numbers 1-7, with a sad face with question marks above the number 1 and the word “guessing,” a face with a straight mouth and the words “not too sure” above the 4 and a happy face with a light bulb above the 7 and the words “very sure.” Appendix B contains the full participant instructions and has a copy of the confidence scale in a reduced size. Participants either pointed to a number on the scale or said their rating aloud. The examiner wrote down participant responses and confidence ratings on paper and controlled the presentation of gates on the computer by pressing the space bar. Before the first gate of each new word, the children heard an alerting phrase, “Here comes the next word,” in the same voice as the stimuli. Prior to beginning the
task, one demonstration trial was completed by the experimenter to model the task, using the word *watch*, and the children completed three practice trials (*bead*, *fuzz* and *base*). If, during the practice trials, a child was slow to respond or responded with many nonsense words, the practice trials were repeated until the child appeared comfortable with the task.

The task consisted of 28 test words and a total of 218 gates.\(^\text{18}\) Children were given a short break after completing the practice trials and the first 14 words (half the way through the experimental trials). If a child did not respond to a gate within approximately five seconds, the examiner encouraged the child to respond by asking, “what was the first word that popped into your head?” If a child responded with a nonsense word on any gate, he was asked to guess a real word. If the examiner was unsure as to what word the participant said, she asked the child to use the word in a sentence, or explain what the word meant. Participant responses were transcribed orthographically and also audiotaped for the purposes of reliability analysis.

### 2.3.1.8 Scoring the gating task

After testing, participants’ responses were analysed and four points were identified: word-initial phoneme identification, the activation, the isolation, and the total acceptance points. Overall accuracy was also measured as the total number of words each participant identified correctly on the last gate.

If a participant identified the correct target, but did not reach a high confidence rating on the final gate, the target’s total duration plus 50 ms (one gate) was used for the TAP score on that word. If a participant did not identify the correct word on the final gate, the target’s total duration plus 50 ms was used for the IP and AP scores and the total duration plus 100

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\(^{18}\) One participant in the SLI group completed gating trials for 4 extra stimuli, to total 32 words. It was decided after this child’s participation to remove 4 words from the gating task.
ms (two gates) for the TAP score on that word. If a participant had not guessed a word with the same initial phoneme as the target by the final gate, the word’s total duration plus 50 ms was used for the PIP. These procedures are in keeping with past gating research with adults and children (e.g., Montgomery, 1999; Dollaghan, 1998; Garlock et al., 2001). Finally, all scores were converted to percentages of a target’s total duration to correct for differences in length across words.

Two examiners administered the standardized and experimental tasks; each participant saw the same examiner in all three sessions. Each examiner scored the gating results of the individuals to whom they administered the task. The audiotapes were used to clarify any confusion in scoring and also for the purposes of reliability analysis. Twenty percent of each participant’s responses (about five to six words per participant) were transcribed and scored by the other examiner. The percentage agreement between examiners was 91%, [kappa] = .90 and was statistically significant at p < .001.

2.3.2 Semantic task

In order to examine the possible contribution of the participants’ semantic representations of the words used in the gating task to their performance in the gating task, participants completed a second picture-pointing task, similar to the Peabody Picture Vocabulary test (the same 28 words from the gating task were tested in the semantic task). Participants were presented with four black-and-white pictures in random order on a single page. Their task was to point to the picture of the item named by the experimenter. The three distractors on each page had either a close semantic relationship to the target in the first condition, or a distant semantic relation to the target in the second condition. Each condition

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19 Both examiners were present in the first session for five (out of seventeen) participants.
was completed in a separate part of the experiment. The participant’s performance on the first part determined which trials she or he would complete in the second part.

In the first part, the distractors had a close semantic relationship to the target (e.g., target: *vine*, foils: *flower, tree, shrub*). Correct performance on this task was taken as evidence of a relatively detailed semantic representation of the target word. Specific trials in second part of the task were administered depending on whether the participant was correct in the first part. If the participant was correct in the first condition, he was immediately asked “do you see another [target]?” in the same array of pictures. The purpose of this question was to determine if he believed any other pictures displayed correspond to the same word; if so, then this was taken as evidence that the semantic representation of the target item is detailed but insufficient to discriminate it from competitors. After completing all items in the close condition (and the ‘another’ question for indicated items), the participant completed the second part of the task, the ‘distant’ condition. For any item for which the participant was incorrect in the first condition, the same items were presented, this time with distractors that were semantically unrelated to the target (e.g., target: *vine*, foils: *button, jar and stool*). Again, the participant was asked to “point to [target].” Successful performance in the second condition of the picture pointing task confirmed that the words in the gating task were in fact in participants’ comprehension vocabularies (as a double check on the words used in the gating task) and constituted evidence of a less elaborate semantic representation for a given word.

2.3.2.1 Stimuli description

The stimuli in the semantic representation task were black and white line drawings similar to the Snodgrass and Vanderwart set (Snodgrass & Vanderwart, 1980). A total of 193
pictures were used (28 targets and 165 distractors):\(^{20}\) 81 (6 targets and 75 distractors) of the 193 pictures were from the Snodgrass Vanderwart set, developed by Rossion and Portois (2001),\(^{21}\) 36 (3 targets and 33 distractors) were from the International Picture Naming Project (IPNP), developed by Szekely et al. (2004),\(^{22}\) and 76 pictures (19 targets and 57 distractors) were hand-drawn from models found on the internet to increase clarity or were from other published sources.\(^{23}\) The Rossion and Portois pictures and some of the hand-drawn pictures were black and white line drawings with texture. The Szekely pictures and some of the hand-drawn pictures were black-and-white line drawings without texture. Appendix C provides a complete set of the picture stimuli used in the semantic task. No picture used as a target was also used as a distractor. The same picture of a target was used in both the close and distant semantic conditions for each target. Given that participants would consider between 112 and 224 pictures, and that all the trials in the close condition were completed prior to those indicated for the distant condition, I was not concerned that participants would recognize the targets thereby overestimating their semantic knowledge.

2.3.2.2 Distractors – Close condition

Semantic distractors were chosen for each target word in the close condition in the following manner. First, the experimenter used her intuition and formulated a list of related words for each target. Next, lists of free association targets compiled through research with

\(^{20}\) Three distractors per target totals 168 distractors; however, 3 items were used twice each. The distractor “dress” was used for two targets: lace and suit, both in the close condition; the distractor “hand” was used for two targets: foot and mitt, both in the close condition; and the distractor “flower” was used for two targets: vine and weed in the close condition.

\(^{21}\) These images were provided courtesy of Michael J. Tarr (Brown University, Providence, RI). Downloaded from http://www.cog.brown.edu/~tarr/stimuli.html.

\(^{22}\) These images were provided courtesy of the Center for Research in Language at the University of California, San Diego. Downloaded from http://crl.ucsd.edu/~aszekely/ipnp.

\(^{23}\) These pictures were copied from Webber Articulation Cards (1998) published by Super Duper Publications and from Taylor, M.L. & Marks, M.M Aphasia Rehabilitation Manual and Therapy Kit published by McGraw Hill.
adults were used to increase the number of related words for each target (Nelson, McEvoy & Schreiber, 1998). Types of words that were considered for each target were: items from the same category (e.g., target: teeth, distractor: lips, both are parts of the mouth), items that are highly associated (e.g., target: dog, distractor: cat), items that perform a similar function (e.g., target: wick, distractors: light bulb filament, fuse on sticks of dynamite), superordinate relations (e.g., target: suit, distractor: clothes) and part/whole relations (e.g., target: foot, distractor: toes). Synonyms were excluded. From this list, the top three distractors were chosen based on imageability (given that pictures were needed to represent each item) and based on the experimenter’s intuition as to which items had the closest semantic relationship to the each target.

Finally, the semantic distance between each target and its distractors was estimated using WordNet, an electronic dictionary (Maki, McKinley & Thompson, 2004). All target words were listed in the dictionary, and most of the distractors on the list were present for their respective targets. The results of this examination suggested that there is a close semantic relationship between the target words and the chosen distractors, and thereby validated the experimenter’s approach to selecting close semantic distractors. See Appendix D for a list of sample target words, their distractors and the semantic distance between them, as measured by WordNet. Once semantic distractors were chosen for each target item, pictures of each were located.

24 Free association responses were provided courtesy of Nelson, McEvoy & Schreiber, 1998 and were downloaded from http://w3.usf.edu/FreeAssociation.  
25 Semantic distance norms were provided courtesy of the Cognitive Science Laboratory at Princeton University under the direction of professor George A. Miller. Downloaded from ftp://ftp.ttu.edu/pub/maki.
2.3.2.3 Distractors – Distant condition

Three distractors were chosen for each target in the following manner. For target words with early AOA, all distractors had a similar AOA rating of 2.69 or less (Gilhooly & Logie, 1980) or 30 months or less (Dale & Fenson, 1996). For late AOA target words, distractors had an AOA rating of 3.00 or higher (Gilhooly & Logie, 1980). Distractors were matched to target items so that they had a similar frequency value, were not semantically related in any obvious way, and did not bear any visual similarity to the target. Furthermore, distractors for which normed pictures were available (i.e., from the Rossion & Portois collection or the Szekely et al. collection) were primarily used in this condition.

2.3.2.4 Stimuli presentation

Pictures were enlarged or reduced so that their relative size was appropriate, as judged subjectively by the examiner and by one adult volunteer. Pictures were presented on a 8 \( \frac{1}{2} \)" by 11" piece of white paper in the landscape orientation. The paper was divided into four equal parts to form a two-by-two grid using two intersecting black lines (see Appendix C). A random numbers table was used to determine the quadrant each target picture would be placed in, first for the close condition and then for the distant condition. Then a random numbers table was used to determine the order of presentation of the stimuli with the following constraint: no more than two consecutive items from one condition. The same, fixed random order was used for both the close condition and the distant condition.\(^{26}\)

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\(^{26}\) Since participants would only do a portion of the distant condition (items for which they responded incorrectly on the close condition) it was decided that the stimuli could be in the same random order in both conditions. This also aided the examiners in presenting the items in the distant condition in a quick and smooth manner.
2.3.2.5 Subjective judgments of the stimuli

An adult volunteer, naïve to the goals of the study, was asked to name all pictures (both targets and distractors), which were not from a normed source (i.e., all pictures not from Roisson & Portois, nor from the IPNP). Those that were named as something other than the intended target were discarded. Where there was more than one picture for an item, the volunteer was asked to select the “best picture” from those that were identified as the intended target, and this item was used. As a further confirmation that the distractors in the close condition represented their intended object, a typically developing pilot subject (aged 9;8) named all the distractors in the close condition. This child named all but seven pictures as their intended target. Three discrepancies were attributable to word-finding difficulty or were items the child may not have known the names of (no response to pitcher, said high up for cliff, and arrows for angle). Four discrepancies were due to visual confusion (corner for wallet, lynx for fox, zipper for price tag and slices of ham for bagel). The bagel picture was replaced, illegible words were added to the price tag and it was enlarged, and the wallet was reduced in size so that its relative size would be more appropriate.

2.3.2.6 Semantic representation procedure

All participants completed the semantic task after the gating task to avoid inadvertent priming effects since the two tasks used the same words. In the semantic task, the examiner showed the child a page with four black and white line drawings and asked the child to “point to [target],” where the targets were the same 28 words in the gating task (i.e., point to foot). Children’s responses were circled on a scoring sheet by the examiner. All children completed all 28 items in the close condition first. If the child’s response was correct, then the examiner immediately asked “Is there another [target]?” (e.g., Is there another foot?).
The examiner recorded the child’s response on a scoring sheet, by circling either “NO” if the child responded no, or by circling the number of the distractor the child pointed to. If the child’s response to the first question “point to _____” was incorrect, then the child was not asked whether there was “another [target].”

In the second part of the task, on any items for which the child was incorrect in the close condition (i.e., gave an incorrect response on the first question to “point to [target]”), the child completed these same items in the distant condition. For example, if the child responded incorrectly in part one of the task on four items (e.g., foot, lace, curve and weed) then the child completed just those four items in the second part. In the second part the target was displayed with distantly-related semantic distractors and the child was asked again to “point to [target].” Prior to the close condition, the participant completed three practice items. Only one participant (from the RV group) did not complete any trials in the distant condition due to a perfect score in the close condition.

This task was scored on line and not videotaped; therefore an examination of inter-rater reliability was not possible.

2.3.3 Nonword Repetition Task

Findings from research on phonological short-term memory have clearly demonstrated that children with SLI have a deficit relative to their peers (Baddeley, Gathercole, & Papagno, 1998). The task most commonly used to assess the capacity of an individual’s phonological short-term memory store (or phonological loop) is the nonword repetition task. In this task, listeners hear nonsense words of varying lengths and repeat them back. Because the stimuli are nonsense words, which have no meaning, the task is hypothesized to be a pure measure of phonological loop storage capacity. Responses are
judged for the number of correct phonemes. Gathercole and Baddeley have conducted the
greater part of the research into the role of the phonological loop in language learning using
their own nonword repetition task (see Baddeley et al., 1998, for a review). Phonological
processing and one aspect of phonological processing in particular – phonological memory –
is hypothesized to be critical to lexical development (Baddeley, Gathercole, & Papagno,
1998).

Dollaghan and Campbell (1998) were concerned that aspects of Gathercole and
Baddeley’s task were confounding prior linguistic knowledge with phonological memory, so
they developed another version of the nonword repetition task. Even with the new task, SLI
participants were still found to have reduced phonological short-term memory capacity
relative to typically developing children.

2.3.3.1 Stimuli preparation

2.3.3.2 Recording the nonwords

The stimulus words for the nonword repetition task were recorded by the same
speaker as in the gating task, using the same equipment and procedures (see page 41). In
accordance with Dollaghan & Campbell’s (1998) protocol, nonwords were produced with no
reduced vowels, primary stress on the first syllable in two- and three-syllable nonwords, and
primary stress on the second syllable in four-syllable nonwords. Again, the experimenter
gave the speaker feedback about her rate; this time the speaker was encouraged to produce
the nonwords at durations consistent with those used in the original experiment (Dollaghan
and Campbell, 1998). The target for one-syllable nonwords was 625 ms, two syllable was
approximately 925 ms, three-syllable was 1250 ms, and four-syllable was approximately
1500 ms. In addition to recording the 16 nonwords, four additional nonwords were recorded to be used as practice trials in the task. Three of these practice words were one syllable in length and one had two syllables. See Appendix E for a list of the practice and stimulus nonwords.

2.3.3.3 Editing the nonwords

The same editing procedure as in the gating task was used for the nonword stimuli (see pp. 41-42 for further details). The duration of the chosen token of each nonword is listed in Appendix E. The one syllable nonwords had a mean duration of 614 ms, the two-syllable nonwords had a mean duration of 956 ms, the three-syllable nonwords had a mean duration of 1227 ms, and the mean duration of the four-syllable nonwords was 1564 ms.

2.3.3.4 Nonword repetition procedure

In the current study, participants completed Dollaghan and Campbell's (1998) nonword repetition task. In this version of the nonword repetition task (NWT), participants hear and repeat 16 nonsense words, four at each of four syllable lengths (one-, two-, three- and four-syllables). All nonwords begin and end with consonants and contain no consonant clusters. One syllable nonwords are CVCs, two syllable nonwords are CVCVCs, three syllable nonwords are CVCVCVCs and four syllable nonwords are CVCVCVCVCs. See appendix E for a list of the nonwords at each syllable length. This task was completed in the third session after the semantic task. Children were instructed that they were going to hear silly words and after each one they were to repeat it back exactly as they heard it. Using E-

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27 The average duration of the one syllable words used in the gating task in the current study is shorter than the average duration of the nonwords; however, I decided to replicate the nonword lengths from the original study by Dollaghan and Campbell to facilitate comparisons.

28 The three, one-syllable practice nonwords were created by Sheila McDonald, as stimuli for her word-learning study. The two-syllable practice nonword was created by the author. The original experiment did not include any practice words; however, a decision was made to include them to insure participants understood the task.
prime, nonwords were presented in order from shortest (one-syllable) to longest (four-syllable) with four words at each of four lengths. At each length the computer generated a random order for the presentation of the four nonwords.

2.3.3.5 Scoring the Nonword Repetition Task

Participant responses were transcribed on-line by the examiner and also audiotaped for use during final transcription as well as reliability analyses. After the testing, each examiner scored the participants that she had tested, using both the audio-recordings and online transcription. Scoring procedures followed those of Dollaghan and Campbell's original study (1998). Phoneme substitutions and omissions were scored as incorrect. Phoneme distortions and additions were not scored as incorrect. Percentage phonemes correct (PPC) was calculated at each syllable length for each participant as well as a score of the percentage phonemes correct for all trials (total). Two randomly selected participants from each group were selected for reliability analysis. Their taped responses from the nonword repetition task were transcribed and scored by the other examiner. Phoneme-by-phoneme percentage of agreement for judgments of correctness between examiners was 91%, \([\kappa] = .77\) and was statistically significant at \(p < .001\).

2.3.4 General procedure

Each participant was tested in three sessions, each 30-45 minutes in length. All participants were tested in a quiet room in their elementary school. For all participants the first session consisted of the TONI (Brown et al., 1990), the PPVT (Dunn & Dunn, 1981), and the CELF Recalling Sentences subtest (Semel et al., 1987). Some participants also completed a second CELF subtest (either Concepts and Following Directions or Understanding Spoken Paragraphs) during the first session because time permitted. For all
participants, the second session consisted of the hearing screening and the gating task. The gating task was presented in two parts with a small break in the middle to give the participant a rest. For all participants the third session consisted of the semantic task, close condition, followed by the semantic task, distant condition, the nonword repetition task, CAPES (Masterson & Bernhardt, 2001) and any remaining CELF subtests. For a given participant, there was a minimum of 24 hours between two sessions. Children appeared focused and able to maintain attention well across the demands of all three sessions. Some children needed more encouragement than others to stay focused during the gating task.

All sessions were conducted by one of two experimenters, one a graduate student in Speech Language Pathology and the other a Research Assistant about to begin graduate studies in Speech Language Pathology.

2.3.5 Analysis strategy

The first seven research questions investigate the effect of lexical characteristics on lexical access in both SLI and RV children, as well as compare the ability of each group to access lexical items. Performance on the gating task was used to answer these questions. A comparison of the effects of AOA and ND on lexical access was made by comparing gating performance in each of the four conditions. The final research question asks whether the semantic level or phonological level of representation (or both) are implicated in lexical access in both typical and language-impaired populations. Performance on the semantic task and nonword repetition task was used to answer this question. Results from the gating task

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29 Three participants completed the hearing screening in the third session due to time constraints. Three participants completed the gating task over two sessions due to technical difficulties and one due to time constraints. Participants who completed the gating task over two sessions began where they left off in the second session.

30 Due to a statutory holiday and the school schedule, one control participant completed the first session in the morning and the second session at the end of the same school day. Two participants completed an extra session due to technical difficulties during the gating task, which could not be resolved at the time.
were correlated with results from the nonword task and semantic task to explore the relationship between levels of lexical representation and processing.

As the items in the distant condition in the semantic task served as a check that the words from the gating task were in each participants' receptive vocabulary, any item a participant responded to incorrectly in both the close and distant conditions was excluded from the gating analysis for that participant. Similarly, in the correlation analysis examining the relationship between performance on the gating task and performance on the semantic task, any item for which a participant responded incorrectly in both the close and the distant condition was excluded in both the semantic results and the gating results for that participant.

To answer the research questions, performance on the gating task for the SLI and RV groups was compared using Analysis of Variance (ANOVA) procedures. A 2 (Group) x 2 (AOA) x 2 (Neighbourhood Density) repeated measures ANOVA was used, where the latter two variables were within-subjects and Group was between subjects. This same procedure was also used to compare the results from the two groups on the semantic task. The nonword repetition results were first analyzed using a 2 (Group) x 5 (Syllable Length) ANOVA, with repeated measures on the second factor. Correlations between performance on the nonword task or semantic task and the gating task were examined, as well as between vocabulary comprehension level and gating performance.
3 Results

3.1 Overview

The purpose of this study was to examine lexical access of words that vary in age of acquisition and neighbourhood density in children with language impairments. Additionally, possible associations between semantic representation and phonological processing and lexical access were explored. This chapter discusses the results obtained from the three experimental tasks: gating, picture-word matching and nonword repetition. The first section will begin with a discussion of a preliminary analysis undertaken of outlier data points in the gating task, followed by presentation of the main effects and interactions found in the gating results, the accuracy results, and post-hoc analyses from the gating task. The next section presents the main effects and interactions from the semantic task. The third section describes a post-hoc analysis of gating results according to performance on the semantic task. Results from the nonword repetition task (main effects and interactions) are presented in the fourth section. The fifth section presents correlations between the gating task and results from three other measures: vocabulary size, phonological memory and semantic representation. This chapter closes with a summary of the major findings.

3.2 Gating task

3.2.1 Overview

The four points measured in participant responses (PIP, IP, TAP and AP) were used as dependent variables in separate 2 (AOA) x 2 (ND) x 2 (Group) mixed-design ANOVAs. Statistical tests for homogeneity of variance (Mauchly’s test of sphericity) indicated that this distribution assumption had been met, for all comparisons of gating results. In this section I will present the results of a preliminary analysis of outliers, followed by the gating results
from each measurement point beginning with the main effects of the experimental variables (Group, AOA and ND), and concluding with a description of the interaction of these three variables on each of the four measurement points.

3.2.2 Outliers

A preliminary analysis was conducted to determine the existence of outliers (results due to inattention, etc.). Results from the gating task for the two groups were analyzed separately. For each group, the minimum, maximum and mean scores as well as the standard deviation were calculated for each stimulus (word). First, outliers were defined using the criterion of +/- three standard deviations from the mean. Using this criterion there were no outlier data points (i.e., participant responses that were more than three standard deviations from the mean for that item).

Next, outliers were defined using the more conservative criterion of +/- two standard deviations from the mean. For exploratory purposes, all participant responses from just six (out of 28) stimuli were examined, using this criterion. It was decided that only a subset of the stimuli would be examined as an empirical test to determine whether most of the outliers were due to performance that was too good or too poor. Responses to six stimuli were examined: one stimulus was from the early/sparse condition, two were from the early/dense condition, two were from the late/sparse condition and one was from the late/dense condition. A small number of outliers (22) were found (9 from SLI participants and 13 from RV). Because there were four measurement points per stimulus per participant, for the six stimuli examined in this analysis, the total number of data points examined to determine outliers is 408 (6 stimuli x 4 measurement points x 17 participants). Therefore 5.4 % of the data points examined were outliers. Many of the outlier data points (12 out of 22) were
participant responses that were too quick, rather than too slow, and therefore, could not be
attributed to inattention (because participants responded with a word). Given that these
responses could not be due to inattention, it was decided that outliers should not be excluded
from the analyses.

Responses from the gating task were analyzed to ensure that stimulus words were in
the comprehension vocabulary of participants. This was determined through performance on
the semantic task. For each participant, responses from the semantic task were analyzed to
identify any word(s) that the participant responded incorrectly to in both the Close and the
Distant condition. A participant’s responses on the gating task to words identified in the
above manner were then excluded from the gating analyses. For example, if a participant
could not correctly point to the picture that corresponded to the word *wick* in both the Close
and Distant conditions of the semantic task, then that participant’s responses to *wick* on the
gating task (the PIP, IP, TAP and AP) were excluded from the ANOVAs conducted on the
gating data. In the SLI group, three participants responded incorrectly to a few items on the
semantic task in both conditions and in the RV group, two participants responded incorrectly
to a few items in the semantic task in both conditions.\(^{31}\) Less than two percent of trials were
excluded in this way.

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\(^{31}\) All incorrect responses identified in this manner were for words in the late AOA condition. For the SLI
group, responses from five trials were excluded in this way (three stimuli for one participant and two for
another). For the RV group responses from two trials were excluded in this way (one stimulus for each of two
participants).
3.2.3 Main effects

This next section examines the results of the gating task and describes the main effects of Group, AOA and ND at each of the four measurement points: PIP, IP, TAP and AP.

3.2.3.1 Group

PIP: The mean proportion of the acoustic signal needed by SLI participants to identify the initial phoneme of all words was .32 (SD = .17). For RV participants, the mean proportion of the acoustic signal needed to identify the initial phoneme of all stimuli was .33 (SD = .22). There was no significant difference between groups in the amount of acoustic signal needed to identify the initial phoneme of words $F(1,15) = .361$, MSE = .004, $p = .557$.

IP: The mean proportion of the acoustic signal needed by language-impaired children to identify a word was .85 (SD = .24). The RV group needed a mean proportion of .77 (SD = .24) to identify a word. Although there was a trend towards the SLI group requiring more of the acoustic signal than the RV group, results indicate no significant difference between the groups $F(1,15) = 1.84$, MSE = .05, $p = .195$.

TAP: For the SLI group, the mean proportion needed to confidently identify a word was .91 (SD = .27). The mean proportion of a word needed by the RV group was .81 (SD = .26). Again, the results indicate no significant difference between the groups $F(1,15) = 2.48$, MSE = .06, $p = .136$; however, there was a trend towards the SLI group requiring more of the signal than the RV group.

AP: The mean proportion of a word needed to activate the target was .73 (SD = .25) for the SLI group. For the RV group, the mean proportion needed to activate a target word
was .70 (SD = .24). There was no significant difference between the groups in activation point F(1,15) = 1.12, MSE = .02, p = .306.

3.2.3.2 AOA

PIP: The mean proportion of the acoustic signal needed by all participants to identify the initial phoneme of early-acquired words was .32 (SD = .20). For later-acquired words the mean proportion of the acoustic signal needed by all participants to identify the initial phoneme was .33 (SD = .21). Results indicate no significant difference between early words and late words F(1,15) = .48, MSE = .004, p = .497.

IP: The mean proportion of the acoustic signal needed to identify early AOA words was .77 (SD = .27). In order to identify late AOA words, the mean proportion of the acoustic signal needed was .85 (SD = .21). Overall, listeners required significantly more of a word's duration to identify late acquired words, as compared to words acquired early F (1,15) = 13.92, MSE = .005, p < .01.

TAP: Results showed a mean TAP of .82 (SD = .29) of a word’s duration to confidently identify words with an early AOA rating. For late words, the mean proportion of the acoustic signal needed to confidently identify word was .89 (SD = .24). These results indicate that the children required significantly more of the acoustic signal to confidently identify late AOA words compared to early AOA words F (1,15) = 15.53, MSE = .004, p < .01.

AP: For early words, the mean proportion of the acoustic signal needed to activate the target word was .68 (SD = .26). Results showed a mean activation point of .76 (SD = .22) for later-acquired words. The results indicate that listeners required significantly more of the
acoustic signal to activate the target for late AOA words as compared to early AOA words F
(1,15) = 27.81, MSE = .004, p < .001.

These results for a main effect of AOA are qualified by the interaction found between
AOA and ND (see section 3.2.4.1.3 below).

3.2.3.3 Neighbourhood Density

PIP: Results showed a mean PIP of .32 (SD = .19) in the sparse condition. The mean
proportion of the acoustic signal needed to identify the initial phoneme of words in the dense
condition was .34 (SD = .22). Participants did not require significantly different amounts of
acoustic information to identify the initial phoneme of words from sparse as opposed to
dense neighbourhoods F(1,15) = .16, MSE = .006, p = .691.

IP: In the sparse condition, the mean proportion of a word’s duration needed to
identify the target was .76 (SD = .26). The mean proportion of the acoustic signal needed to
identify words from dense neighbourhoods was .85 (SD = .22). The results indicate that
listeners required significantly more of the acoustic signal for words from dense
neighbourhoods as compared to words from sparse neighbourhoods F (1,15) = 15.96, MSE =
.007, p < .01.

TAP: Results showed a mean TAP of .80 (SD = .28) of a word’s duration in the
sparse neighbourhood condition. The mean TAP in the dense condition was .91 (SD = .25)
of a word’s duration. Results revealed that children required significantly more of the
acoustic signal to accurately and confidently identify words from dense neighbourhoods
compared to words from sparse neighbourhoods F(1,15) = 18.25, MSE = .008, p < .01.

AP: In the sparse condition, the target word was activated with a mean of .65 (SD =
.26) of the acoustic signal. The mean proportion of the signal needed to activate the target
word in the dense condition was .78 (SD = .22). The results indicate that listeners required a significantly greater proportion of the acoustic signal to activate the target in the dense condition as compared to the sparse condition $F(1,15) = 32.58$, $MSE = .225$, $p < .007$.

These results for a main effect of ND are qualified by the interaction found between AOA and ND (see section 3.2.1.4.3 below).

3.2.4 Interaction effects

3.2.4.1 Two-way interactions

3.2.4.1.1 AOA x Group

There was no significant interaction between AOA and Group for any of the dependent variables. All p values were greater than .10. The mean proportions of acoustic signal needed by each group to identify word-initial phonemes (PIP) and to activate (AP), identify (IP), and confidently identify (TAP) early- and late-acquired targets are summarized in Table 3 below. Both groups needed more of the acoustic signal to activate or identify late-acquired words compared to early acquired words. Word-initial phonemes were identified with similar amounts of the acoustic signal for both early- and late-acquired words and for both groups.

Table 3. Mean (SD) proportion of acoustic signal needed by children with SLI and RV controls for early- and late-acquired words.

<table>
<thead>
<tr>
<th>Group</th>
<th>Proportion of signal needed</th>
<th>M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PIP $AOA$</td>
<td>AP $AOA$</td>
</tr>
<tr>
<td></td>
<td>Early</td>
<td>Late</td>
</tr>
<tr>
<td>SLI</td>
<td>.32</td>
<td>.32</td>
</tr>
<tr>
<td></td>
<td>(.19)</td>
<td>(.18)</td>
</tr>
<tr>
<td>RV</td>
<td>.32</td>
<td>.34</td>
</tr>
<tr>
<td></td>
<td>(.20)</td>
<td>(.24)</td>
</tr>
</tbody>
</table>
3.2.4.1.2 ND x Group

Results revealed no significant interaction between Neighbourhood density and Group for the four measurement points: PIP, IP, TAP, and AP. All p values were greater than .10. Words residing in sparse neighbourhoods were recognized with less of the acoustic signal than words from dense neighbourhoods, for both groups. Results of ND by Group are summarized in Table 4 below.

Table 4. Mean (SD) proportion of acoustic signal needed by children with SLI and RV controls for words from sparse and dense neighbourhoods.

<table>
<thead>
<tr>
<th>Group</th>
<th>Proportion of signal needed M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PIP Neighbourhood Density</td>
</tr>
<tr>
<td></td>
<td>Sparse</td>
</tr>
<tr>
<td>SLI</td>
<td>.32 (.18)</td>
</tr>
<tr>
<td>RV</td>
<td>.32 (.19)</td>
</tr>
</tbody>
</table>

3.2.4.1.3 AOA x ND

Phoneme Identification Point: there was a significant interaction between AOA and ND F(1,15) = 24.84, MSE = .007 p < .001. Results showed that less of the acoustic signal was needed to recognize the initial phoneme of early acquired words from sparse neighbourhoods (mean PIP = .27, SD = .05) versus dense neighbourhoods (mean PIP = .38, SD = .27). The reverse pattern was found for late acquired words: mean PIP for sparse words = .38 (SD = .27), mean PIP for dense words = .29 (SD = .14).

There was a significant interaction between AOA and ND for the Isolation Point: F(1,15) = 31.67, MSE = .003, p < .001, Total Acceptance Point: F(1,15) = 33.82, MSE =
.005, \( p < .001 \), and Activation Point: \( (F, 1,15) = 43.67, \text{MSE} = .002, p < .001 \). Results were consistent for all three measurement points (IP, TAP and AP): children needed significantly more input to activate/identify early words from dense neighbourhoods than early words from sparse neighbourhoods. By contrast, the mean IP, mean TAP and mean AP did not differ significantly for late words from sparse neighbourhoods compared to late words from dense neighbourhoods. Thus, ND only had an effect on early words. See Table 5 below which lists the mean proportions for words from all four conditions (early/sparse, early/dense, late/sparse and late/dense) for all four measurement points.

Table 5. Mean (SD) proportion of acoustic signal needed for early- and late-acquired words and words from sparse and dense neighbourhoods.

<table>
<thead>
<tr>
<th></th>
<th>Proportion of signal needed M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PIP</td>
</tr>
<tr>
<td>ND</td>
<td>AOA</td>
</tr>
<tr>
<td></td>
<td>Early</td>
</tr>
<tr>
<td>Sparse</td>
<td>.27 (.05)</td>
</tr>
<tr>
<td>Dense</td>
<td>.38 (.27)</td>
</tr>
</tbody>
</table>

3.2.4.2 Three-way Interaction: AOA x ND x Group

The three-way interaction between AOA x ND x Group was not significant for any measurement point: Phoneme Identification Point \( F(1,15) = .046, p = .833 \), Isolation Point \( F(1,15) = 2.05, p = .173 \), Total Acceptance Point \( F(1,15) = .73, p = .407 \), and Activation Point \( F(1,15) = .37, \text{MSE} = .0009, p > .55 \). Figures 2, 3, 4 and 5 display the means for each measurement point for AOA, ND and Group.

3.2.5 Accuracy

For each participant, overall accuracy was calculated by counting the number of words from all conditions that the participant identified correctly by the final gate (out of 28 words). The SLI group correctly identified a mean of 71.9 percent of words (SD = 19.2) on
the final gate as compared to the RV group, which had 82.1 percent of words (SD = 15.4) correct on the final gate. Overall accuracy on the gating task between the two groups was not significantly different $t(15) = 1.220, p = .241$.

Figure 2. Comparison of Mean (SD) Phoneme Identification Point (PIP) by each group for words in four AOA x ND conditions (scale: proportion of acoustic signal needed).
Figure 3. Comparison of Mean (SD) Activation Point (AP) by each group for words in four AOA x ND conditions (scale: proportion of acoustic signal needed).

Figure 4. Comparison of Mean (SD) Isolation Point (IP) by each group for words in four AOA x ND conditions (scale: proportion of acoustic signal needed).
3.2.6 Summary of gating results

Results revealed robust effects of AOA and ND on word recognition: children identified early-acquired words with significantly less acoustic information than late-acquired words, and words from sparse neighbourhoods with significantly less acoustic information than words from dense neighbourhoods. The interaction between AOA and ND was also significant: early-acquired words from sparse neighbourhoods were identified with less of the signal than words from the other three conditions. Neither AOA nor ND had an effect on word-initial phoneme identification results (however there was an interaction between the two variables).

No group differences were found for word-initial phoneme identification, word activation or overall accuracy. There was a trend towards RV participants identifying and
confidently identifying target words with less acoustic information than SLI participants, but the effect was not significant.

3.2.7 Post hoc analyses

3.2.7.1 Reclassifying participants based on a processing-dependent measure

Previous research has suggested that a deficit in phonological short-term memory is a phenotypic marker of SLI (Conti-Ramsden, 2003). Performance on the nonword repetition task is typically used to establish phonological STM abilities. Previous studies into SLI have used performance on the NWT as an inclusionary criterion for children in the SLI group (e.g., McGregor, et al, 2002). I was interested in whether participants in the current project would fall into the same groupings based on performance on a nonword repetition task, and whether there would be a difference in word recognition between the two new groups.

For this reason, participants were split into two groups based on their performance on the nonword repetition task (NWT) by calculating their mean scores: percentage phonemes correct summed for all lengths (see page 80 below for a description of the results of the nonword repetition task). Total scores for this task ranged from 60.42 to 92.71 percent phonemes correct, with a mean of 77.76 (SD = 8.92). Nine participants (7 RV and 2 SLI) with scores above the mean were grouped as “high” and eight participants (6 SLI and 2 RV) with scores below the mean were grouped as “low.” With these new groupings, the four points measured in participant responses (PIP, IP, TAP and AP) on the gating task were re-analyzed as dependent variables in separate 2 (AOA) x 2 (ND) x 2 (NWT Group) mixed-design ANOVAs. Statistical tests for homogeneity of variance (Mauchly’s test of sphericity) indicated that this distribution assumption had been met. Only significant results involving the new independent variable NWT Group are reported below.
3.2.7.1.1 NWT Group

PIP results showed a trend towards a group effect, but the results did not reach significance $F(1,15) = 4.03$, $MSE = .003$, $p = .063$. The low NWT Group identified the initial phoneme of a target with 34 (22) percent of the signal and the high NWT Group with 32 (19) percent of the signal. Unlike the results found in the ANOVAs used with Groups defined by intervention status, a significant main effect of NWT Group was found for the Activation Point $F(1,15) = 5.29$, $MSE = .01$, $p < .05$. Participants who performed well on the nonword repetition task required significantly less of a word’s acoustic signal ($M = .69$, $SD = .24$) to activate a target than participants who performed poorly on the nonword task ($M = .75$, $SD = .25$).

3.2.7.1.2 Interactions

PIP: Results showed a significant interaction between neighbourhood density and NWT Group $F(1,15) = 5.37$, $p < .05$. For the group who obtained high scores on the NWT, the initial phoneme of words from sparse neighbourhoods was identified earlier ($M = .29$, $SD = .14$) than words from dense neighbourhoods ($M = .34$, $SD = .23$). For the low NWT group, neighbourhood density did not have the same effect on the PIP (sparse words: $M = .35$, $SD = .22$ and dense words: $M = .33$, $SD = .21$)

PIP results also revealed a significant interaction between AOA, ND and NWT group: $F(1,15) = 6.44$, $p < .05$. For early-acquired words, from both sparse and dense neighbourhoods the low NWT group needed more of the acoustic signal than the high NWT group to identify the word-initial phoneme. Similarly, for late-acquired words from sparse neighbourhoods, the low NWT group needed more input to identify the first phoneme; in contrast for late-acquired words from dense neighbourhoods the low NWT group needed less
input than the high NWT group to identify the first phoneme of target words. The low group experienced a processing advantage for late/dense words that the high NWT group did not. Furthermore, for both groups density had opposite effects on early- and late-acquired words: for early-acquired words, less input was needed to identify the initial phoneme of words from sparse neighbourhoods compared to dense neighbourhoods but for late-acquired words, less input was needed to identify the initial phoneme of words from dense neighbourhoods compared to sparse. See Figure 6 below for a depiction of the results. There was no significant interaction between NWT Group, AOA and ND for the other three measurement points (IP, TAP and AP) (see Table 6).

Figure 6. Comparison of Mean (SD) Phoneme Identification Point (PIP) by each NWT Group for words in four AOA x ND conditions (scale: proportion of acoustic signal needed).
Table 6. Mean (SD) proportion of signal required for each NWT group for early- and late-acquired words from sparse and dense neighbourhoods.

<table>
<thead>
<tr>
<th>ND</th>
<th>NWT Group</th>
<th>Proportion of signal needed M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PIP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Early</td>
</tr>
<tr>
<td>Sparse</td>
<td>Low</td>
<td>.28 (.06)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>.27 (.04)</td>
</tr>
<tr>
<td>Dense</td>
<td>Low</td>
<td>.39 (.28)</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>.37 (.26)</td>
</tr>
</tbody>
</table>

3.2.7.2 Reclassifying participants based on vocabulary comprehension

Differences in word recognition between groups of different ages have lead to the claim that vocabulary size affects lexical-phonological representations thereby affecting word recognition (e.g., Garlock et al. 2001; Metsala, 1997a). I was interested to see if there would be a difference in word recognition between the children in the current project who had larger vocabularies and those with smaller vocabularies. Hence, results from the gating task were re-analyzed with participants divided into two groups based on vocabulary size.

The mean of all participants’ raw PPVT scores was calculated ($M = 105.29$, SD = 17.57) and participants above the mean formed a high group and those below the mean formed a low group. Ten participants (6 RV and 4 SLI) formed the high group (minimum PPVT raw score: 107, maximum: 131, $M = 117.8$, SD = 7.32) and seven participants (3 RV and 4 SLI) formed the low group (minimum PPVT raw score: 71, maximum: 97, $M = 87.43$, SD = 10.47).

Separate 2 (Vocabulary Group) x 2 (AOA) x 2 (ND) mixed design ANOVAS were
conducted for each data point (PIP, IP, TAP and AP). No significant main effect of Vocabulary Group or interactions with Vocabulary Group were found at a p value of .05.

3.2.7.3 Acoustic analysis

To explore the possibility that words with certain types of sounds are harder to identify than words without those sounds, responses for a subset of the stimuli in the gating task were analyzed using an acoustic-phonetic criterion. Two groups of five words each were created. Five words that began with a fricative formed the fricative condition (sign, vine, suit, foot, and sock) and five words that did not begin with a fricative formed the non-fricative condition (cub, bun, toad, goat and neck). I wondered if words that began with fricatives might be more difficult to recognize than words that began with plosives (and one nasal) based on research that found that children had more difficulty categorizing fricatives than plosives (Hazan & Barrett, 2000). The two subgroups of stimuli were matched as close as possible for AOA and ND and for the final sound. See Table 7 below for the lexical and acoustic characteristics of the subset of words.

Table 7. Lexical and Acoustic Characteristics of Words Used in the Acoustic Analysis.

<table>
<thead>
<tr>
<th>Fricative condition</th>
<th>Non-fricative condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>WORD</td>
<td>AOA/ND</td>
</tr>
<tr>
<td>Sign</td>
<td>Early/dense</td>
</tr>
<tr>
<td>Vine</td>
<td>Late/sparse</td>
</tr>
<tr>
<td>Suit</td>
<td>Late/dense</td>
</tr>
<tr>
<td>Foot</td>
<td>Early/sparse</td>
</tr>
<tr>
<td>Sock</td>
<td>Early/dense</td>
</tr>
</tbody>
</table>

WI refers to word-initial.
WF refers to word-final.
Gating data on the subset of ten words were analyzed in separate 2 (Group) by 2 (Acoustic Characteristic) mixed design ANOVAs for PIP, IP, TAP and AP. No significant main effects (group or acoustic characteristic) or significant interactions were found.

3.2.7.4 Frequency analysis

Given that the average frequency of words in each condition was not balanced, it was important to examine whether word frequency affected participants’ performance on the gating task. Separate 2 (group) x 2 (frequency) mixed-design ANOVAs were conducted for the four dependent variables (PIP, IP, TAP and AP). No significant main effect of Frequency or interactions with Frequency were found.

3.2.7.5 Summary of post hoc analyses

Four post hoc analyses of the gating results were conducted. When participants were grouped based on their ability to repeat nonsense words (high percentage phonemes correct versus low percentage phonemes correct), results showed that participants in the high group needed significantly less of the acoustic signal to activate target words (AP) than participants in the low group. Participants were re-grouped based on the size of their comprehension vocabulary (high versus low) but no significant group differences in word recognition were found. A subset of the stimuli was categorized based on whether the word-initial phoneme was a fricative or non-fricative (stop or nasal) and performance on the two subset groups was compared. No significant effect of acoustic characteristic was found. Finally, gating results were reanalyzed to see if word frequency had an effect on word recognition; no significant effect of frequency was found.
3.3 Semantic task

3.3.1 Overview

Participants’ semantic knowledge of a word was measured by using four dependent variables: close, distant, semantic associate and total.\(^{34}\) If the child was able to select the correct picture corresponding to the word spoken by the examiner from an array of close semantic competitors, the participant was said to have a detailed semantic representation of the word. If the child chose the correct picture in the close condition, but also selected another picture, a semantic associate, as corresponding to the word spoken by the examiner, then the child was said to have a detailed but overlapping (with associated members from the same category) semantic representation of the word. If the child was incorrect in the close condition but correctly selected the target picture from an array of distant semantic distractors (during the second part of the task), then the participant was said to have a general understanding of the meaning of the word. Finally, whether the child had a semantic representation of the word at all (either in the close or distant condition) was measured as a total knowledge score. Each of the four semantic measures was used as a dependent variable in separate 2 (AOA) x 2 (ND) x 2 (Group) mixed-design ANOVAs. Statistical tests for homogeneity of variance (Mauchly’s test of sphericity) indicated that this distribution assumption had been met. The results from each dependent variable are presented below, beginning with the main effects of the experimental variables (Group, AOA and ND), followed by a description of the interaction of these three variables. In the analyses conducted for the following section, participants’ responses are represented in terms of percent correct. The effect of AOA on semantic representations reflects another aspect of

\(^{34}\) See chapter two, section 2.3.2, for an explanation of the relationship between a target and distractors, as well as the task procedure.
word familiarity – depth of knowledge of a word’s meaning. ND, on the other hand, does not have an obvious relationship to semantic representation; however, in an interactive system processing at one level affects other levels. An effect of ND on depth of semantic knowledge would provide further support for interactive activation models of lexical access.

3.3.2 Main effects

3.3.2.1 Group

There was no significant group effect on any of the dependent variables (Close $F(1,15) = .26$, $MSE = .03$, $p = .620$, Distant $F(1,3) = 7.2$, $MSE = .04$, $p = .075$, Semantic associate $F(1,15) = 2.51$, $MSE = .09$, $p = .134$ and Total $F(1,15) = .54$. $MSE = .004$, $p = .472$); however, there was a trend towards a group effect in the Distant condition, such that RV participants made fewer errors ($M = 95$, $SD = 22$), than the SLI participants ($M = 90$, $SD = 30$). Table 8 outlines the percent correct in each condition for each group.

Table 8. Percent correct in each condition on the semantic task for children with SLI and RV controls.

<table>
<thead>
<tr>
<th>Group</th>
<th>Close</th>
<th>Distant</th>
<th>Semantic associate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLI</td>
<td>82 (39)</td>
<td>90 (30)</td>
<td>78 (42)</td>
<td>98 (13)</td>
</tr>
<tr>
<td>RV</td>
<td>84 (37)</td>
<td>95 (22)</td>
<td>89 (32)</td>
<td>99 (9)</td>
</tr>
</tbody>
</table>

Note: For these calculations, the number of trials completed by each participant varied because the Distant and Semantic associate questions were contingent on performance in the Close condition. In the Distant condition, the number of trials completed by each participant with SLI ranged from 2-7 and from 1-7 for participants in the RV group. In the Semantic Associate condition, the number of trials completed by each participant with SLI ranged from 20-26 and from 20-28 for participants in the RV group.

3.3.2.2 AOA

The results revealed a significant effect of AOA on participants’ ability to select the correct target displayed amongst close semantic distractors. Participants were correct significantly more often on early acquired words ($M = 90$, $SD = 30$) as compared to late AOA words ($M = 75$, $SD = 44$) $F(1,15) = 23.27$, $MSE = .02$, $p < .001$. For the dependent
variable Total (whether a participant was correct in either the close or distant condition) there was a trend towards an effect of AOA but it was not significant $F(1,15) = 3.37$, $MSE = .004$, $p = .086$. Participants pointed to the correct picture of all words with an early AOA rating ($M = 100$, $SD = 0$) but made incorrect responses for some late-acquired words ($M = 97$, $SD = 16$).

3.3.2.3 ND
There was a small, but significant effect of neighbourhood density in the Total condition, such that participants correctly matched more target words to the correct picture for words from sparse neighbourhoods ($M = 100$, $SD = 7$) compared to dense neighbourhoods ($M = 98$, $SD = 14$) $F(1,15) = 4.57$, $MSE = .001$, $p < .05$. There were no significant effects of neighbourhood density for the other three dependent variables (Close, Distant and Semantic associate).

3.3.3 Two-way interactions
3.3.3.1 AOA x ND
In the close semantic condition, there was a trend towards an interaction between AOA and ND, but the effect was not significant $F(1,15) = 3.87$, $MSE = .01$, $p = .068$. For early acquired words, children were able to correctly identify the target word from closely related distractors more often for sparse words ($M = 94$, $SD = 8$) than dense words ($M = 87$, $SD = 13$). However, for later-acquired words, children correctly identified more words from dense neighbourhoods ($M = 76$, $SD = 10$) than from sparse neighbourhoods ($M = 73$, $SD = 19$).

For the dependent variable Semantic associate, results revealed a significant interaction between AOA and ND $F(1,15) = 9.69$, $MSE = .02$, $p < .01$. Paralleling the
interaction that resulted in the close condition, for early words, children were correct more often for sparse words ($M = 90, SD = 17$) compared to dense words ($M = 78, SD = 21$); however, for late words, children were correct more often for dense words ($M = 85, SD = 18$) compared to sparse words ($M = 77, SD = 25$).

Finally, there was a significant interaction between AOA and ND for the dependent variable Total $F(1,15) = 4.57$, MSE = .001, $p < .05$. All early-acquired words, both sparse ($M = 100, SD = 0$) and dense ($M = 100, SD = 0$), were correctly identified by all children in at least one of the two conditions (close or distant). However, for late-acquired words, some children were unable to correctly identify some sparse words ($M = 99, SD = 4$) and a greater number of dense words ($M = 96, SD = 8$). Table 9 outlines the interaction between AOA and ND for each of the four dependent variables.

Table 9. Mean percent correct M (SD) on the Semantic task for early- and late-acquired words from sparse and dense neighbourhoods.

<table>
<thead>
<tr>
<th>ND</th>
<th>Close condition AOA</th>
<th>Distant condition AOA</th>
<th>Semantic associate AOA</th>
<th>Total condition AOA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early</td>
<td>Late</td>
<td>Early</td>
<td>Late</td>
</tr>
<tr>
<td>Sparse</td>
<td>94 (08)</td>
<td>73 (19)</td>
<td>100 (00)</td>
<td>90 (22)</td>
</tr>
<tr>
<td>Dense</td>
<td>87 (13)</td>
<td>76 (10)</td>
<td>100 (00)</td>
<td>70 (45)</td>
</tr>
</tbody>
</table>

3.3.3.2 ND x Group, AOA x Group and AOA x ND x Group

There were no significant interactions between neighbourhood density and group or between age-of-acquisition and group for any of the dependent variables. In addition, there were no significant interactions between the three independent variables (AOA, ND and Group) for any of the dependent variables.
3.3.4 Summary of semantic task results

AOA and ND had an effect on participants' ability to correctly match a picture to a spoken word. Participants correctly matched a significantly higher number of early-acquired words than late-acquired words and a significantly higher number of words residing in sparse neighbourhoods than dense. AOA and ND interacted in an interesting way. For early-acquired words, children correctly matched more words from sparse neighbourhoods than dense neighbourhoods. In contrast, for late-acquired words, children correctly matched more words from dense neighbourhoods than sparse neighbourhoods.

3.4 Close versus Distant post hoc analysis of gating data

It was hypothesized that the depth of semantic knowledge for a word would affect word recognition: words that have detailed semantic representations would be recognized more readily than words with sparser semantic representations. Accordingly, the gating results were re-analyzed to compare word recognition for items that participants knew well (correctly identified in the close semantic condition) versus words that were known less well (incorrectly identified in the close condition, but correctly identified in the distant condition). Separate 2 (Group) x 2 (Level of semantic knowledge) mixed-design ANOVAs for each measurement point (PIP, IP, TAP, AP) were used to examine this relationship. Statistical tests for homogeneity of variance (Mauchly's test of sphericity) indicated that this distribution assumption had been met.

No significant effect of level of semantic knowledge was found. The only significant effect found was for the Activation Point. A significant main effect of group was found, such that SLI participants needed more acoustic information to activate a target word \((M = .73, SD = .25)\) as compared to RV controls \((M = .70, SD = .24 F(1,14) = 6.47, MSE = .007, p = .023)\).
This significant result is likely due to the loss of data from one RV participant in the analysis, because the participant was able to correctly match all words and pictures in the close condition of the semantic task, and therefore, the comparison could not be made. Thus, this finding of a group difference is likely spurious (and it speaks to the need for a larger sample size).

3.5 Nonword Repetition Task (NWT)

3.5.1 Overview

As in the original study by Dollaghan and Campbell (1998), for each participant five separate scores were calculated: percentage phonemes correct (PPC) for the four 1-syllable stimuli (1PPC), for the four 2-syllable stimuli (2PPC), for the four 3-syllable stimuli (3PPC), for the four 4-syllable stimuli (4PPC), and an overall score which is the percentage of phonemes correct at all lengths summed (TOTPPC). To examine the performance of the two groups on this task, a 2 (Group) x 5 (Length) mixed design ANOVAs was used.

3.5.2 Main effects

3.5.2.1 Group

Results showed a main effect of group $F(1,15) = 10.21$, MSE = 167.33, $p < .01$. SLI participants had a smaller mean percentage phonemes correct ($M = 74.73$, SD = 15.7) than RV participants ($M = 84.46$, SD = 12.38).

3.5.2.2 Length

Statistical tests for homogeneity of variance (Mauchly's test of sphericity) indicated that the distribution was not normal for this comparison; therefore, Greenhouse-Geisser results are reported. Results revealed a main effect of length $F(2,33) = 25.19$, MSE = 141.26, $p < .001$. Table 10 below lists the mean PPC at each length for each group. As nonword
length increases, participants in both groups correctly repeated a smaller percentage of phonemes (except for the two-syllable nonwords which had the highest percentage scores for both groups).

Table 10. Mean Percentage Phonemes Correct at each nonword length by children with SLI and their Receptive Vocabulary matched controls.

<table>
<thead>
<tr>
<th>Nonword Length</th>
<th>Group</th>
<th>Percentage Phonemes Correct: M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SLI (n = 8)</td>
<td>RV (n = 9)</td>
</tr>
<tr>
<td>1-syllable</td>
<td>83 (7.7)</td>
<td>86 (5.9)</td>
</tr>
<tr>
<td>2-syllable</td>
<td>91 (9.0)</td>
<td>96 (6.3)</td>
</tr>
<tr>
<td>3-syllable</td>
<td>75 (13.8)</td>
<td>87 (11.7)</td>
</tr>
<tr>
<td>4-syllable</td>
<td>57 (10.7)</td>
<td>71 (14.1)</td>
</tr>
<tr>
<td>Total</td>
<td>72 (6.6)</td>
<td>83 (8.0)</td>
</tr>
</tbody>
</table>

3.5.3 Interactions

Unlike past research (Dollaghan and Campbell, 1998), a significant interaction of group by length was not found F(4,12) = .67, p = .623. Possible reasons for this will be explored in the discussion chapter.

3.6 Correlating lexical access with semantic knowledge and phonological processing

The final set of analyses explored correlations between lexical access and three separate factors: semantic representations, phonological processing and vocabulary level. To investigate possible relationships between these abilities, correlations between scores on the gating task and: vocabulary scores, scores on the semantic task and scores on the nonword task were examined.

3.6.1 Vocabulary size and lexical access

Past research has examined the effect of vocabulary development on lexical access, mostly through comparing gating performance by children of different age groups (e.g.,
Garlock, Walley & Metsala, 2001). Vocabulary comprehension level can be more accurately estimated through a standardized test, such as the PPVT (Dunn & Dunn, 1981). In this analysis, a Pearson’s bivariate correlation was conducted between raw PPVT scores and gating performance (all four dependent variables, PIP, AP, IP and TAP, were included). Raw PPVT scores were used in this analysis as they represent the overall size of a child’s vocabulary.\(^{35}\)

When all subjects were considered together, there were significant negative correlations between the activation point and PPVT raw scores for late AOA words from dense neighbourhoods (\(r = -.511, p > .05\), two tailed). These results suggest that the larger a participant’s vocabulary the less of the acoustic signal needed to activate a target word. Late-acquired words from dense neighbourhoods would be the most difficult words to identify, if their connections are relatively weak (since they have been recently learned) and if they experience significant competition from the many similar sounding words in the neighbourhood. On the other hand, if dense neighbourhoods facilitate word recognition for words with weak connections, then late-acquired words from dense neighbourhoods would be recognized more readily than late-acquired words from sparse neighbourhoods.

Conflicting results regarding the interaction between AOA and ND have been found.

No significant correlations were found between PPVT and PEP, EP or TAP results when all subjects were considered together.

When the SLI subjects were considered separately, significant negative correlations were found between the activation point and the PPVT raw scores for early AOA words from dense neighbourhoods (\(r = -.826, p < .05\), two-tailed) and for late AOA words from sparse...\(^{35}\)

Two main types of PPVT scores are calculated for each participant: raw scores and standardized scores. Standardized scores are useful for making decisions regarding intervention, but do not indicate the relative size of a child’s vocabulary.
neighbourhoods \((r = -0.723, \ p < 0.043, \text{ two-tailed})\). There was a similar trend for words in the late/dense condition, but the correlation was marginally significant \((r = -0.694, \ p = 0.056, \text{ two-tailed})\). Furthermore, when SLI subjects’ overall performance on the gating task was considered (words from all four conditions analyzed together), there were strong negative correlations between the activation point and the PPVT raw scores \((r = -0.906, \ p < 0.01, \text{ two-tailed})\).

Significant correlations were also found between raw PPVT scores and the phoneme identification point for both the SLI group: a significant negative correlation was found between PPVT raw scores and overall PIP (for all words) \((r = -0.768, \ p < 0.05, \text{ two-tailed})\) and between PPVT raw scores and PIP in the late/sparse condition \((r = -0.849, \ p > 0.01, \text{ two tailed})\). For the RV participants considered separately, and for both groups considered together, no significant correlation was found between the PIP for all words and vocabulary size nor for the PIP in the late/sparse condition and vocabulary size. However, one significant, moderate, negative correlation was found between PPVT raw scores and PIP performance for the RV participants considered separately, this time for words in the late/dense condition \((r = -0.673, \ p < 0.05, \text{ two-tailed})\). These results suggest that for both groups there is a relationship between word-initial phoneme perception and vocabulary size.

3.6.2 Phonological memory and lexical access

Lexical learning requires the organization and storage of phonological information. Lexical access requires retrieval of stored phonological information associated with words. Dollaghan and Campbell’s (1998) nonword repetition task measures the ability to store and reproduce phonological information without the influence of prior language knowledge. Researchers have argued for the use of processing measures, such as nonword repetition
tasks, in the identification of language impairments (Conti-Ramsden, 2003). Children with SLI have been found to exhibit significant deficits at longer syllable lengths (3- and 4-syllable nonwords) relative to typically developing children. Furthermore, in a post hoc analysis it was found that when participants were grouped based on high or low phonological STM span, there was a group difference in Activation Point results. This suggests that there is an important relationship between phonological STM and spoken word recognition. The next analysis explored this relationship between lexical access and phonological memory through a Pearson’s bivariate correlation between nonword repetition scores and gating performance. Scores at 3-syllable, 4-syllable and total lengths were used to represent phonological processing abilities.

For the two groups taken together, there were significant negative correlations between overall gating performance (all words), measured at the Activation Point (AP), and the 3-syllable nonword score ($r = -.548$, $p < .05$, two-tailed), the 4-syllable nonword score ($r = -.526$, $p < .05$, two-tailed) and the total nonword score ($r = -.624$, $p < .01$, two-tailed). In addition, there were significant negative correlations between the AP for early/dense words and the 3-syllable nonword score ($r = -.524$, $p < .05$, two-tailed), between the AP for late/sparse words and the 4-syllable nonword score ($r = -.510$, $p < .05$, two-tailed), and the AP for late/sparse words and the total nonword score ($r = -.530$, $p < .05$, two-tailed). The more accurately a participant repeated the longer nonwords, the more quickly he or she activated a target word in the gating task.

It is curious that the correlations between phonological STM and word recognition of early/sparse and late/dense words were not significant. We know from the gating results that all participants recognized the early/sparse words more quickly than words from all three
other conditions. It is possible that the early/sparse words were so well represented in participants’ lexicons (i.e., strong connections between levels) that level of phonological processing ability didn’t have an effect. For late/dense words, it is possible that the high phonotactic probability of targets facilitated word recognition (due to increased overall connection strength), outweighing the effect of phonological STM span.

In terms of word-initial phoneme perception (PIP scores), for the two groups taken together, there were significant negative correlations between overall gating performance (all words) and the 3-syllable nonword scores ($r = -0.539$, $p < .05$, two tailed) and the 4-syllable nonword scores ($r = -0.569$, $p < .05$, two-tailed) and the total nonword score ($r = -0.580$, $p < .05$, two-tailed). The more accurately a participant repeated the longer nonwords, the more quickly he or she identified the initial phoneme of target words in the gating task.

No significant correlations were found between nonword repetition and the IP or the TAP for both groups analysed together and for each group analysed separately.

When the RV group was analysed separately, a strong relationship was found between nonword repetition performance and word-initial phoneme identification. Results revealed a strong negative correlation between the PIP for all words and the 4-syllable nonword score ($r = -0.962$, $p < .001$, two-tailed) and the total nonword score ($r = -0.945$, $p < .001$, two-tailed), and a moderate negative correlation between the PIP for all words and the 3-syllable nonword score ($r = -0.667$, $p < .05$, two tailed). Moderate, negative correlations were found between the AP for all words and the 4-syllable nonword score ($r = -0.682$, $p < .05$, two-tailed) and the total nonword score ($r = -0.774$, $p < .05$, two-tailed).

When the SLI group was analysed separately, correlations were found between the nonword repetition score and the PIP. Results revealed negative correlations between the PIP
for all words and the 3-syllable nonword score ($r = -.749$, $p < .05$, two-tailed) and the total nonword score ($r = -.747$, $p < .05$, two-tailed). No significant correlations were found between the AP and nonword repetition scores when the SLI group was analysed separately.

3.6.3 Semantic Representation and Lexical Access

Another level of processing that may affect lexical access is semantic representation and activation. Correlations between mean performance on the gating and the semantic tasks,\textsuperscript{36} in the Close condition (detailed semantic knowledge) and in the Semantic associate condition (distinct or overlapping semantic boundaries between related items) were investigated using Pearson's bivariate correlation. Gating results at all four measurement points (PIP, IP, TAP and AP) were correlated with results from the semantic task, measured as percent correct in the Close and Semantic associate conditions. For both the gating task and the semantic task data used in this correlation analysis, any item for which a participant could not match the spoken word to the correct picture in both the close and the distant condition of the semantic task was excluded for that participant.

No significant correlations were found between the overall gating performance (all words) at the activation point and either the Close condition or the Semantic associate condition when all subjects were considered together or when RV controls were considered separately. However, when the SLI subjects were considered separately, a moderate negative correlation was found between the AP for all words and performance in the close condition ($r = -.671$, $p = .068$) that almost reached significance. That is, the higher the number of words a SLI participant correctly identified in the close condition of the semantic task, the more

\textsuperscript{36} For this analysis a small number of trials were excluded from the gating results and the semantic task results. For any item for which a participant could not match the spoken word to the correct picture in at least one of the close or the distant condition of the semantic task (i.e., the participant did not know the meaning of the word) these trials were excluded from both the gating results and the semantic results used in this correlation analysis.
quickly a target word was activated, suggesting that semantic knowledge plays a role in lexical access for children with SLI.

3.6.4 Summary of correlations

Vocabulary size correlated negatively with word activation of the hardest words for all participants: the larger a child’s vocabulary size, the more quickly late-acquired words from dense neighbourhoods were activated. When the SLI group was analyzed separately a strong negative correlation was found between vocabulary size and activation of all target words: the larger the vocabulary of an SLI child the more quickly target words were activated. Finally, word-initial phonemes were identified more quickly the larger a participant’s vocabulary. Phonological short-term memory also correlated with word recognition: for both groups the higher the nonword repetition score (three- and four-syllables, and total scores) the more quickly words were activated in the gating task. Similar results were found when the RV group was analyzed separately, but not when the SLI group was analyzed separately. A marginally significant correlation between semantic knowledge and word recognition was found for the SLI group only: the higher the number of words an SLI participant could correctly match in the Close condition, the more quickly words were activated on the gating task.

3.7 Summary of major findings

1. Age-of-acquisition: Listeners needed significantly more acoustic input to activate, identify and confidently identify late-acquired target words compared to early-acquired target words. There were no significant AOA by Group interactions for any of the dependent variables. There was a significant AOA by ND interaction, such that early-acquired words from sparse neighbourhoods were identified earlier than words in the three other conditions.
2. **Neighbourhood Density**: Listeners were able to activate, identify and confidently identify words from sparse neighbourhoods with significantly less acoustic information as compared to words from dense neighbourhoods. There were no significant ND by Group interactions.

3. **Group Differences**: Results revealed no significant differences between groups for the Phoneme Identification point or the Activation Point. There was a trend towards the SLI group needing more acoustic information to identify a target word than the RV group; however, the effect was not significant. Yet, when participants were split into groups based on performance on a processing-dependent measure (nonword repetition task), a group effect was found, such that participants who performed well on the nonword repetition task (scored above the mean) needed significantly less acoustic input to activate a target word than participants who performed poorly (scored below the mean).

4. **Semantic Representation**: AOA and ND also had an effect on participants’ ability to match a picture to a spoken word, such that participants were correct on a significantly higher proportion of trials of early-acquired words as compared to later-acquired words, and also on a significantly higher proportion of words from sparse neighbourhoods compared to words from dense neighbourhoods. However, the interaction between AOA and ND suggests a more complicated picture. For early-acquired words, children correctly matched more words from sparse neighbourhoods than dense neighbourhoods. In contrast, for late-acquired words, children correctly matched more words from dense neighbourhoods than sparse neighbourhoods.

5. **Nonword Repetition**: The SLI group performed significantly more poorly on the nonword repetition task compared with the RV group. There was also a main effect of length
such that all participants were significantly more accurate on shorter nonwords than longer nonwords. Results did not reveal a significant group by length interaction.

6. **Lexical Access and Semantic Representation versus Phonological Memory**: For both groups, results revealed a relationship between vocabulary size and word-initial phoneme perception and target word activation, such that the bigger the vocabulary the more quickly word initial phonemes and target words were recognized. In addition, the results suggest a relationship between phonological memory and lexical access for all participants and a relationship between semantic representation and lexical access; however, the latter was true only for participants with SLI. A trend was found, such that SLI participants with more detailed semantic representations activated target words more quickly than those with less detailed semantic representations; however, the results were not significant.
Discussion

The aim of the current study was to examine spoken word recognition by children with typical language development and children with specific language impairment. The effect of lexical characteristics (age-of-acquisition and neighbourhood density) on word recognition by these children was also investigated. As well, the relationship between spoken word recognition and phonological short-term memory and semantic representation was explored. The following discussion will present and interpret the principal results of this study in relation to the hypotheses outlined in chapter one and as they relate to the current research literature. Limitations of the study, clinical implications and suggestions for future research will close this chapter.

4.1 Spoken Word Recognition

In this section I will review the hypotheses made regarding the gating task and summarize the main findings, first for the main effects of Group, AOA and ND, and then for interactions. This will be followed by a discussion of past research as it relates to the findings from the current project and the implications for children with SLI.

4.1.1 Hypothesis #1: Group differences

The first goal of the current study was to investigate whether children with SLI would display word recognition deficits compared to typically developing vocabulary-matched children. Children with SLI show lexical deficits early in life as well as low-level auditory-perceptual deficits; therefore, it was hypothesized that children with SLI would need to hear more of a word to recognize it compared to vocabulary-matched children.

The results for the four dependent variables did not confirm this prediction, with three results of primary interest: 1) Children in both groups required a similar percentage of the
acoustic signal to discriminate the first phoneme of the target word and guess a word beginning with the same phoneme. This suggests that children with SLI perceive auditory phonemic information (small amounts, at least) as accurately as RV controls, 2) No significant group differences were found for the amount of the signal needed to discriminate a word from similar sounding words (IP and TAP), although there was a trend towards the SLI group needing more of the signal (85 %) compared to the RV group (77 %) and 3) To activate the target word (AP), no group differences were found, suggesting that children with SLI performed equally to typical children with the same vocabulary level.

It is important to remember that the three dependent variables that measure word recognition are affected differently by task variables. All three points (AP, IP and TAP) reflect lexical activation and selection, because one word must be selected in order to respond to the trial. Behaviorally, the activation point is the first point at which the correct word is spoken. The AP results suggest that children with SLI activate and select words in their lexicon as readily as typically developing children. The isolation and total acceptance points are likely more influenced by what a participant thinks about the task. For example, if a child guesses a certain word on an early gate and then is presented with another gate, the child may take this to mean that he or she did not have the right answer in a previous trial and should guess a different word. Given the influence of a participant's meta-task understanding, IP and TAP results are a less reliable indicator of lexical selection compared to AP.

All results from the gating task must be interpreted with caution given the small number of participants in each group. In particular, the finding of no group difference between the two groups for the IP and TAP should be replicated because, although it was not
significant, a trend was found towards the SLI group requiring more of the acoustic signal, and the lack of significance could be due to the small number of participants in each group.

4.1.2 Hypotheses #2 and #3: Main effects of AOA and ND

Age-of-acquisition and neighbourhood density have been shown to affect word recognition by both children and adults; listeners more quickly identify ‘easy’ words (early AOA or sparse neighbourhood density) compared to ‘hard’ words (late AOA or from dense neighbourhoods) (Garlock et al., 2001). Thus, hypothesis #2 projected that children would need to hear less of early-acquired words to identify them compared to late-acquired words. Hypothesis #3 predicted that children would need less input to identify words from sparse neighbourhoods compared to words residing in dense neighbourhoods.

Results for the three dependent variables that measure recognition of the word (LP, TAP and AP) confirmed both hypotheses. Significantly less of the acoustic signal was needed to activate (.68), identify (.77) and confidently identify (.82) early words compared to late words (.76, .85, and .89, respectively). Similarly, significantly less of the acoustic signal was needed to activate (.65), identify (.76), and confidently identify (.80) words from sparse neighbourhoods compared to words from dense neighbourhoods (.78, .85, and .91, respectively).

Results of the phoneme identification point revealed no significant effects of AOA or ND, suggesting that lexical characteristics do not influence perception early in the time course of word recognition (word-initial phoneme identification).

4.1.3 Hypotheses #4 and #5: Interactions of Group x AOA and Group x ND

Given Montgomery’s (1999) finding of no difference in spoken word recognition between children with SLI and vocabulary-matched peers for familiar words and Dollaghan’s
finding of a group difference in spoken word recognition of newly acquired words, it was hypothesized that there would be interactions between the variables of Group and AOA and between Group and ND. Previous results suggest that in the current project, a group difference should be found for 'hard' words but not for 'easy' words. Specifically, hypothesis #4 stated that children with SLI would need more input to identify late-acquired words compared to controls, but for early-acquired words the two groups would not differ. Similarly, hypothesis #5 predicted that children with SLI would need more input than typically developing control children to recognize words from dense neighbourhoods but not for sparse neighbourhoods.

Results from the gating task did not confirm these predictions. There was no significant Group x AOA or Group x ND interaction for the PIP, IP, TAP or AP variables. To identify easy words, the control group needed less input than the SLI group and the same result was found for hard words, though the group differences were not significant. In addition, for both groups, there was no significant difference in the amount of the word needed to identify the first phoneme for hard words versus easy words.

4.1.4 Hypothesis #6: Interaction of AOA x ND

The final hypothesis regarding a two-way interaction of independent variables concerned the interaction between age-of-acquisition and neighbourhood density. Past research demonstrated an effect of AOA on words from both sparse and dense neighbourhoods as well as an effect of ND on both early and late words for children in grades one and two (Garlock et al., 2001). Thus, it was hypothesized that there would be no interaction between the two variables for the participants of the current study who were of a similar age.
Contrary to my predictions, results for word recognition (IP, TAP, and AP) did reveal an interaction between age-of-acquisition and neighbourhood density. Early-acquired words from sparse neighbourhoods were recognized with significantly less acoustic information than words in the other three conditions (early/dense, late/sparse and late/dense). These results suggest that density has an effect on early-acquired words only. While my prediction was not confirmed, these results do parallel the accuracy results found by Garlock et al. (2001) for younger children (mean age 5.6) using a word repetition task (to be discussed further below).

Results also revealed an interaction between AOA and ND for the PIP: the initial phoneme was identified much earlier in early/sparse words and late/dense words than early/dense words and late/sparse words. This interaction is unexpected given the lack of main effects of AOA and ND for this dependent variable, which suggest that lexical characteristics do not affect the perception of a word-initial phoneme. It is likely that this result is spurious and due to poor identification of the word-initial phoneme for three stimuli: *hill* (early/dense) and *vine* and *geese* (late/sparse). Specifically, 13 out of 17 participants had great difficulty identifying the first phoneme of the stimulus *hill* (from the early/dense condition; many perceived /p/ at early gates and perseverated in this response), and in the late/sparse category there were two stimuli that posed significant difficulty for children: 6 out of 17 had difficulty with *geese* (common response: *keys*) and 4 out of 17 had difficulty with *vine* (common response *find*). Given that virtually all participants identified the initial phoneme by the first or second gate for the other stimuli, it is likely that the results for the above three stimuli increased the mean PIP, resulting in the observed interaction.
4.1.5 Hypothesis #7: Three-way interaction

The final hypothesis about word recognition concerned the three-way interaction of Group, AOA and ND. Previous research (Garlock et al., 2001) found that typically developing children (mean age 7.6) were more accurate in repeating sparse words than dense words for both early- and late-acquired words. While no previous research into the effect of these lexical characteristics on word recognition by children with SLI existed to guide our hypotheses, results from younger children (mean age 5.6) were available which suggested that ND had an effect on early words but not late words (Garlock et al., 2001). Given that children with SLI often perform like younger children (due to language level or developmental state), I used these results to guide my hypothesis. Specifically, it was hypothesized that density would have an effect on both early and late words for RV controls, but that density would only affect early words in the SLI group.

Contrary to these predictions, results revealed no significant interaction of AOA, ND and Group for the PIP, IP, TAP and AP variables. The pattern was the same for both groups: early/sparse words showed an advantage compared to early/dense words, late/sparse words and late/dense words. As mentioned above, both groups in the current study performed like the younger children in Garlock et al. (2001) with regard to the interaction between age-of-acquisition and neighbourhood density.

4.1.6 Summary of main findings

Results from the gating task did not show a significant difference between groups for word-initial phoneme identification or for word activation and recognition. Early-acquired words were recognized with significantly less of the acoustic signal than late-acquired words and words from sparse neighbourhoods were recognized with significantly less acoustic
information than words from dense neighbourhoods. Furthermore, AOA and ND interacted such that early/sparse words were identified with significantly less acoustic information than early/dense, late/sparse and late/dense words. AOA and ND did not have an effect on the phoneme identification point. Finally, results revealed no significant interaction of AOA x Group, ND x Group or AOA x ND x Group for any of the dependent variables.

4.1.6.1 Previous research with children with SLI

The results of the current project suggest that children with SLI do not have deficits in spoken word recognition, even for ‘hard’ words (late-acquired and/or with many phonological neighbours) compared to typically developing children at the same vocabulary level. We know from Montgomery (1999) that children with SLI recognize highly familiar (‘easy’) words as readily as typically developing children (both age-matched and vocabulary-matched). On the other hand, the results of Dollaghan (1998) revealed a difference between children with SLI and age-matched controls in the recognition of very ‘hard’ words (in this case newly learnt nonwords). The results of the current study provide information about how children with SLI recognize words that are not just learned but also are not highly familiar (words that are in the middle of the continuum of lexical knowledge).

The late-acquired and high neighbourhood density words used in the current project were not as familiar as the words used by Montgomery but likely more familiar than the words used by Dollaghan since the ‘hard’ words in the current project were real words, and it was confirmed that they were in the receptive lexicons of participating children. The ‘hard’ words in Dollaghan’s study, by contrast, were presented only nine times each (presented with a novel object) and participants only had to produce each new word at least two times. This fast mapping procedure likely created very weak representations of the newly learnt lexical
items. Taken together, the results of all three studies suggest that once a word is in the receptive vocabulary of a child with SLI, regardless of whether it is a hard or easy word, his or her ability to recognize the word is comparable to typically developing children at the same vocabulary level.

Results from the current study contradict those recently published in a conference poster (Mainela-Arnold, Evans & Coady, 2005). This study found a significant group difference in spoken word recognition between 20 children with SLI and 20 age-matched peers (age range 8;5 to 12;3). As in the current study, Mainela-Arnold et al. used a gating task; they measured responses at two points: the ‘Point of Isolation’ and the ‘Point of Acceptance’, which correspond to the current study’s AP and IP, respectively. Their results revealed a significant effect of group for the point which reflects later lemma selection (IP in the current study) but not for the earliest point of word selection (AP in the current study). The authors suggested that the children with SLI had activated lexical items as readily as typically developing children, but that they “vacillated between multiple word candidates for longer times.” One possible explanation of the conflicting findings is the nature of the control groups used: Mainela-Arnold et al. employed an age-matched control group which likely had a higher vocabulary level than the children with SLI. The current study employed a vocabulary-matched control group: younger children with the same vocabulary comprehension level. It is very possible that the difference found by Mainela-Arnold et al. was due to the difference in language abilities (specifically vocabulary size) of participants in each group.

37 The children in the current project ranged in age from 8;4 to 10;10 and therefore were a little younger than in Mainela-Arnold et al.
A second possible, but less likely, explanation of the difference should be mentioned. While the current study did not find a significant group difference at the IP, a trend towards the SLI group requiring more acoustic information (vacillating longer) was found. It is possible that the lack of significance was due to the small number of participants in the current study. Given this possibility the current study should be replicated with a larger sample size.

4.1.6.2 Implications for SLI

The fact that the two groups identified word-initial phonemes with equal ease suggests that basic phoneme perception is no different in children with SLI than vocabulary-matched typically developing children. Low-level auditory perceptual impairments demonstrated in children with SLI do not appear to be causing difficulties in word recognition early in the time course of recognition. We can use these results to project that children with SLI recognize word-initial phonemes of spoken words as accurately as typically developing RV matched children in real life listening situations. Compared to other tasks, such as the discrimination and identification of synthesized phonemes, the gating task is high in ecological validity. In the gating task real words are presented, from the beginning of a word, and are produced by a human speaker.

Similarly, the current finding that SLI and RV children activated target words (the AP variable) with equivalent amounts of input suggests that for their level of vocabulary development, children with SLI activate items in their lexicon normally. The activation point can be thought of as representing the earliest point of lexical selection. The lack of group differences at the AP suggests that this period of lexical processing occurs in a normal fashion for children with SLI.
Finally the finding of no group difference for the two dependent variables that measure word recognition (the IP and TAP) suggest that children with SLI also recognize words as readily as typically developing, vocabulary-matched children. However given the contrasting findings of Mainela et al. (2005) and the small number of participants employed in the current study, these findings should be taken with caution until replicated. These results suggest that children with SLI do not have more difficulty inhibiting competing lemmas (phonologically similar words from the same neighbourhood), than RV children. Furthermore, if children with SLI have reduced resources in the system, it is not affecting the amount of time it takes them to reach the threshold necessary for selection of the correct lemma. Finally, it does not appear that the children with SLI had more difficulty discriminating and encoding a stream of phonological information (a spoken word) than RV children as predicted by the literature on auditory-perceptual impairments in SLI.

4.1.6.3 Previous gating research with children

Both Metsala (1997a) and Garlock et al. (2001) explored the effect of lexical characteristics on spoken word recognition as it develops in childhood. Both studies found an effect of word familiarity (measured as word frequency by Metsala, and AOA and WF by Garlock) on word recognition, as was found in the current project: children identify more familiar words more readily than less familiar words. Furthermore, both studies found a similar effect of neighbourhood density. Metsala (1997a) and Garlock et al. (2001) found that words residing in sparse neighbourhoods were easier to recognize than those from dense neighbourhoods, which converges with the results of the current study.

While Garlock et al. did not find a significant main effect of neighbourhood density on the gating task when considering all subjects, they did find that older children (mean age
7.6, similar to children in the current project) and adults needed less input to identify and confidently identify words residing in sparse neighbourhoods compared to those from dense neighbourhoods. Notably, on the word repetition task they did find a significant effect of ND for all groups. Together, these results provide further support for the relevance of the Neighbourhood Activation Model, and interactive-activation models of spoken word recognition by children. The current finding of slower recognition of words residing in dense neighbourhoods compared to words from sparse neighbourhoods (for early-acquired words only) in children is evidence of the automatic and unconscious activation of lexical items that share phonological units with the target word, as predicted by interactive-activation models.

Regarding the interaction of AOA and ND there are significant differences between Metsala’s findings, Garlock et al.’s findings and those of the current project. Metsala found an interaction between WF and ND for the adult group only.\textsuperscript{38} Furthermore, the pattern of interaction that Metsala found contrasts with the pattern found by Garlock and in the current study. Metsala reported that the recognition of familiar (high frequency) words was facilitated in sparse neighbourhoods compared to dense neighbourhoods and that, conversely, the recognition of less familiar (low frequency) words was facilitated in dense neighbourhoods. By contrast, Garlock et al. found that both early- and late-acquired words (highly and less familiar) were recognized more accurately from sparse neighbourhoods as opposed to dense neighbourhoods for both the older children (mean age 7.6) and adults. However, for the youngest children in the Garlock et al. study, words from sparse neighbourhoods only had an advantage over words from dense neighbourhoods if they were acquired early. There was no effect of density for late-acquired words.

\textsuperscript{38} The results for the three groups of children (mean ages of 6;3, 9;2 and 10;10) parallel those of the adult group but did not reach significance.
Results from the current study on the interactions of ND and AOA converge with those for the youngest children in the Garlock et al. study even though the children from both groups in the current study were closer to the age of the children in the "older" group. In both cases, neighbourhood density only had an effect on recognition (or repetition in Garlock et al.) of early-acquired words. Why would the performance of children in the current study resemble that of younger children in Garlock et al.? While the mean age of the older group (7;7) in the Garlock study was just a little younger than the mean age of the participants in the current project (8;4), a comparison by chronological age is not fair given the involvement of an impaired population in the current study. A better comparison would be receptive vocabulary level. Garlock measured the receptive vocabulary level of participants using the PPVT (Dunn & Dunn, 1981), the same standardized test used in the current study. The mean receptive vocabulary level of Garlock et al.'s older group was higher (mean raw score = 112) than in the current study (SLI mean raw score = 105, RV mean raw score = 106 and M = 105 for both groups). This difference in vocabulary development (size) could account for the contrasting results: the vocabulary level of the children in the current study was not high enough to result in adult-like performance. Perhaps, a certain vocabulary size is required before late AOA words are specified enough to show effects of ND.

Also contrasting with the findings of the current study regarding ND and AOA are the findings of Mainela-Arnold et al. (2005). While the current study found that children in both groups identified (AP, IP and TAP) early-acquired words from sparse neighbourhoods more quickly than words from dense neighbourhoods, Mainela-Arnold found no significant effect of ND on word recognition (IP) for the typically developing group and found that children
with SLI recognized (IP) words from dense neighbourhoods *more quickly* than words from sparse neighbourhoods.

Mainela-Arnold et al.’s findings for the SLI group are difficult to reconcile with the current study’s findings without more information about the language abilities of their participants and the characteristics of their stimuli. However, Mainela-Arnold et al.’s findings do coincide with those of Luce & Pisoni (1998) and Metsala (1997a) who also found a facilitating effect of ND – but only for low frequency words. One possible interpretation of Mainela-Arnold et al.’s results is that the SLI children in her study had weak connections at all levels of the lexical network and were benefiting from the high phonotactic probability of the dense neighbourhoods.

While no significant differences in word recognition between the two groups were found in the current study, AOA and ND were shown to have significant effects on word recognition. Children needed a significantly larger proportion of the acoustic signal to activate and recognize hard words (late-acquired or from dense neighbourhoods) compared to easy words (early-acquired or from sparse neighbourhoods). Semantic knowledge and phonological processing are two areas of linguistic development that could be related to word recognition. In the next section I review post-hoc and correlational analyses that were conducted to explore these relationships.

4.2 Linking Word Recognition to semantic representation and phonological memory

4.2.1 Hypothesis #8: correlations between tasks

Priming studies have clearly demonstrated the facilitative effect of semantically related information (using printed and spoken words and pictures) on naming performance (McGregor & Windsor, 1996). Recent research (McGregor et al., 2002) suggests that limited
semantic knowledge contributes to naming errors made by children with and without SLI. This raises the possibility that the integrity of semantic representations and/or their access could also affect word recognition since both naming and word recognition depend on successful lexical access. Alternatively, primary deficits at the phonological level (in encoding and storing phonological information) in children with SLI could lead to difficulties in spoken word recognition. In the final hypothesis, I predicted that both limited semantic representations and phonological memory limitations would contribute to slower word recognition. This would be demonstrated by: 1) correlations between the gating task and the semantic task, or 2) a finding that words with detailed semantic representations were recognized more quickly than words with sparser semantic representations, and 3) correlations between the gating task and the nonword repetition task. In this section I will summarize the findings from these analyses and discuss them in light of past research. Then I will discuss the implications of the results for an interactive-activation model of spoken word recognition.

4.2.1.1 Phonological short-term memory and spoken word recognition

Conti-Ramsden (2003) claims that nonword repetition performance is a sensitive marker of specific language impairment, and several researchers have used performance on this task as an inclusionary criterion in their studies of the abilities of children with SLI (e.g., McGregor et al., 2002). In the current study, the nonword task was used as an experimental measure rather than a criterion for language status, yet we were curious whether the children in the SLI group would have been included in the study had the NWT been used as a criterion for participation.
One way to evaluate NWT performance is to take the total scores (TOTPPC) for all participants and average them. With this mean score, participants can be divided into two groups depending on whether their score was higher than the mean (high group) or lower than the mean (low group). By this method, 6 SLI participants and 2 RV controls formed a low group and 7 RV controls and 2 SLI participants formed a high group. Performance on the gating task for these new groups was then submitted to a 2 (Group) x 2 (AOA) x 2 (ND) repeated measures analysis of variance.

Results revealed that participants who performed poorly on the NWT needed significantly more (75 percent) of the signal to activate a word (AP) than participants who performed well on the NWT (69 percent). This group difference was not found when the ANOVA was conducted with the original SLI/RV groupings. This suggests that basic phonological encoding/memory abilities support spoken word recognition by children with impaired and normal language abilities. Further support for this interpretation is the trend towards a group difference in identification of word-initial phonemes. While this finding did not reach traditional levels of significance (p = .063), the High NWT group identified word-initial phonemes with less of the signal (32 percent) than the Low NWT group (34 percent). This result suggests that children who perform well on nonword repetition tasks have better phonological processing (perception, encoding and/or storage).

In a second analysis of the relationship between phonological short-term memory and word recognition, a bivariate correlation was conducted between NWT scores (at 3- and 4-syllable lengths and for the total score) and spoken word recognition. A moderate, negative correlation was found between the AP for all words and the NWT scores at the 3-syllable, 4-syllable and total lengths. NWT scores also correlated negatively with word-initial phoneme
identification. These results suggest that for both typically developing children and children
with SLI, those with larger phonological STM spans identify word-initial phonemes and
activate lexical items with less acoustic input.

When the two groups were analyzed separately, different results were found for each
group. For the RV subjects, strong negative correlations were found between word-initial
phoneme identification and phonological STM at the 4-syllable and total lengths (-.962, -.945
respectively) and moderate negative correlations were found between word activation and
phonological STM at 4-syllable and total lengths (-.682 and -.774 respectively). For the SLI
subjects there were no significant correlations between the AP and phonological STM;
however moderate, negative correlations were found between the PIP and nonword repetition
at the 3-syllable and total lengths (-.749 and -.747, respectively). It should be noted that,
while not significant, the relationship between NWT and the AP for all words for the SLI
group was in the same direction as for the RV group (negative) and the smaller correlation
and lack of significance is likely due to the small group size. These results need to be
replicated with larger sample of children.

These correlation results between the NWT and the gating task suggest that
phonological processing and storage contributes significantly to spoken word recognition
abilities. Nonwords have no lexical or semantic representations associated with them, and the
non-word repetition task is, therefore, interpreted to reflect aspects of phonological
processing and memory. In particular, the finding of strong correlations between the NWT
and word-initial phoneme identification suggests that phoneme perception plays a crucial
role in nonword repetition. Unlike the primary gating results, this correlation suggests that
participants had varying abilities to identify word-initial phonemes in the current study and
that more accurate word-initial phoneme perception supports nonword repetition. It is also possible that phonological STM supports word initial phoneme perception since correlational analyses cannot tell us about the causal nature of the relationship.

While many theorists believe that phonemic categorization abilities are in place well before the end of the first year of life, recent research has started to challenge this notion (Hazan & Barrett, 2000 and Nittrouer, 2001). Nittrouer (2001) found high levels of individual variability amongst infants (ages 6 – 14 months) and preschoolers (ages 2;6 to 3;4) in the ability to discriminate phonemic contrasts in natural and synthetic stimuli. Moreover, even school-age children as old as 12 have been found to be less consistent in phonemic categorization than adults (Hazan & Barrett, 2000), and have high levels of individual variability. These studies provide converging evidence of significant variation in word initial phoneme perception amongst elementary school-aged children.

In sum, these results suggest that there is a strong relationship between word-initial phoneme perception and nonword recognition for both children with and without specific language impairment. Furthermore, they suggest that word recognition and phonological STM are related for both groups, though this finding should be replicated with a larger number of children with SLI.

4.2.1.2 Semantic representations and spoken word recognition

Another aspect of lexical access that could affect spoken word recognition is semantic representation. Just as word familiarity affects word recognition, words with robust semantic representations could be recognized more quickly than words with sparse semantic representations. Level of detail in semantic representation could simply be another aspect of word familiarity, or alternatively, semantic representation could be coded in connection
strengths, affecting overall activation levels and resources required. It was predicted (hypothesis #8) that word recognition would occur earlier for words with detailed semantic representations compared to words with sparse semantic representations. In this section, I will summarize the findings from several post-hoc analyses that were conducted to explore this possibility.

To directly explore the possibility that robustness of semantic representation affects word recognition, results from the semantic task were used to distinguish words with detailed semantic representations (words identified successfully in the Close condition of the semantic task) from words with sparser semantic representations (words incorrectly identified in the Close condition but correctly identified in the Distant condition). Based on these groupings the results from the gating task were re-submitted to a 2 (Group) x 2 (Level of Semantic Knowledge: detailed, sparser) mixed-design ANOVA.

Contrary to my prediction, the results showed no main effect of level of knowledge – target words were activated, identified and confidently identified with similar amounts of acoustic input regardless of depth of semantic knowledge. It is possible that the semantic task (picture pointing) was not a sensitive enough measure of semantic knowledge and that a productive measure such as the defining and drawing tasks used by McGregor et al. (2002) would more accurately distinguish words based on the level of semantic representation, which could result in a difference in spoken word recognition.

The second analysis performed to examine the relationship between semantic knowledge and spoken word recognition was a bivariate correlation between performance on the gating task and on the semantic task. In sum, correlations were found for the SLI group only: a significant negative correlation was found between the mean AP of all words and the
percent correct in the Close condition of the semantic task. This suggests that the more acoustic input needed to activate a target, the less detailed were the semantic representations overall. Again, due to small numbers of participants in each group, the lack of significant finding for the RV group must be taken with caution and should be replicated.39

4.2.1.3 Summary of correlation results

To summarize the relationship between spoken word recognition and semantic representations and phonological processing, it seems that semantic knowledge, as measured by a picture-word matching task, is closely related to spoken word recognition for the SLI children but not for the RV children. And yet the SLI group did not demonstrate semantic deficits relative to the RV group. However, the nonword repetition task revealed significant phonological short-term memory deficits in the children with SLI relative to controls. One interpretation of these results is that when word discrimination is more difficult, a word’s semantic information can assist with recognition. If phonological processing is more difficult in general for children with SLI than vocabulary-matched children, then we would expect to find that children with SLI are assisted by semantic representations but that typically developing children are not. The correlation between semantic knowledge and ease of spoken word recognition for the children with SLI and not for controls supports this interpretation.

Further support comes from a study by Tyler, Voice & Moss (2000) that examined the interaction of phonology and semantics in spoken word recognition. Adults in this study completed two tasks: auditory lexical decision and word repetition; reaction time was measured in both. Stimuli (single one- and two-syllable words) varied in terms of familiarity

39 However, for the RV group the correlation between percent correct in the close condition and the AP for all words was positive (opposite direction to that found for the SLI group) and not significant; therefore, it is less likely that a significant correlation would be found with a larger sample than for the nonsignificant correlation between gating (AP) and NWT found for the SLI group alone (see p.18).
and imageability, or "the degree to which [a word's] referent can be perceived through the senses" (Tyler et al., 2000, p.320). Results from both tasks showed that participants responded to high-imageability words faster than low-imageability words. Results from the repetition task also revealed an interesting interaction between imageability and cohort size (which corresponds roughly to neighbourhood density).\footnote{Words that form a cohort share onsets (CV) with each other and are therefore phonologically similar; like ND, words from large cohorts experience greater competition than words from small cohorts.} Imageability had an effect only on words from large cohorts; from this interaction the authors concluded that semantics help when phonological discrimination is most difficult. If phonological discrimination is more difficult for children with SLI than typically developing children at the same vocabulary level, then strong connections between lexical items and the semantic level could aid or compensate in word recognition. Strong semantic connections would assist by raising activation levels of the target lemma, thereby facilitating word recognition.

An important difference between the current study's findings and those of Tyler et al. must be noted. Whereas Tyler et al. found a relationship between representation at the semantic level and word recognition by adults with normal language, the current study only found a relationship between semantics and word recognition by the participant group with disordered language. However, task differences could account for the difference. In word repetition, the listener only hears the target word once, compared to the gating task in which the listener hears the first half of a word at least three to four times. As a result, it is likely that discrimination is easier in gating than in repetition. If this is the case, then one could argue that even for words from high density neighbourhoods, discrimination of a word in the gating task does not become difficult enough to reveal the effects of semantics for typically developing children.
Support for this claim can be found in Garlock et al. (2001), who suggest that the word repetition task is “more sensitive to both listener and stimulus characteristics” than the gating task and who appeal to these task differences to explain the contrasting results they found.\(^{41}\) However, for individuals who have a more difficult time in general discriminating spoken words (e.g., children with SLI), semantics does affect spoken word recognition in a gating task. The poorer nonword repetition performance of the SLI group compared to the control group in the current study provides evidence for the claim that the children with SLI have a more difficult time with word discrimination at the phonological level.

4.3 Lexical characteristics and semantic representation

The strong effects of AOA and ND on word recognition found in the current study provide another avenue for examining the effect of semantic representation on word recognition. Given that children needed significantly more acoustic information to recognize late-acquired words and those from dense neighbourhoods, if it is also found that late-acquired words or those from dense neighbourhoods have less detailed semantic representations than words from sparse neighbourhoods or those early-acquired then this would suggest that the semantic representation could be affecting word recognition.

The lexical characteristics, AOA and ND, explored in the current project could have an impact on semantic knowledge for two very different reasons. It is reasonable to expect that experience with a word over time enables one to develop a more thorough understanding of a word; therefore words acquired later would have sparser semantic representations than words acquired earlier. One might expect children to be able to select the correct picture that

\(^{41}\) Garlock et al. found an effect of neighbourhood density for young children (mean age 5.6 years) in a word repetition task but not in a gating task.
represents early-acquired words in the presence of close semantic competitors more often than for late-acquired words.

In contrast, the effect of neighbourhood density on performance in the semantic task would arise not from experience with words, but from the architecture of the lexicon and the nature of processing. From a connectionist perspective, lexical access involves automatic and interactive activation of representations at the phonological, lexical and semantic levels. In a picture-pointing task, the automatic activation of phonological competitors caused by feedback from the lemma level to the phonological level and back to the lemma level, could impact success in a picture-pointing task by causing activation of several lemmas and requiring more resources to inhibit the incorrect lemmas. If this is the case, then we would predict that one would be more successful on words from sparse neighbourhoods compared to dense neighbourhoods.

In the semantic task, results of the ANOVA revealed a strong effect of AOA in the Close condition: participants correctly pointed to 90 percent of words with early AOA versus 74 percent of words with late AOA. In the Distant and Total conditions, the effect of AOA did not reach traditional levels of significance (p = .075 and p = .086, respectively); however, children correctly pointed to the target on a higher percentage of trials for early words than late words in both conditions.

These results suggest that children have more detailed semantic representations of early-acquired words than late-acquired words. This is not surprising. Given the correlation found between the semantic task and gating results, it is possible that lexical items with more detailed semantic representations have stronger connections to their respective lemmas, which supports word recognition. It is also likely that early-acquired words have stronger
connections at all levels due to experience with the word over time compared to late-acquired words.

The results of the ANOVA on the semantic task results also revealed a significant interaction between AOA and ND in the Semantic associate condition (p = .007). For this variable, children from both groups performed best for early/sparse words compared to words from all other categories. However, for late words, participants had a higher percentage correct on dense words than sparse words. Two alternative explanations for this result are plausible. It is possible that for late-acquired words dense neighbourhoods facilitate the activation of the target and retrieval (or activation) of semantic information so that a semantic judgment can be more accurately made. This would be a processing advantage, enabling access to more semantic information for dense words compared to sparse words. However this is counter to the competition effect proposed by the Neighbourhood Activation Model (Luce & Pisoni, 1998) in which competition is higher for words from dense neighbourhoods, leading to a processing advantage for sparse words, not dense words. If the interaction between ND and AOA is simply a matter of processing demands at the time of retrieval, one would expect that children would perform most poorly on late-acquired words from dense neighbourhoods. However, this was not the case.

Alternatively, the effect could be due to differences in representation, if late words from dense neighbourhoods have more detailed semantic representations than late words from sparse neighbourhoods. Why would this be? While the link between phonological similarity neighbourhoods and the encoding of semantic representations does not seem transparent, a 2001 study by Storkel provides converging evidence for this interaction and an insightful explanation.
Neighbourhood density is positively correlated with phonotactic probability, which is a measure of the frequencies of segments (phonemes) and of sound sequences (two or more adjacent phonemes) (Storkel, 2001; see Vitevich & Luce, 1998 for further discussion). Some segments and sound sequences (e.g., /d/ or /bi/) occur more frequently in words than others (e.g., /g/ or /zi/), and dense phonological neighbourhoods are populated with the more common sounds and sound sequences. Storkel (2001) used a clever experiment to investigate word learning in typically developing pre-schoolers. After exposures of various lengths to nonwords that either had common or rare sound sequences she measured the children’s receptive knowledge of the word forms and word meanings using multiple choice tasks and productive knowledge of the word form using a naming task. Results revealed that the children acquired new words with common sound sequences more rapidly than those with rare sequences. Storkel also examined children’s incorrect responses to see whether phonotactic probability affected the formation of semantic or lexical representations or the link between the two. She found that nonwords with rare sound sequences were more likely to have sparse semantic representations than nonwords with common sound sequences.

Storkel appealed to the claim that children have limited resources to employ in the task of word learning. When fewer resources are available than are required, processing and storage of information may be diminished. As explained by Storkel, in the process of learning a new word, the child does not yet have any representation at the semantic or lexical level; however, the sound pattern of the word will match existing representations of phonemes. New words with common sequences of phonemes may require fewer resources for processing at the phonological level (due to lower thresholds of activation for those phonemes), freeing up resources for processing at the lexical and semantic levels.
This explanation accurately predicts the current study's findings that for recently acquired words (late AOA) children have more detailed semantic representations of dense words than sparse words. Early-acquired words no longer show an advantage for words in dense neighbourhoods because the child's experience with early-acquired words has given them opportunities to build semantic representations for them, and the advantage for words from dense neighbourhoods disappears. In contrast, for words that children have just recently learned, the high probability phonotactic patterns of words from dense neighbourhoods frees up resources that allow the child to encode a more detailed semantic representation. As a result, for late-acquired words residing in dense neighbourhoods children in the current study were better able to distinguish between items with a close semantic relationship and respond correctly in the Semantic associate condition of the semantic task.

4.3.1 Implications for SLI

While there was no significant effect of group in the results from the semantic task, closer examination of the results from the Semantic associate condition revealed that neighbourhood density made a bigger difference for late-acquired words for children with SLI (12 percent difference between sparse and dense words with late AOA) compared to RV matches (3 percent difference). This suggests that for children with SLI when learning new words, the processing advantage conferred by words from dense neighbourhoods (and therefore with high probability phonotactics) is higher than for typically developing children. Or conversely, children with SLI have greater difficulty encoding semantic information for words from sparse neighbourhoods (with low probability phonotactics). Thus, during word learning children with SLI may need more support in learning the meaning of a new word, particularly when the word is composed of rarer sound sequences.
4.4 Implications for models of lexical access

The finding that semantic representations are related to spoken word recognition provides further support for interactive-activation models of lexical access. In a connectionist model, words with more detailed representations have stronger connections between the lexical and semantic levels and/or have a greater number of connections between the semantic and lexical levels. In the case of difficulty discriminating a word (as appears to be the case for late-acquired words), weaker connection strengths or fewer connections decreases activation at the lexical level which then impacts the phonological level by demanding more resources to activate the correct phonemes.

4.5 Conclusions

In sum, the results of this study supported some of my hypotheses and not others. The hypothesis that children with SLI would need more of the acoustic signal to recognize spoken words was not supported. My hypotheses that children would need more acoustic information to recognize late-acquired words and also to recognize words from dense neighbourhoods were supported. Two hypotheses that predicted children with SLI would have more difficulty recognizing 'hard' words (late-acquired or from dense neighbourhoods) compared to typically developing children were not supported. Results revealed an interaction of AOA and ND, contrary to my sixth hypothesis. I hypothesized an interaction between AOA, ND and Group, but this was not found. Finally, I found tentative support for the hypothesis that phonological STM and the quality of semantic representations would be related to word recognition.

Overall, AOA and ND were found to have significant effects on word recognition by children both with and without SLI. These lexical characteristics do not appear to have an
effect on discrimination early in the time course of word recognition (e.g., word-initial phoneme identification). Notably, no significant group differences were found for word-initial phoneme identification, word activation or word recognition. Results from the current study provide support for interactive-activation models and for the claim that processing at all three interconnected levels (semantic, lexical and phonological) affects word recognition.

4.6 Limitations of the current study

The current study has a number of limitations. The first is the small number of participants in each group, which makes it difficult to confidently generalize the results to the larger population of children with SLI. As stated above, the results of Mainela-Arnold et al. (2005) provide diverging evidence of a group difference (for at least the IP and TAP), thus further research is needed.

The second limitation is that word frequency is confounded with age-of-acquisition. Unfortunately, the early-acquired words from sparse neighbourhoods in the current study are also more frequent than early-acquired words from dense neighbourhoods and late-acquired words from both types of neighbourhood. The gating results did find that spoken word recognition was fastest for early/sparse words compared to all others. This could be a result of the higher frequency in the early/sparse category. However, Garlock et al. (2001) examined the effects of both word frequency and AOA on spoken word recognition by children and found minimal effects of WF and significant effects of AOA. Garlock et al.'s results support the interpretation of the current findings indicating a strong effect of AOA on word recognition. Furthermore, the results from the ANOVA which contrasted high and low frequency words found no significant effect of frequency on any of the dependent variables (PIP, IP, TAP and AP).
The third limitation of the current study is the reliability of the semantic task. While picture-pointing tasks have been used to measure vocabulary comprehension for many years, (the first edition of the PPVT was published in 1965), the semantic distance between the distractors (both closely and distantly related to the target) needs to be validated. Given the evidence supporting the accuracy of subjective judgments of AOA, a study could be conducted where adults rated the semantic distance between words using a Likert scale. Another means of validating the semantic distance between the target and distractors would be to use another task paradigm, such as a priming study and compare the advantage provided by close versus distant distractors.

Finally, the lack of an age-match control group is a limitation of the current study. My comparison with vocabulary-matched children speaks to whether children with SLI might have deficits in word recognition for their vocabulary level; however, it does not speak to whether they have a delay in word recognition abilities for their age. Future studies should employ both age-matched and vocabulary-matched control groups.

4.7 Clinical implications

The current results suggest that children with SLI do not have a deficit relative to vocabulary-matched peers in spoken word recognition. However, given that this study examined the recognition of single words, these results do not speak to the recognition of larger amounts of spoken information (phrases, etc.).

The results also suggest that semantic information could aid in phonological processing for children with SLI. The current findings suggest that children with SLI have a deficit in phonological STM and in semantic representations of later-acquired words. One way to aid children with SLI in word comprehension would be to work on developing more
detailed semantic representations, especially of words composed of rare sound sequences. The hope would be that by developing the semantic representations of words phonological processing will be easier for these children. Another possibility would be to improve phonological processing.

4.8 Future research

Further research could qualitatively examine the incorrect guesses in the gating task to determine the lexical characteristics of the words that make up the incorrect guesses. It would be interesting to see if the incorrect guesses have higher frequency and earlier AOA values than the targets. One could also examine the neighbourhood density of incorrect guesses to see whether they have the same neighbourhood density or if they are in the neighbourhood of the target but actually have a neighbourhood that is less dense than the target.

To further examine the impact of semantic representations on word recognition by children with SLI, one could take a group of words and measure how well they are known. Then one could work on increasing the semantic knowledge of half of the words. After that, the children’s word recognition (using repetition or gating) could be measured to see if those with stronger or richer semantic representations are recognized more quickly.

A future study could employ a regression analysis in order to examine the relative contribution of semantic representation, vocabulary size, phonological STM, and other abilities (e.g., nonverbal auditory processing) to spoken word recognition. This was not feasible in the current study because the small number of participants in relation to the number of variables did not allow for adequate statistical power.
Finally, it would be useful to compare word recognition by children with SLI across two tasks: gating and word repetition. The results of the gating task suggest that children with SLI identify word-initial phonemes as accurately as typically developing vocabulary matched children but that in final word identification there may or may not be a difference between the two groups. It is possible that the gating task gives children with SLI an advantage that they do not have in real life by presenting just the initial acoustic information of a word at first. It is possible that children with SLI would have more difficulty with word initial phoneme identification on a word repetition task because there is more acoustic information to process. On the other hand, in a word repetition task there is more top-down support for word recognition. However, if it is the case that there is an advantage in word initial phoneme identification in the gating task, then children with SLI may have more difficulties in spoken word recognition in real-life and other experimental tasks than this study suggests.
5 References


learning impaired children improved with acoustically modified speech. *Science* 271, 81-84.


### Appendix A: Gating Stimuli

#### Condition 1: Early-acquired, sparse neighbourhood (n = 8)

<table>
<thead>
<tr>
<th>Word</th>
<th>AOA</th>
<th>ND</th>
<th>Source of ND rating</th>
<th>Frequency</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>foot</td>
<td>1.81</td>
<td>7</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>70</td>
<td>535</td>
</tr>
<tr>
<td>teeth</td>
<td>1.94</td>
<td>5</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>103</td>
<td>423</td>
</tr>
<tr>
<td>worm</td>
<td>2.38</td>
<td>8</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>4</td>
<td>544</td>
</tr>
<tr>
<td>dirt</td>
<td>2.25</td>
<td>6</td>
<td>Metsala 1997a</td>
<td>43</td>
<td>441</td>
</tr>
<tr>
<td>neck</td>
<td>2.44</td>
<td>7</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>81</td>
<td>414</td>
</tr>
<tr>
<td>dog</td>
<td>1.44</td>
<td>6</td>
<td>Metsala 1997a</td>
<td>75</td>
<td>416</td>
</tr>
<tr>
<td>goat</td>
<td>2.81</td>
<td>8</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>6</td>
<td>366</td>
</tr>
<tr>
<td>sky</td>
<td>1.94</td>
<td>3</td>
<td>Metsala 1997a</td>
<td>58</td>
<td>580</td>
</tr>
</tbody>
</table>

Mean  
\[ M = 2.13 \]  
\[ M = 6.25 \]

#### Condition 2: Early-acquired, dense neighbourhood (n = 7)

<table>
<thead>
<tr>
<th>Word</th>
<th>AOA</th>
<th>ND</th>
<th>Source of ND rating</th>
<th>Frequency</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>sock</td>
<td>1.5</td>
<td>22</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>4</td>
<td>455</td>
</tr>
<tr>
<td>bag</td>
<td>2.81</td>
<td>20</td>
<td>Metsala 1997a</td>
<td>42</td>
<td>359</td>
</tr>
<tr>
<td>hill</td>
<td>2.25</td>
<td>16</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>72</td>
<td>543</td>
</tr>
<tr>
<td>mitt</td>
<td>2.56</td>
<td>16</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>1</td>
<td>409</td>
</tr>
<tr>
<td>bun</td>
<td>2.63</td>
<td>15</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>1</td>
<td>443</td>
</tr>
<tr>
<td>comb</td>
<td>3.00</td>
<td>12</td>
<td>Metsala 1997a</td>
<td>6</td>
<td>488</td>
</tr>
<tr>
<td>sign</td>
<td>3.38</td>
<td>11</td>
<td>Metsala 1997a</td>
<td>94</td>
<td>519</td>
</tr>
</tbody>
</table>

Mean  
\[ M = 2.59 \]  
\[ M = 16.0 \]

#### Condition 3: Late-acquired, sparse neighbourhood (n = 6)

<table>
<thead>
<tr>
<th>Word</th>
<th>AOA</th>
<th>ND</th>
<th>Source of ND rating</th>
<th>Frequency</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>toad</td>
<td>4.31</td>
<td>2</td>
<td>Metsala 1997a</td>
<td>4</td>
<td>482</td>
</tr>
<tr>
<td>curve</td>
<td>4.94</td>
<td>8</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>45</td>
<td>453</td>
</tr>
<tr>
<td>leash</td>
<td>4.19</td>
<td>4</td>
<td>Metsala 1997a</td>
<td>3</td>
<td>447</td>
</tr>
<tr>
<td>vine</td>
<td>5.63</td>
<td>9</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>4</td>
<td>495</td>
</tr>
<tr>
<td>badge</td>
<td>4.81</td>
<td>8</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>5</td>
<td>454</td>
</tr>
<tr>
<td>geese</td>
<td>3.94</td>
<td>6</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>3</td>
<td>457</td>
</tr>
</tbody>
</table>

Mean  
\[ M = 4.64 \]  
\[ M = 6.17 \]

#### Condition 4: Late-acquired, dense neighbourhood (n = 7)

<table>
<thead>
<tr>
<th>Word</th>
<th>AOA</th>
<th>ND</th>
<th>Source of ND rating</th>
<th>Frequency</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>suit</td>
<td>4.25</td>
<td>13</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>48</td>
<td>531</td>
</tr>
<tr>
<td>wine</td>
<td>5.13</td>
<td>14</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>72</td>
<td>479</td>
</tr>
<tr>
<td>mug</td>
<td>4.25</td>
<td>14</td>
<td>Metsala 1997a</td>
<td>1</td>
<td>413</td>
</tr>
<tr>
<td>wick</td>
<td>5.56</td>
<td>20</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>4</td>
<td>368</td>
</tr>
<tr>
<td>cub</td>
<td>4.31</td>
<td>12</td>
<td>Garlock, Walley &amp; Metsala, 2001</td>
<td>1</td>
<td>403</td>
</tr>
<tr>
<td>lace</td>
<td>4.06</td>
<td>14</td>
<td>Metsala 1997a</td>
<td>7</td>
<td>536</td>
</tr>
<tr>
<td>weed</td>
<td>4.50</td>
<td>11</td>
<td>Metsala 1997a</td>
<td>1</td>
<td>490</td>
</tr>
</tbody>
</table>

Mean  
\[ M = 4.58 \]  
\[ M = 14.0 \]

---

42 From Metsala (1997a), using a 9-point scale: where 1 means acquired at 0-2 years, 2 = by age 3, 3 = by age 4, 4 = by age 5, 5 = by age 6, 6 = by age 7, 7 = by age 10, 8 = by age 12 and 9 = age 13 and up.

43 From Kucera and Francis (1967). Values of 70 and higher indicate high frequency.
Appendix B: Gating Task Instructions

The following instructions were given to all participants prior to the gating task:

"Now you will play a word guessing game. Your job is to listen to a woman saying pieces of a word. At first the pieces will be very short, then they'll get longer. Every time you hear a piece, I want you guess what the word is. It's a bit of a race so you need to guess the first word that pops into your head.

Sometimes you might need to change your guess when you hear a bigger piece of the word. That's fine. I just want you to make your very best guess after each piece you hear. I'll give you two hints: they're all real words and they are short words like cap or ball.

I'll show you how to do the first one."

Confidence Scale (reduced size, original was on a 8 1/2” x 11” paper in the landscape orientation)
Appendix C: Picture stimuli used in Semantic Task (Close Condition)

- Distractor: punch
- Distractor: pop
- Distractor: juice
- Target: wine
Distractor: clothes

Target: lace

Distractor: dress

Distractor: tie
Distractor: wallet
Distractor: box
Distractor: briefcase
Target: bag
Target: dog

Distractor: fox

Distractor: raccoon

Distractor: cat
Distractor: zig zag

Distractor: straight line

Target: curve

Distractor: angle
Distractor: *price tag*

Target: *badge*

Distractor: *ribbon*

Distractor: *brooch*
Target: hill

Distractor: mountain

Distractor: volcano

Distractor: cliff
Distractor: lips
Target: teeth
Distractor: toothbrush
Distractor: tongue
Distractor: muffin

Distractor: bread

Target: bun

Distractor: bagel
Target: leash

Distractor: collar

Distractor: rope

Distractor: belt
Target: *mitt*

Distractor: *hand*

Distractor: *scarf*

Distractor: *glove*
Distractor: *rock*

Distractor: *sand*

Distractor: *puddle*

Target: *dirt*
Target: vine

Distractor: shrub

Distractor: tree

Distractor: flower
Distractor: turtle

Distractor: frog

Distractor: lizard

Target: toad
Distractor: flower

Target: weed

Distractor: houseplant

Distractor: corn
Distractor: *lightbulb filament*

Distractor: *dynamite fuse*

Distractor: *match*

Target: *wick*
Target: suit

Distractor: dress

Distractor: jacket

Distractor: shorts
Target: comb

Distractor: hair

Distractor: brush

Distractor: barrette
Target: cub

Distractor: kitten

Distractor: puppy

Distractor: lamb
Distractor: slippers

Distractor: boot

Target: sock

Distractor: shoe
Appendix D: Semantic distances for sample of targets and close distractors

Semantic Distance as estimated by WordNet® (http://wordnet.princeton.edu)

Dictionary statistics: Range 0-30.5 (where 0=synonym), Mean = 11.5, Standard Deviation = 6.6, Median = 12.3.

<table>
<thead>
<tr>
<th>Close Distractors</th>
<th>TARGET: foot</th>
<th>Semantic Distance</th>
<th>TARGET: curve</th>
<th>Semantic Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>hand</td>
<td>0.509</td>
<td>line</td>
<td>1.047</td>
<td></td>
</tr>
<tr>
<td>toe</td>
<td>5.575</td>
<td>angle</td>
<td>2.763</td>
<td></td>
</tr>
<tr>
<td>leg</td>
<td>3.578</td>
<td>*corner</td>
<td>4.508</td>
<td></td>
</tr>
<tr>
<td>*shoe</td>
<td>11.572</td>
<td>zig zag</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Close Distractors</th>
<th>TARGET: neck</th>
<th>Semantic Distance</th>
<th>TARGET: dog</th>
<th>Semantic Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>*arm</td>
<td>7.458</td>
<td>cat</td>
<td>2.243</td>
<td></td>
</tr>
<tr>
<td>face</td>
<td>6.587</td>
<td>fox</td>
<td>2.954</td>
<td></td>
</tr>
<tr>
<td>head</td>
<td>6.425</td>
<td>racoon</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>shoulder</td>
<td>5.154</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*items with asterisk were considered as potential close semantic distractors but were ultimately excluded, due to low imageability or because the distance rating was too high.
Appendix E: Nonword stimuli (From Dollaghan & Campbell, 1998)

**Practice Nonwords**

<table>
<thead>
<tr>
<th>Phonetic transcription of word</th>
<th>Duration (milliseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZA<em>r</em></td>
<td>.592</td>
</tr>
<tr>
<td>luo*</td>
<td>.567</td>
</tr>
<tr>
<td>géo</td>
<td>.391</td>
</tr>
<tr>
<td>daj<em>nuk</em></td>
<td>.785</td>
</tr>
</tbody>
</table>

**Test Nonwords**

<table>
<thead>
<tr>
<th>Phonetic transcription of word</th>
<th>Duration (milliseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One syllable nonwords</td>
<td></td>
</tr>
<tr>
<td>nárb</td>
<td>.723</td>
</tr>
<tr>
<td>voorp</td>
<td>.552</td>
</tr>
<tr>
<td>taurz</td>
<td>.647</td>
</tr>
<tr>
<td>doorf</td>
<td>.534</td>
</tr>
<tr>
<td>M = .614</td>
<td></td>
</tr>
<tr>
<td>Two syllable nonwords</td>
<td></td>
</tr>
<tr>
<td>télvak</td>
<td>.858</td>
</tr>
<tr>
<td>koorvaeg</td>
<td>.842</td>
</tr>
<tr>
<td>vœkarb</td>
<td>.978</td>
</tr>
<tr>
<td>norf</td>
<td>1.146</td>
</tr>
<tr>
<td>M = .956</td>
<td></td>
</tr>
<tr>
<td>Three syllable nonwords</td>
<td></td>
</tr>
<tr>
<td>tsi norf taurb</td>
<td>1.305</td>
</tr>
<tr>
<td>norf kovveib</td>
<td>1.344</td>
</tr>
<tr>
<td>dorf xaurvæb</td>
<td>1.136</td>
</tr>
<tr>
<td>M = 1.227</td>
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</tr>
<tr>
<td>Four syllable nonwords</td>
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</tr>
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<td>vêitarf dorfp</td>
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</tr>
<tr>
<td>dæverständtig</td>
<td>1.558</td>
</tr>
<tr>
<td>nai-tai-tauvæb</td>
<td>1.663</td>
</tr>
<tr>
<td>M = 1.564</td>
<td></td>
</tr>
<tr>
<td>tæ va fsi narg</td>
<td>1.432</td>
</tr>
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</table>