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SPOKEN WORD RECOGNITION IN CHILDREN WITH
SPECIFIC LANGUAGE IMPAIRMENT :
EFFECTS OF IMAGEABILITY AND FREQUENCY

by

Cecelia Davidson, M.Phil.

A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1998

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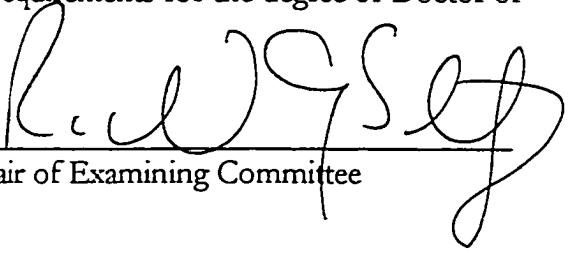
CECELIA DAVIDSON, M.Phil.

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This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction of the dissertation requirements for the degree of Doctor of Philosophy.

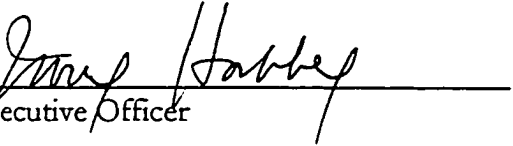
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THE CITY UNIVERSITY OF NEW YORK

Abstract**SPOKEN WORD RECOGNITION IN CHILDREN WITH
SPECIFIC LANGUAGE IMPAIRMENT:
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by

CECELIA DAVIDSON, M.Phil.

Advisor: Professor Richard G. Schwartz, Ph.D.

Children with Specific Language Impairment (SLI) are usually described as having language deficits unrelated to cognitive or sensory impairment. However, recent studies suggest that the notion of spared cognitive ability may be inaccurate. One possible explanation for the cause of the SLI sequelae is a general problem with symbolism, one aspect of which is the mental representation of images.

A lexical-decision task was employed with words that varied in their associations with visual representations and their frequency in English. Fifteen children with SLI ages 8;6-10;11 ($M=10;0$, $SD=.58$) were chronologically age-matched within 3 months to 15 children with normal language (NL) ($M=10;0$, $SD=.55$). Stimuli included digitized words divided into four categories: high imageability/high frequency, high imageability/low frequency, low imageability/high frequency, and low imageability/low frequency. Pseudowords that were phonetically matched to the words were also included.

Subjects indicated by pressing a button connected to a computer when they heard a word (GO/NO GO). The stimuli were presented a second time in a simple reaction time task (SRT) with subjects pressing a button as soon as they heard either a word or a pseudoword (GO/GO).

As the imageability and frequency of the stimuli changed from high to low, reaction time (RT) increased for both groups. High frequency/high imageability words had the fastest RT for the groups. Low imageability/low frequency words had the slowest RT.

However, only for the SLI group did frequency and imageability interact. The children with SLI were not slower than the NL children in performing the SRT.

The children with SLI in this study did not have modality specific impairments nor did they have generalized response slowing. Their auditory recognition reaction time was directly affected by the sparseness of the lexical input. The combined effects of low imageability and low frequency resulted in lexical items that were sparse in linguistic and imagistic representation. The consequence was burdened lexical processing and therefore a slower RT. Children with SLI may use imagistic information to facilitate lexical processing when a word's linguistic information is underrepresented.

*To my parents Charles and Florence Davidson,
sister Cheryl, brothers Stan, Stephen, Charles, Jon, Michael, and Paul,
and to my children Hannibal and Rahakmah.
Viva la familia.*

To Dean Harrison

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CHAPTER 1: INTRODUCTION

The nature of specific language impairment

Traditionally, children with Specific Language Impairment (SLI) have been defined by exclusion. Their impairment cannot be attributed to cognitive development delays, physical disabilities, or sensory impairments. A distinction is therefore drawn between children with SLI and other language-impaired groups such as the mentally retarded, brain injured, and hearing impaired. This exclusionary definition arises from our failure to identify the source of SLI despite extensive research.

Children with SLI differ from children who are developing language normally (NL) in their lexical abilities. Children with SLI may show signs of delayed vocabulary in early childhood (Leonard, Schwartz, Chapman, Rowan, Prelock, Terrell, Weiss, & Messick, 1982; Schwartz, Leonard, Messick, & Chapman, 1987; Watkins, Rice, & Moltz, 1993). In school-age children lexical problems may appear as: (a) vocabulary that is limited in size and content (e.g., Watkins, Rice, & Moltz, 1993); (b) slowness in recalling words (e.g., Kail & Leonard, 1986); and (c) time delays when producing words (e.g., Wolf & Obregon, 1992). Although we have descriptions of deficits in these areas, we lack information regarding their underlying cause. Most investigations have relied on behavioral observation such as off-line (i.e., untimed and non-speeded) measurement of children's responses. As a result, we know more about deficits in the end products of language processing (i.e., incorrect responses) than about the course of language processing itself.

Research investigating deficits in auditory processing and grammar have enhanced our understanding of end product deficits demonstrated by these children. Auditory-processing deficits have been explored in several studies (Tallal & Piercy, 1976; Tallal, Stark, & Curtiss, 1976; Tallal, Stark, Kallman, & Mellitis, 1980; Tallal, Stark, & Mellitis, 1985; Tallal,

1990; Tallal, Miller, Bedi, Byma, Wang, Nagarajan, Schreiner, Jenkins, & Merzenich, 1996). Such deficits have been attributed to problems with one or more of the following skills: Discrimination, sequencing, memorization, synthesis of speech sounds, and processing of rapid acoustic events. Like auditory processing deficits, grammatical deficits in children with SLI have been widely explored (Cleave & Rice, 1997; Leonard, Eyer, Bedore, & Greler, 1997; Rice, 1994; Rice & Oetting, 1993; Rice, Wexler, & Cleave, 1995; Rice & Wexler, 1996;). This research suggests that the difficulty these children experience producing appropriate morphology and syntax is one source of the differences between SLI children and their NL peers. For example, some children with SLI have problems pluralizing nouns and making subjects and verbs agree in a sentence. Leonard et al. (1997) compared three accounts of grammatical morpheme difficulties reported in SLI children: the *Implicit Rule Deficit*, the *Extended Optional Infinitive*, and the *Surface Account*. The Implicit Rule Deficit account (Gopnik & Crago, 1991) hypothesized that those with SLI are unable to form grammatical rules based on features such as tense, number, and person, a phenomenon known as *feature blindness*. This account suggests that the underlying representation of morphology is absent. The Extended Optional Infinitive account suggested that SLI children have the underlying knowledge to use markers such as tense but do not apply them consistently (e.g., Rice, 1994). The Surface Account (Leonard, Eyer, Bedore, Greler, 1997; Leonard, Bortolini, Caselli, McGregor, & Sabbadini, 1992; Leonard, McGregor, & Allen, 1992) attributes SLI children's difficulties with grammatical morphemes to incomplete processing. Morphemes, whose realization in utterances such as unstressed syllables and single consonants, have brief duration and are thought to be more difficult for these children to process. Therefore, more frequent exposure to these morphemes is necessary for them to become established in the

grammars of children with SLI. In the Surface account, the underlying grammars of children are intact but affected by processing limitations.

Descriptive information gained from the two lines of research described above has helped to establish a clinical marker for the SLI sequelae (Rice & Wexler, 1996) but these research areas have been unable to explain the range of deficits that may be characteristic of these children. Children with SLI may have unexplained lexical and non-linguistic deficits when they are compared to their chronologically aged matched peers.

Because descriptive information about auditory processing and grammar in SLI children have not fully explained the range of deficits within the disorder, some researchers have concentrated instead on cognitive attributes in seeking to get beyond the exclusionary definition of SLI with which this discussion began. Cognitive attributes may manifest themselves as subtle non-linguistic differences between SLI children and their NL peers (Condino, Im-Humber, & Stark, 1990; Johnston, 1994; Johnston & Ramstad, 1983; Kamhi, 1981; Restro, Swisher, Plante, & Vance, 1992; Swisher, Plante, & Lowell, 1994; Swisher & Plante, 1993; Savich, 1984; Stark, & Tallal, 1981). These investigations imply that one of the underlying causes of SLI may be a deficit in symbolic representation.

Symbolic representation, mental images, and language

Although young children with SLI appear to have deficits in symbolic play compared to age-matched peers, their abilities equal or exceed those of language-matched peers (e.g., Terrell, Schwartz, Prelock, & Messick, 1984; Roth & Clark, 1987; Terrell, & Schwartz, 1988; Thal & Bates, 1988). Because these investigations have been descriptive in nature, we can only conclude that language deficits tend to be accompanied by deficits in symbolic play skills.

In older children with SLI, symbolic abilities have been examined in terms of the ability to perform mental rotations of objects (Johnston & Ellis Weismer, 1983). The children judged whether two rows of geometric shapes rotated (about their centers 45, 90, or 135 degrees) in their orientation. This required the children to use *anticipatory imagery*. Although there were no differences between NL and SLI groups in accuracy, the children with SLI responded more slowly than the normal language children. There was no direct connection between these symbolic limitations and the language deficits associated with SLI.

Similarly, children with SLI exhibit deficits in a haptic recognition task (Kamhi, Catts, & Lewis, 1984). In this task, the children held an unseen and were then asked to select from an array of objects one that matched the shape of the held object. The children with SLI also lagged behind their peers in receptive vocabulary, as measured by the Peabody Picture Vocabulary Test-Revised (PPVT-R) (Dunn & Dunn, 1981).

Whitmire and Stone (1991) examined the relationship among imagery skills, syntax, and semantics in language-learning-disabled children (LLD) using more extensive psychometric testing. Importantly, the Columbia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972), an intelligence test that does not rely on mental imagery, was used to assess performance abilities. Four standardized tests that assess mental imagery were also administered: The Minnesota Paper Form Board-Revised Test (MPFB-R) (Likert & Quasha, 1970), the Spatial Relationships Subtest of the Primary Mental Abilities Test (PMA) (Thurstone & Thurstone, 1965), the Kuhlmann-Finch Space Test (KF) (Kuhlmann, 1951) and a Perceptual Matching Test (PM).

A significant positive correlation was found between the language score, TOLD-P total score, and accuracy on two of the imagery tests, the MPFB-R and the KF. When the composite scores (quotients) were compared with the imagery tests, the Semantics Quotient (consisting of the Picture Vocabulary Subtest and the Oral Vocabulary Subtest) was found to have the strongest correlation with the PMA. The children with NL outperformed the LLD children on the PM task.

Deficits in lexical comprehension, symbolic manipulation and imagery appear to be related. However, further exploration of representational abilities in children with SLI is needed to determine whether deficits in these abilities are directly related to language impairments. To determine whether symbolic representation and lexical deficits are related, relevant variables must be experimentally manipulated.

Assessment of lexical abilities

Because most assessments of children's lexical abilities involve identification tasks with pictures, the vocabulary tested is limited to words that can be depicted. Furthermore, most of these tasks are non-speeded and untimed. Thus, they only examine the end points of processing. The PPVT-R, a commonly used instrument for testing the receptive vocabulary of SLI children, is typical of the pictorial approach. Children are shown an array of pictures and asked to point to the picture that corresponds to a spoken word. The restriction of words to those that can be clearly imaged in a picture reduces the inventory of words that can be tested. If children with SLI have problems with the mental representation of imagery, responses to tests such as the PPVT may not adequately represent their lexical abilities. By testing only words that can be pictured, lexical abilities may be overestimated.

The lexical decision paradigm: language abilities and response speed

An alternative method for examining the lexical skills of children is the lexical decision paradigm (e.g., Forster, 1989, 1990). Because the lexical decision paradigm usually involves the timed (on-line) measurement of the child's recognition of words, it can more accurately reflect the mechanisms involved in lexical processing than picture-based assessments. The lexical decision paradigm has been used to measure speed of reaction time (RT) for distinguishing words from pseudowords (non-words). Subjects are presented with words and pseudowords in oral or written form. They are then directed to indicate which stimuli are words by pressing a button, by lifting a finger, or by responding orally. Reaction times for words are assumed to be faster than for pseudowords because of stored lexical representations.

Children with SLI demonstrate slow RT compared to their NL peers. Slow reaction times have been reported in both off-line (Johnson & Ellis Weismer, 1983; Kail & Leonard, 1986, experiments 1, 4, 5, & 7) and in on-line language tasks (Cirrin, 1980; Kail & Leonard, 1986, experiments 2, 3, & 6). However, because the tasks in these experiments were dissimilar, it is difficult to interpret these data generally. One remaining question is whether the slow reaction times of the SLI children were due to lexical or non-lexical factors.

Edwards and Lahey (1993) used a lexical decision task involving real and pseudowords with NL children and adults. The subjects were asked to perform a simple reaction time task by saying yes or no to indicate when they heard a tone. To correct for the possible influence of age-related differences in motor response speed the mean RT for responding to tones was subtracted from the mean real-word response time for each subject (or for each item).

Reaction times for both the real and the non-word stimuli decreased with age. This was consistent with previously published data (Cirrin, 1980). Developmental differences disappeared, however, when vocal reaction times were taken into account. Edwards and Lahey's study supported the assertion that basic auditory-motor response speeds must be considered when comparing groups (see also Kail, 1991). Edwards and Lahey also noted that differences in RT alone cannot be used to determine the presence or absence of different processing strategies with children.

Kail (1994) further explored the issue of slower than usual reaction times for children with SLI in a meta-analysis across 5 experiments and 22 conditions. The RT for SLI children increased linearly as a function of RT for NL children. Kail suggested that this slower RT of the SLI children is not specific to language tasks but reflects some general component of cognitive processing.

A limited number of recent studies of children with SLI using off-line and on-line RT have attempted to explore further the response slowing assumption. These studies compare the relationship of response slowness to specific language skills. Montgomery, Schudder, & Moore (1990) found that children with SLI were slower recalling words than their younger aged-matched peers when words were presented in sentential context. This did not occur when words were isolated and randomized. Using a memory scanning task, Sininger, Klatzky, & Kirchner (1989) observed that children with SLI were slower retrieving words from short term memory than their normally developing peers. However, when no memory components were involved, the children with SLI were not any slower in encoding the spoken words and initiating a response.

In a recent experiment, Edwards & Lahey (1996) used an on-line lexical decision task with a vocal response to compare spoken word recognition in children with SLI and

their NL peers. They were particularly interested in examining the relationship of RT to SLI children's language comprehension skills as determined by standardized language assessments. Children were instructed to say "yes" or "no," depending on whether they perceived the word presented as real or not. In order to draw conclusions about the relationship between RT and language comprehension skills, SLI subjects were grouped by the nature of their impairment: expressive language impairment alone, or mixed impairment (receptive and expressive). Consistent with previous off-line research, Edwards and Lahey found that children with SLI responded more slowly than their normally developing peers. However, RT did not correlate with the language abilities of children with SLI. That is, a longer RT did not differentiate groups of impaired subjects nor indicate increased severity of language deficits. Edwards & Lahey found high between subject and within subject variability that made it difficult to interpret differences among the SLI group. They concluded that this variability might be related to task completion strategies and processing non-linguistic variables related to lexical access. Therefore, the differences were not related to language factors.

One of the limitations of the study mentioned above and previous off-line attempts to clarify RT with SLI children is that the stimuli have not been controlled in ways that would allow more precise inferences about lexical processing. In the Edwards & Lahey studies, for example, words and non-words were matched for similarity of phonetic structure. However, the researchers did not consider word frequency or other factors that have been demonstrated to influence lexical processing speed. They chose words according to their judgments of what children would recognize. They did not consider variables such as referent type, count/mass noun differences, singular/plural differences, and grammatical category (e.g., nouns that also function as verbs). All these factors affect the stimulus words

in myriad ways, and this variability may affect processing speed. Any procedures using RT as a dependent measure require direct control of lexical factors that affect processing speed.

The lexicon and imageability

The studies described did not consider lexical factors that may influence processing such as *Imageability*. The imageability of word-referents has been described alternatively as “indirect reactivations of former sensory or perceptual activity” (Bugelski, 1970, p. 1002) and “the ability of a subject to generate or synthesize a sensory-like datum in the absence of physical stimulation” (Weber & Bach, 1969, p. 1991). These definitions distinguish the two major views of imageability: (a) the picture theory (Kosslyn, 1980) and (b) the structural descriptions theory (Pylyshyn, 1973; Tyre, 1991).

The picture theory describes mental images as pictorial representations of objects in the world (Kosslyn, 1980). The structural descriptions theory, on the other hand, describes image representation as more conceptual than pictorial. According to this theory, the imageability of a word-referent is a symbolic description rather than a picture degraded in form: people are said to construct inner descriptions of objects using previously developed concepts. The image is highly dependent on a person’s knowledge. Both theories describe some type of mental representation. To date, research with children has not provided substantial support for either theory. Before determining which theory best describes children’s perceptions of visual imagery associated with word-referents, the potential role of images in children’s lexical organization must be established.

The imageability of word-referents has been explored in adult cognitive studies as it relates to memory and to mental representation (Farah, 1984; Friendly, Franklin, & Hoffman, 1982; Hebb, 1968; Kosslyn, 1980; Kosslyn, Brunn, Cave & Wallach, 1984; McMullen, & Bryden, 1987; Paivio, 1971; Paivio, 1968). Mental images are generally

considered to arise post-access. That is, initial lexical access is necessarily based on the acoustic-phonetic structure of the word; thereafter, other information may be used, including mental imagery. According to the cohort theory (Marslen-Wilson, 1987, 1989), during the initial 150 to 200 msec of speech, a group of lexical entries that matches the initial representation is activated. Recognition occurs at a *uniqueness point*, the point at which the cohort of words is reduced to a single lexical item. Contextual information is exploited as part of the post-perception semantic integration. Such information includes experience stored in the form of mental representations that elaborate our knowledge of a word or its referent.

In their series of experiments on lexical retrieval, Kail and Leonard (1986) found that SLI children's retrieval of lexical items followed the same patterns as that of NL children, suggesting that the two groups were influenced by the same factors. However, the children with SLI always showed a slower RT. Kail and Leonard suggested that the slower responses may be the result of less elaborate representations of words in the SLI children's lexical storage. It is not clear, though, whether the representation is lacking linguistic, cognitive, or imagistic information.

In an off-line study of NL French-speaking children (Theobald, Rondal, & Kaens, 1995) mental imagery was found to facilitate the comprehension of action in declarative sentences. Children were identified as visualizers and nonvisualizers based on their performance on a mental rotation and mental reconstruction task. Children classified as visualizers demonstrated better comprehension of action sentences than nonvisualizers.

Using an on-line lexical decision paradigm with visual stimuli with NL children, Akins (1989) found that the effects of imageability were minimized with context. This research attempted to evaluate whether the dual-coding model (Paivio, 1968, 1971) or the

context availability model (Schwanenflugel, Harnishfeger, & Stowe, 1988; Schwanenflugel & Shoben, 1983; Schwanenflugel & Stowe, 1989) could explain differences in normal children's reaction time. NL children were found to use imagery to manage rapid comprehension of information, but not for tasks in which the children could draw on prior knowledge.

The literature on imageability and the concrete/abstract dichotomy of words has often been unclear. Sometimes the terms are used synonymously. Akin's collection of imageability norms reflects such lack of clarity in the literature. When subjects were instructed to rate words on sensory stimulation and on ease of thinking of a picture, the results reflected both imageability and concreteness. Following typical adult-rating protocols, children were asked to rate words on a scale. Each point was associated with a different descriptive label relating to the level of difficulty imaging the referent of the target word. On a seven-point scale, a rating of "7" indicated a word that most readily evoked an image; a "1" indicated a word that did not evoke an image easily.

The problem with such imageability ratings is that they are unable to fully distinguish between a word's association or lack of association with a mental image and the more general dichotomy of concrete versus abstract. In the literature, the distinction between the imageability and the concreteness/abstractness of words has varied (Friendly, Franklin, & Hoffman, 1982; Gilhooly, Logie & Logie, 1980; Paivio, 1968). Specifically, the concrete/abstract dichotomy may not take into account the relative imageability within each word. Concrete words tend to be associated with physical sensorimotor experiences whereas abstract words do not, yet these lie on a continuum. For example, kinship terms such as "sister" and "father" are rated as low-imageability in adult rating scales but are concrete words in concrete/abstract studies. In this research (see the section on children's

imageability ratings), NL children rated such terms as high-imageability. The children's images for words may be influenced by their personal reference to specific examples rather than general categories of words and ideas.

Concrete words may have far greater imageability than abstract words, but within these groups there is a wide range of imageability. This may be influenced by words with a prototype object in the physical world. For example, the word "blood" may have a more commonly shared referent than the word "wife". The referent for the word "blood" may be basic, a single semantic category member with a single referent. Therefore, it may be less affected by experience and culture than the referent for the word "wife", that potentially could have multiple referents. The distinction between abstract and concrete words represents a basic dichotomy; words tending to fall into either category. However, imageability may be a continuum with words having a range of association with a visual representation. Therefore, abstract and concrete words are both potentially imageable, with different strengths of association with a visual image. However, we do not have enough experimental evidence to determine whether the distinction between imageability and concreteness/abstractness makes a difference in lexical processing.

Akin's study collected reaction time to visual stimuli. Therefore, limited attention needed to be given to the structural properties of words used in the experiment (e.g. grammatical class, morphology (plurals), and phonetic form were not controlled). For example, the stimulus set included nouns and verbs, singular and plural nouns, as well as words with consonantal and vowel onsets. The structural properties of words can significantly affect auditory reaction time. The application of research using visual lexical decision is unclear. Stimuli that are uncontrolled for structural form permit conclusions about the influence of linguistic factors on processing. Akin concluded that imageability

effects are reduced when sentence contexts of words are controlled is not directly applicable to the processing of isolated lexical stimuli auditorily presented.

Word frequency

Unlike word-referent imageability, word frequency has been extensively studied and affects the mechanisms involved in lexical processing. Indeed, word frequency appears to be an organizing principle of the lexical system. High-frequency words are processed more rapidly than low-frequency words, as determined by reaction-time measurements (Bradley & Forster, 1987; Cirrin, 1980; Forster, 1990; Forster, 1989; Whaley, 1978). Higher frequency words have multiple representations in the lexicon, allowing easier recognition, hence greater speed of retrieval. The cohort model of lexical processing (Marslen-Wilson, 1987, 1989) proposes that the listener can start to analyze speech from the initial phone onset. The words become uniquely distinguishable before the whole word is heard. Less than full acoustic/phonetic information is needed to recognize the word. If this model is accurate, then word frequency should have minimal or no effects on word recognition. Therefore, Marslen-Wilson's model cannot explain the frequency effects observed in experimental studies and whether these effects occur before or after lexical access (Bradley & Forster, 1987). Kail and Leonard (1986) concluded that SLI children have unembellished (basic) lexical representations. This conclusion suggests that for these children, less familiar words have less elaborate representations. Therefore, we would expect the lexical processing of SLI children to be sensitive to word frequency. We have yet to determine how familiarity with a word is integrated with acoustic/phonetic information during lexical processing for these children.

Familiarity with words is difficult to quantify directly. Word frequency (Kucera & Francis, 1967) from word counts of printed English is often used to describe familiarity.

Although the use of adult norms is typical, frequency norms based on children's literature are more appropriate in developmental studies (Carroll, Davies, & Richman, 1971). All frequency measures of this type, however, have similar limitations. Spoken language word frequency cannot be assumed to be the same as written language word frequency. Children use language more in spoken form than written form. We are unable to accurately quantify the frequency of children's exposure to the spoken word through daily experiences.

Although we must rely on standard frequency measures of written language for auditory language studies, this procedure may have an underlying flaw. Our interpretation of frequency effects using such measures must be cautious. Lexical skills such as word recognition and word comprehension cannot be assumed to be identical for listening to words and reading them. Although the underlying mechanisms for processing both spoken and written words may converge in some aspects, word frequency effects of oral and written language may be different.

Research questions

In this experiment, a lexical decision paradigm was used with an auditory presentation of words. The target words were selected to represent two levels (high and low) of word-referent imageability and word frequency. The imageability of a word-referent was a measure of how strongly a word was associated with a visual mental image of something in the physical world. If there were a strong association with an actual object in the physical world, subjects might be able to associate it with a mental picture that they could recognize. Words readily associated with mental images were coded as having high imageability. Words with weak or no association with a mental image were coded as having low imageability. In addition, words were separated into high/low frequency categories to examine the effects of familiarity on lexical processing.

Words whose referents have high imageability were those words rated by normal language children as having a strong association with a mental picture. It is inferred that such words have an image representation. When the referent of a word is imageable, the image of the word is part of the stored information about it. When a word-referent has a weak association with an image, the stored image mental representation may change.

Imageability is a factor in adults' processing of lexical stimuli. However, investigations involving SLI and NL children have been limited. This experiment was designed to examine the effect of imageability and word frequency on reaction times. The overarching question was "Is a word with a strong associated image recognized faster than a word with a weak associated image?"

The specific aims of this research were as follows:

1. To examine patterns of word recognition in children between the ages of 8 and 11 years using a lexical decision paradigm, to extend the information on young school-aged children's real-time recognition of words and pseudowords.
2. To clarify patterns of word recognition in children with SLI using a lexical decision task. Subjects listened to words and pseudowords. Their recognition of these two stimuli was measured for speed of decision (reaction time/RT). A simple reaction time (SRT) task was used to examine baseline response rate.
3. To examine two properties of words, word imageability and word frequency, that may affect children's recognition of words.

The research had four components:

1. Teacher ratings of student exposure and familiarity to words were collected.

These ratings were used to confirm the appropriateness of lexical stimuli.

2. Imageability ratings were collected from normal language (NL) students and their teachers. These ratings were used to supplement published adult imagery ratings. Many of the words rated by adults in imageability studies were not developmentally appropriate for children.

3. Reaction times for words were collected, with stimulus words categorized for imageability and frequency.

4. Finally, a simple reaction time task, was used to obtain a comparison of RT in a lexical decision (GO/NO GO) test to continuous responses (GO/GO).

Consistent with the literature, the frequency factor should produce effects on RT for both the NL and SLI groups. High frequency words should produce faster RTs than low frequency words. Imageability should produce effects on RT for both groups, but that the pattern of effects may differ. Given the evidence from untimed/non-speeded tasks SLI children have symbolic representation deficits. The magnitude of difference on RT should be larger in the SLI group than in the NL group under conditions of low imageability. SLI subjects should have significantly more difficulty recognizing words with low-imageability than their NL peers. Furthermore, consistent with the literature on SLI children's slow motor speed, the RT for SLI children on the simple reaction time task may be longer than the RT for NL children.

Chapter 2: Methods

Subjects

Subject selection criteria. Thirty children, 22 boys and 8 girls, ranging in age from 8;6 to 10;11 served as subjects. All subjects were normal hearing, monolingual, English-speaking children. Fifteen of the children had a diagnosis of SLI ($M= 10;0$, $SD = .58$), and 15 were chronologically age and gender matched children ($M= 10;0$, $SD=.55$) with language abilities falling within the normal range (NL). All subjects were in grades three, four, or five and were enrolled in elementary schools within the same school district.

Screening procedures for NL children. Children with normal language were selected from a pool of potential subjects recommended by third, fourth, or fifth grade classroom teachers at the participating school. Teachers were asked to recommend monolingual English speaking students who were not receiving any therapeutic or remedial services and who demonstrated age and grade level achievement in their classes. In order to establish normal hearing, potential participants were required to pass a hearing screening at 25-dB HL at 500, 1000, 2000, and 4000 Hz (ANSI, 1989). School medical records indicated the absence of developmental hearing loss. Nursing records also confirmed the absence of medical or behavioral difficulties that might interfere with school achievement.

A consistent record of age appropriate school achievement was determined by passing scores on the Comprehensive Test of Basic Skills 4 (CTBS/4) (Mc Graw-Hill), a standardized school based test given to all elementary school children in the school district these children attended. Student scores were reviewed for their present grade and two years prior. The children's language exposure and primary language spoken in the home was evaluated using a home language survey. This survey was completed by parents as part of

school registration when the child was enrolled in school. Parent responses were used to confirm that the child had a fluent understanding of English. The parent's country of origin and a list of languages spoken in the home other than English were also indicated.

Socio-economic status (SES) was determined by eligibility for the federal lunch program in school. Federal income guidelines provide free or reduced fee lunch to children whose family incomes fall within a low income range for their family size. Children in this study qualifying for free lunch were categorized as low SES. Children qualifying for reduced fee lunch were categorized as middle SES. Children whose family incomes exceeded the maximum salary for inclusion in the lunch program were categorized as high SES. These income designations are specific to the local community.

Appendix A presents subject information for the NL group including socioeconomic status, gender, chronological age at the onset of the experiment, and ethnicity. Subjects participating in this research represented a cross section of economic and ethnic groups reflective of the community in which they lived.

Documentation of SLI. Appendix B presents subject information for the SLI group including socioeconomic status, gender, chronological age at the onset of the experiment, and ethnicity. Criteria for SES remained the same for this group. As with the NL group, the profiles of these children represented the economic and ethnic diversity of the community in which they lived. Across the children in this group, the most consistent characteristic was family incidence of disability. Seven of the 15 subjects had one or more siblings documented with a speech and/or language learning disability.

All of the SLI children participating in the research had been diagnosed by a speech language pathologist as having a language disability at least two years prior to the onset of the experiment. All of the children were receiving therapeutic services and were receiving

some educational interventions to help them overcome the impact of their language disability on school achievement. For comparisons of the NL children's school performance with the SLI children's performance, see Appendix C. The educational profiles of SLI children are presented in Appendix D. Appendix C lists previous educational interventions for those children identified with a disability prior to third grade. The programs in which the subject participated prior to the research are indicated as well as the programs in which the child participated at the time of this research. Performance on the standardized testing required in the subject's school district is also presented. This particular school district used the reading and mathematics sections of the Comprehensive Test of Basic Skills-4. A profile of performance over three consecutive years prior to participation in the experiment is listed. In contrast to the NL group, the children with SLI had an inconsistent performance over time. Overall, mean scores for each year were below the 50% level for the normal curve equivalent (NCE).

Assessment of cognitive and language abilities. A battery of standardized tests was used to establish the children's cognitive status and language abilities. It was important to determine whether language impaired children demonstrated non-verbal intelligence within the normal range on standardized measures. Cognitive status was established using performance measured on the matrix subtest of the Kaufman Brief Intelligence Test (K-Bit) (Kaufman & Kaufman, 1990). All children identified in this study as SLI achieved scores of 85 or above on the K-Bit scale, falling within the average range. NL matched controls were assumed to have average or better intellectual functioning based on present and archived records of school performance.

Receptive vocabulary was measured using the Peabody Picture Vocabulary Test-Revised (PPVT-R) (Dunn & Dunn, 1981). Overall language abilities were measured using the

Test of Language Development-Primary (TOLD)(Hammill & Newcomer, 1977) or the Test of Language Development-Intermediate (TOLD I:2)(Hammill & Newcomer, 1988), depending on the child's age. SLI children's language difficulties were determined by a score on the PPVT-R that fell 1.5 standard deviations or more below age-expected norms and scores 1.5 standard deviations or more below age-expected norms on at least 3 of the 5 subtests of the TOLD. Children that scored within normal limits on the PPVT-R but whose language fell within the range described on the TOLD Test were included. Subtest V on the TOLD I:2 was ignored for children suspected of having linguistic knowledge of African American English or an English-based Caribbean Creole language due to the bias of some test items towards Standard English. For these children, the scores on the remaining subtests were analyzed.

All students were administered Subtest XI- picture fragments of the Detroit Test of Learning Aptitude (DTLA). This subtest consists of 27 line drawings, each with part of the picture missing. Children are asked to make timed judgments of what the picture is by naming it. The subtest was administered in a non-standard way, ignoring response ceilings. Because visual perception and visual imagery are said to share some of the same processing mechanisms (Kosslyn, 1980) performance on this subtest was used as a baseline of visual imagery skills.

Tables 1 and 2 present the means for the NL and SLI subjects on tests administered. Individual scores are provided in the Appendix C and D.

Table 1. Means and standard deviations for NL children's performance on the PPVT-R, TOLD (Primary and Intermediate) & DTLA Picture Fragments Subtest

	<u>PPVT(%tile)</u>	<u>TOLD (M)</u>	<u>DTLA (% correct)</u>
<u>M</u>	66	57	36
	(30)	(11)	(7)

All subjects scored within the average range or above on the PPVT-R and the TOLD Test. The score for the TOLD test represents a mean of all subtests administered.

Table 2. Means and standard deviations for SLI children's performance on the K-Bit, PPVT-R, TOLD (Primary and Intermediate) & DTLA Picture Fragments Subtest

	<u>K-Bit(S.S.)</u>	<u>PPVT-R (%tile)</u>	<u>TOLD (M)</u>	<u>DTLA (% correct)</u>
<u>M</u>	109	20	21	33
	(10)	(18)	(7)	(9)

All SLI subjects scored within the average range on the K-Bit. The means presented are standard scores. Two of the 15 subjects scored within the average range on the PPVT. All subjects showed discrepancies with language development based on the TOLD test. The mean of all TOLD subtests is represented in Table 2.

Subject matching. NL subjects were matched to SLI subjects for gender and chronological age. All NL subjects fell within 3 months of age with their SLI subject match.

Table 3 presents the subjects as they were matched.

Table 3. Subject Matching

Group	Gender	Age	NL Group	Gender	Age
1	male	10.0	1	male	10.0
2	male	10.3	2	male	10.4
3	male	10.1	3	male	10.0
4	male	10.2	4	male	10.2
5	male	9.7	5	male	9.7
6	male	9.7	6	male	9.6
7	female	10.11	7	female	10.9
8	female	10.3	8	female	10.2
9	female	9.0	9	female	9.1
10	male	10.6	10	female	10.5
11	female	10.7	11	female	10.4
12	male	10.2	12	male	10.3
13	male	10.1	13	male	10.2
14	male	10.6	14	male	10.7
15	male	8.6	15	male	8.9
<u>M</u>		10(.58)	<u>M</u>		10 (.55)

Stimuli

Teacher ratings for word exposure. A set of the proposed words were judged for appropriateness by 10 third- and fourth-grade teachers to determine the suitability of words selected for children. Teachers were asked to rate 400 words according to the extent of exposure they believe children have had. The numbers for rating ranged from 0 (no exposure) to 4 (exposure and understanding). Exposure in this study meant any of the following: (a) heard the word spoken by someone, either directly or through television, radio, or other media; (b) encountered the word through curriculum presented; or (c) saw the word. Understanding meant that the children know the referent of the word.

Teachers were directed to follow written instructions and were asked to complete the ratings individually. The complete instructions given to the teachers follow in the appendix. Teacher responses were analyzed across individual words. Words with mean ratings less than 3 were eliminated.

Children's imageability ratings. Fifth-grade children, 15 boys and 15 girls, from regular education classes, were administered an imageability-rating inventory. The inventory consisted of 111 nouns selected from the words rated by teachers. Some of these words were previously rated by adults for imageability, and some had not appeared in published adult ratings (Friendly, Franklin, & Hoffman, 1982; Gilhooly, Logie, & Logie, 1980; Paivio, 1968). The children were given verbal instructions and then were asked to rate written words on a four-point scale. The words were simultaneously read while subjects followed along silently. A score of 3 indicated a word that was easily associated with a mental picture. Scores less than 3 were difficult to associate with a mental picture. The subjects were given a rest period halfway through the word list. During this time, as part of a group discussion,

subjects were asked to comment on how they rated words. After the rest period, the instructions to the children were repeated, and the remainder of the words were presented.

Ratings were analyzed based on the number of students scoring the word less than 3; less than a strong association with a mental picture. Calculating the mean scores for each word directly was considered since this method has a precedent in the adult literature. However, the children in this study appeared to respond to the target words in a more categorical manner. Mean calculations did not capture this type of response.

Words with weak associations, rated by 7 or more students with a score other than 3, were categorized as “low imageability”. The strongest exemplars of high and low contrasts were selected from the pool of words rated. See Appendix G for the imageability ratings for experimental words. A two way ANOVA with factors imageability and frequency was used to analyze the children’s ratings. There was a main effect of imageability, $F_1(1,36)=192.37$, $p<.0001$. There was no effect of frequency; $F_1(1,36)=0.32$, $p>.50$. There was no interaction of these factors; $F_1(1,36)=0.04$, $p>.50$. The subjects made distinctions between words that were high and low imageability.

Word Frequency. Frequency designations were based on log frequencies obtained from Carroll, Davies, and Richman (1971). This frequency reference was developed from word frequencies in children’s textbooks and was therefore more relevant to the present research. High-frequency words had log frequency ratings greater than or equal to 60 ($M=64$, $SD=3$). Low-frequency words had frequency ratings less than or equal to 58.4 ($M=51$, $SD=5$).

Categorization of word stimuli. Words in the experimental trials were sorted across imageability and frequency parameters: high-imageability/high-frequency, high-imageability/low-frequency, low-imageability/high-frequency, and low-imageability/low-

frequency (cf. McMullen and Bryden, 1987). These high and low category distinctions of the factors were maintained in the present research. However, in contrast to the McMullen and Bryden's stimuli, only words assumed to have a predominant meaning for children as a noun were selected. All experimental words began with initial consonants. Table 4 presents the final categorization of words used for the experiment. There were 10 words in each experimental category

Table 4. Experimental words

<u>HI/HF</u>	<u>HI/LF</u>	<u>LI/HF</u>	<u>LI/LF</u>
house	rag	fact	law
door	bush	today	month
water	coin	moment	hint
girl	salad	unit	habit
body	chin	problem	deed
woman	jelly	life	moral
dog	cigar	rule	fault
sand	math	voice	mood
food	toy	time	noun
man	lip	power	god

HI/HF- High imageability/high frequency

HI/LF- High imageability/low frequency

LI/HF- Low imageability/high frequency

LI/LF- Low imageability/low frequency

Formation of pseudowords. 40 pseudowords (PW) in this experiment were used to provide an opportunity for no responses. All PW began with a consonant and were constructed to match the stress pattern and duration of the matched word. All PW conformed to English phonotactic rules. A list of the PW stimuli can be found in Appendix I.

Stimulus preparation. Both words and pseudowords were recorded by a female speaker. The digital recordings were converted to digitized computer files using a sampling rate of 22 kHz using 16-bits and were filtered at 11 kHz using the Q Display waveform editing software (Yeung & Swinney, 1995) on a 486 personal computer. All stimuli were equalized to 50 dB. Word files were edited for duration to remove artifacts and noise. Digitized words were evaluated for recognition and accuracy by three adult listeners. There was 100% agreement among the adults for word identification.

Auditory stimuli are deployed over time. To insure that there were no differences in word duration confounding the variables of interest, frequency and imageability, a two-way ANOVA was conducted. The ANOVA indicated that there were no systematic differences among stimulus categories. All F_s were <1 . The mean acoustic duration values of the stimulus categories can be found in Appendix J.

Design of the experimental sequence. There were unscored practice trials at the beginning of each run. After the training sequence, subjects were presented with 16 practice stimuli on line. The experiment consisted of two runs, each composed of 5 experimental blocks. Each experimental block was preceded by 4 practice words. This was done to minimize errors at the beginning of each run.

The sequence was also designed to minimize predictability of the sequence.

Therefore, words and pseudowords were pseudo randomized. A block was composed of 8 stimuli. The second run presented was a mirror reversal of the first run.

Procedures

Training. Subjects were tested individually. Each subject was required to attain an accuracy level of 80% on two blocks of practice trials before continuing the experiment. The first training block consisted of an off-line practice with 5 words and 5 pseudoword stimuli. Subjects listened to the stimuli without earphones and responded verbally when they heard a word. The examiner manually recorded answers. If errors were made, the examiner explained the procedures to make sure the subject understood. In the second training block, subjects used earphones to listen to the stimuli, and responded using the response button. This procedure was untimed. If errors were made the tape recording was stopped. Then the examiner explained the procedures and discussed the subject's response. If a subject failed to reach the 80% accuracy criteria by second training block, the oral instructions and the practice blocks were repeated.

Experimental Tasks. The first part of the experiment was the lexical decision task implemented as GO/NO GO. The subjects were given a response button that interfaced with a timing board allowing the computer to record reaction time. Subjects were directed to press the button every time they heard a string of speech sounds that was a real word of English. Reaction times were measured and stored in the computer. The simple reaction time task followed the lexical decision task. Subjects were directed to press the response button every time they heard a stimulus (real or pseudoword). Reaction times were measured and stored in the computer.

Presentation of the stimuli. A single, quasi randomized order of stimuli was created. Words from each of the 4 imageability/frequency categories were interspersed throughout the experimental sequence. The stimuli were presented through headphones with a 3 msec interstimulus interval (ISI). The button press triggered collection of RT from the timing mechanism. After the response, it also triggered the beginning of the next collection interval. The responses were collected, categorized, and measured for reaction time by the RT Lab computer program (Swinney, 1995) on a 386 personal computer. The experiment was divided into two runs with a brief rest period between each. During the rest period, instructions were reviewed with the subjects.

The simple reaction time task followed the lexical decision task. In this task, the same stimuli were presented again. The experimental events remained the same, but the subject responded to every stimulus heard.

Chapter 3: Results

This research used two experimental tasks to examine SLI children's lexical abilities. NL children were chronologically age matched to the SLI children and were used as controls. The first part of the experiment examined auditory lexical decision performance. The second part of the experiment examined the children's attention and simple reaction time in detecting an auditory stimulus. The stimuli for both tasks were words falling into four classes defined by the factorial combination of imageability (high/low) and frequency (high/low). Pseudowords were used in the experimental sequence.

The experiment was a 2X2X2 factorial design (group x imageability x frequency) with repeated measures on: imageability (high/low) and frequency (high/low). There were four analysis of the data. First, practice trials were analyzed to examine the success of the children with training procedures. Second, the relationship of stimulus type to reaction time was measured for each subject and between the NL and SLI groups. F_1 (subject analysis) and F_2 (item analysis) statistics were applied to the data. In the third analysis, univariate ANOVAs were used post hoc analysis to examine NL and SLI groups. Finally, RTs for words and pseudowords in the simple reaction time task were examined.

Practice trials

The error rate for the first 10 practice words and the first 10 pseudowords within the experimental sequence order of encounter were analyzed for the NL and the SLI groups. The number of errors for each subject in the NL and the SLI groups were estimated across all practice items. The misses (failed to press the button for words) for the NL children constituted 2.7% of the responses. The error rate for false alarms (indicated a pseudoword was a word) was 6.0%. The error rates for SLI children were 2.0% misses and 14% false alarms.

Group comparisons on the lexical task: subject-based analysis

Imageability and frequency affected the NL and the SLI groups. The groups exhibited increases in RT as the stimulus categories changed from high to low. The greatest difference between groups was with low Imageability/low frequency words. SLI subjects were 143 msec slower than NL subjects. Statistical analysis confirmed the data pattern. A three way ANOVA with factors Group x Imageability x Frequency indicated that there was a three-way interaction, $F_1(1,28) = 3.81, p=.0610$. There was a main effect of Imageability, high versus low, $F_1(1,28)=64.03, p<.001$. There was a main effect of frequency, high versus low, $F_1(1,28)=32.81, p<.001$. There was no main effect of group, NL versus SLI, $F_1(1,28)=.93, p>.25$. There were no two-way interactions. With factors Group x Imageability, $F_1(1,28)=2.56, p>.10$. There was an interaction with factors, Group x Frequency, $F_1(1,28)=1.15, p>.25$. With factors, Imageability x Frequency, $F_1(1,28)=2.79, p>.10$

Table 5 presents the mean RT for the stimulus conditions for the NL and SLI groups.

Table 5. Mean latencies (RT in msec) for NL and SLI groups for each stimulus condition (standard errors in parenthesis)

	<u>High Frequency</u>		<u>Low Frequency</u>	
	<u>High Imageability</u>	<u>Low Imageability</u>	<u>High Imageability</u>	<u>Low Imageability</u>
NL	1108(37)	1242(69)	1205(42)	1330(79)
SLI	1144(69)	1275(40)	1215(43)	1473(107)
Difference	36	33	10	143

Figure 1 presents NL and SLI children's lexical decision latency for word stimuli as a function of imageability and frequency.

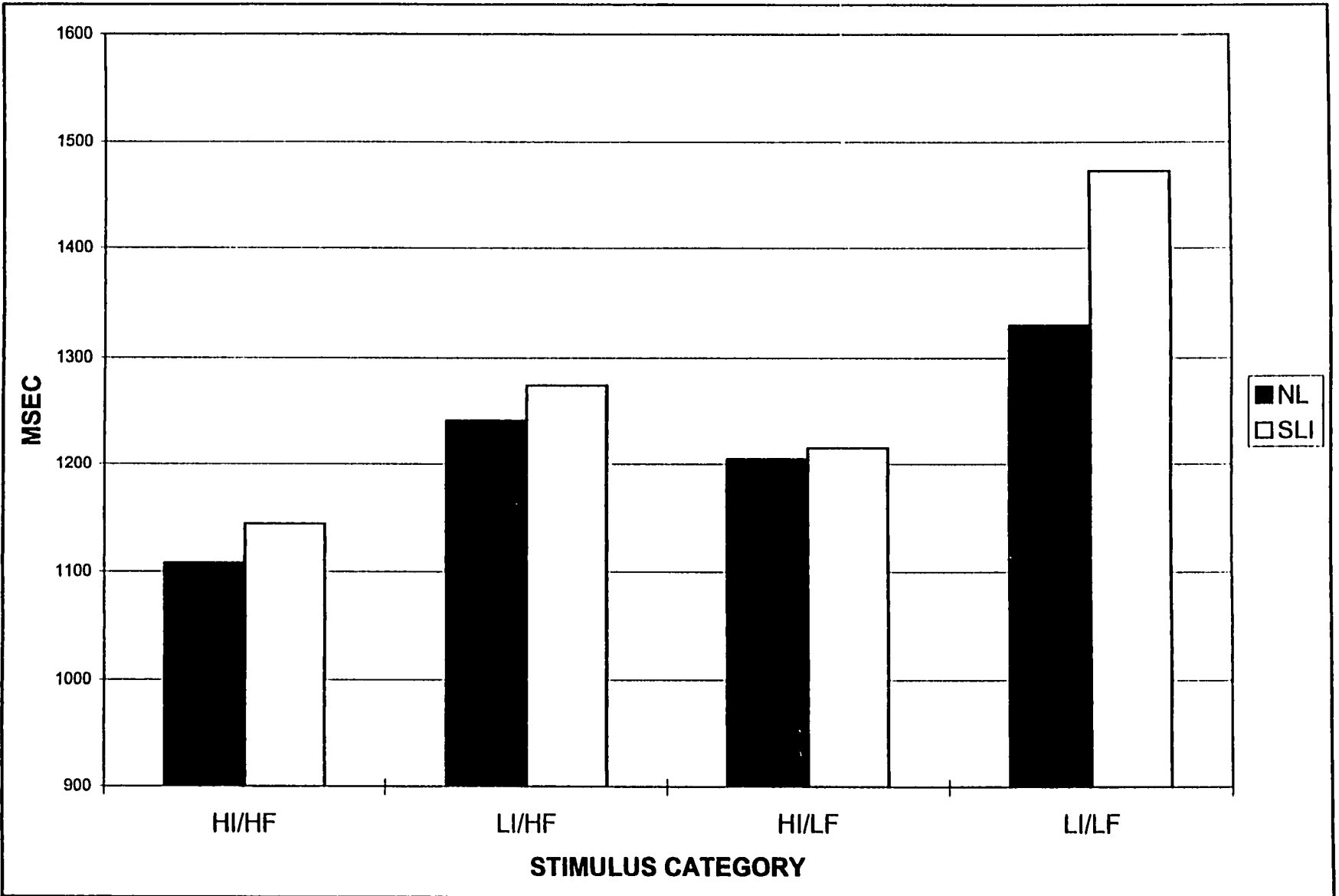


Figure 1: NL and SLI children's lexical decision latency for word stimuli as a function of imageability and frequency

Post-hoc analysis further examined the effects of the imageability and frequency factors. Univariate ANOVA analysis examined these factors within each of the NL and SLI groups.

NL children's performance on the lexical task: subject-based analysis

For the NL group, the analysis of RT data showed that imageability was an important determinant of the speed with which lexical decisions could be made. High imageability words were judged faster than low imageability words with a mean RT of 1157 msec compared to 1286 msec. The difference between high and low imageability words was 129 msec. High frequency words were classified faster than low frequency words with a mean RT of 1175 msec compared to 1268 msec. The difference between high and low frequency words was 93 msec. The difference between words that were high frequency and high/low imageability was 134 msec with high frequency/low imageability words having the longest latency. The difference between words that were low frequency and high/low imageability was 125 msec with low imageability/low frequency words having the longest latency. A two-way ANOVA for the NL group indicated a main effect of imageability, $F_1(1,14)=21.45, p<.01$; a main effect of frequency, $F_1(1,14)=18.48, p<.01$; but no interaction, $F_1(1,14)=.04, p>.05$. With the NL group, the effects of imageability and frequency were purely additive. There was an independent action of both factors with no interaction.

SLI children's performance on the lexical task: subject-based analysis

For the SLI group, the analysis of RT data showed that as with the NL group, imageability was an important determinant of the speed with which lexical decisions could be made. High imageability words were classified faster than low imageability words with a mean RT of 1180 msec compared to 1374 msec. The difference between high and low

imageability words was 194 msec. High frequency words were also classified faster than low frequency words with a mean RT of 1209 msec compared to 1344 msec. The difference between high and low frequency words was 145 msec. The difference between words that were high frequency and high/low imageability was 131 msec with high frequency/low imageability words having the longest latency. The difference between words that were low frequency and high/low imageability was 258 msec with low imageability/low frequency words having the longest latency. A two-way ANOVA for the SLI group indicated a main effect of imageability, $F_1(1,14)=44.13, p<.01$; a main effect of frequency, $F_1(1,14)=16.36, p<.01$; and a two-way interaction, $F_1(1,14)=5.98, p<.05$. With the SLI group, the effects were in the same direction, with the low imageability/low frequency words presenting with the longest response latency. However, this stimulus condition presented with non-additive effects, with RT exceeding the effects that could be accounted for by the independent action of each factor.

Group performance on the simple reaction time task: subject-based analysis

Table 6 presents the mean RT for the stimulus conditions for the NL and SLI groups in the simple reaction time task. Figure 2 presents the children's lexical decision latency for word stimuli as a function of imageability and frequency.

Table 6. Mean latencies (RT in msec) for NL and SLI groups for each stimulus condition in the simple reaction time task (standard errors in parenthesis).

	<u>High Frequency</u>		<u>Low Frequency</u>	
	<u>High Imageability</u>	<u>Low Imageability</u>	<u>High Imageability</u>	<u>Low Imageability</u>
NL	1110(64)	1079(61)	1078(63)	1100(61)
SLI	884(55)	965(61)	944(61)	994(49)
Difference	226	114	134	106

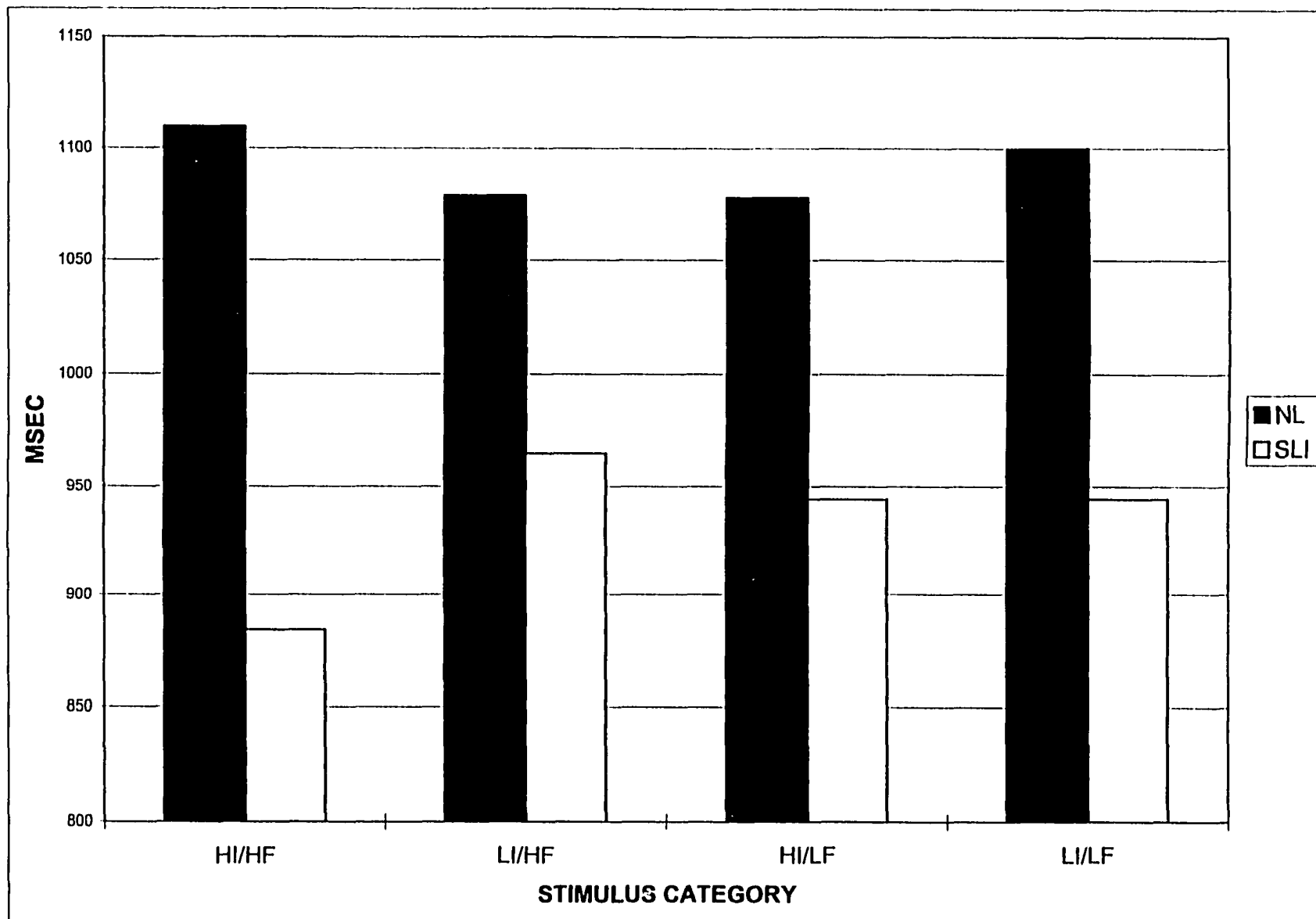


Figure 2: NL and SLI children's lexical decision latency for stimuli as a function of imageability and frequency on the simple reaction time task

Statistical analysis confirmed the data pattern. A three-way ANOVA with factors Group x Imageability x Frequency a trend in the main effect for group, $F_1(1,28)=3.17, .05 < p < .10$. There was a main effect of imageability, $F_1(1,28)=4.99, p < .05$. There was no main effect of frequency, $F_1(1,28)=1.66, p > .10$. There was a two-way interaction of Group x Imageability, $F_1(1,28)=7.12, p < .025$. There was a trend in the two-way interaction of Group x Frequency, $F_1(1,28)=3.20, .05 < p < .10$.

The responses for NL and SLI subjects were examined further separately. For the NL subjects, a two-way ANOVA with factors Imageability x Frequency indicated that there were no main effects, all $F_s < 1$. There was no interaction, $F_1(1,14)=3.26, .05 < p < .10$. The NL groups presented with no difference in RT across conditions.

For the SLI group, a two-way ANOVA with factors Imageability x Frequency indicated a main effect of imageability, $F_1(1,14)=9.93, p < .01$, There was a trend in the main effect of frequency, $F_1(1,14)=3.50, .05 < p < .10$. There was no interaction, all $F_s < 1$.

Group comparison on RT for pseudowords for the simple reaction time task

The final analysis examined and compared responses to words and pseudowords in the simple reaction time task. Table 7 presents the mean RT (msec) for words and pseudowords for the NL and SLI groups in the simple reaction time task. These responses are also presented in Figure 3.

Table 7. Mean latencies (RT in msec) for the NL and SLI groups for words and pseudowords on the simple reaction time task.

<u>Group</u>	<u>NL</u>	<u>SLI</u>
Stimulus Type		
Word	1110 (235)	947 (209)
Pseudoword	1136 (307)	944 (192)

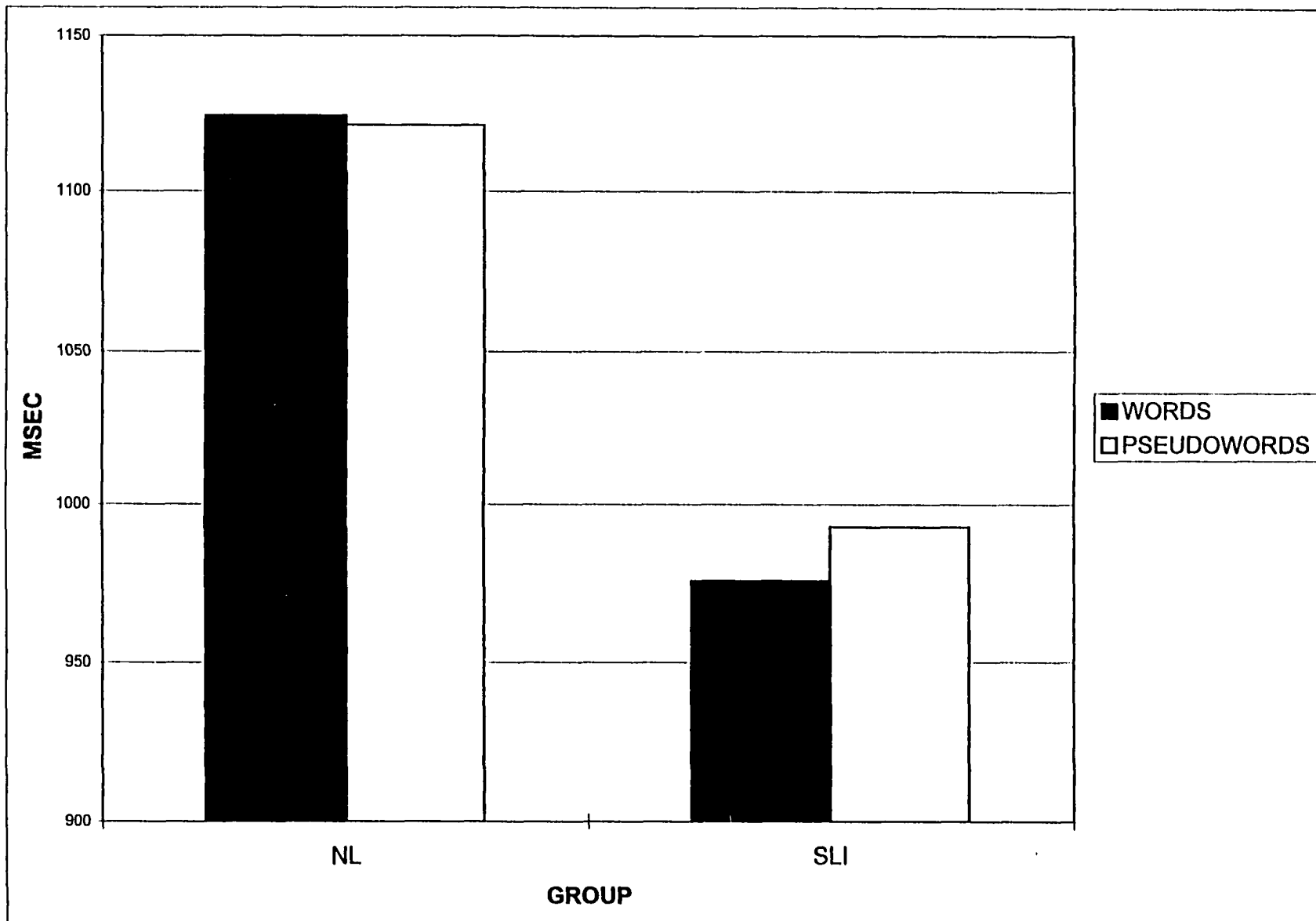


Figure 3: Comparison of NL and SLI children's word and pseudoword responses on the simple reaction time task

A two-way ANOVA with factors Group x Stimulus (W/PW) was analyzed with a reduced subject group ($n=26$). Subjects with more than 10% anticipations, and RT falling below a lower cutoff of $<250\text{msec}$, were not included in the analysis. There was a main effect of Group, $F_{1,24}=5.05$, $p<.05$. There was no main effect of stimulus type, or interactions. All $F_s < 1$ in these analysis.

Item-based analysis of the data

F_2 item based statistical analysis was applied to the data to examine the contribution of word stimuli. A three way ANOVA with factors Group x Imageability x Frequency indicated that there was a three-way interaction, $F_2(1,36)=8.18$, $p<.01$. There was a main effect of imageability, high versus low, $F_2(1,36)=13.75$, $p<.001$. There was a main effect of frequency, high versus low, $F_2(1,36)=5.90$, $p<.025$. There was a main effect of group, NL versus SLI, $F_2(1,36)=21.02$, $p<.001$. With factors Group x Imageability there was an interaction indicated, $F_2(1,36)=8.50$, $p<.01$. With factors, Group x Frequency there was an interaction, $F_2(1,36)=4.37$, $p<.05$. With factors, Imageability x Frequency there was no interaction, $F_2(1,36)=0.31$, $p>.25$.

Post-hoc analysis further examined the effects of the imageability and frequency factors. Univariate ANOVAs examined these factors within the NL and SLI groups.

A two-way ANOVA for the NL group indicated there were main effects for imageability, $F_2(1,36)=7.24$, $p=.01$, and for frequency, $F_2(1,36)=2.91$, $p>.10$. There was no interaction, $F_2(1,36)=.13$, $p>.01$.

A two-way ANOVA for the SLI group indicated a main effect of imageability in the item-based analysis, $F_2(1,36)=18.77$, $p<.01$ and for frequency, $F_2(1,36)=8.37$, $p<.01$ but no interaction, $F_2(1,36)=1.91$, $p>.05$.

Statistical analysis of responses to the motor task were the same as for the lexical task. A three-way ANOVA with factors Group x Imageability x Frequency indicated a main effect, $F_2(1,36)=115.76, p,.0001$. There was no main effect of imageability, $F_2(1,36)=1.90, p>.10$. There was no main effect of frequency, $F_2(1,36)=.52, p>.1$ There was a two-way interaction of Group x Imageability, $F_2(1,36)=4.85, p<.05$. There was a trend in the two-way interaction of Group x Frequency, $F_2(1,36)=3.83, .05<p<.10$.

The responses for NL and SLI subjects were examined further separately. For the NL subjects, a two-way ANOVA with factors Imageability x Frequency indicated that there were no main effects, $F_2(1,36)=1.29, p>.25$.

For the SLI group, a two-way ANOVA with factors Imageability x Frequency indicated a main effect of imageability, $F_2(1,36)=3.96, .05<p<.10$. There was no main effect of frequency, $F_2(1,36)=1.86, p>.10$. There was no interaction, $F_2<1$.

The final analysis examined and compared responses to words and pseudowords in the motor task. A two-way ANOVA with factors Group x Stimulus indicated a main effect of Group, $F_2(1,78)=117.33, p<.001$. There were no main effects of stimulus type, or interactions. All $F_s < 1$ in these analysis.

Chapter 4: Discussion

General conclusions

This study examined the effects of frequency and imageability on auditory word recognition by children with SLI and NL controls. Words and pseudowords were presented in a lexical decision task and a simple reaction time task. In the first experiment, the lexical decision task, RT was measured for words falling within four combinations of the factors. These combinations were high imageability/high frequency, high imageability/low frequency, low imageability/high frequency, and low imageability/low frequency. Reaction time to GO/NO GO lexical decisions were analyzed for stimuli. In the second task, the simple reaction time task, subjects were directed to respond to every stimulus they heard whether a word or pseudoword. This task was used to examine general attentiveness and response speed. Reaction time for words were compared to pseudowords.

Several predictions were made regarding the effects of the imageability and frequency factors. As expected, the effects of frequency resembled those reported in the literature (e.g. Bradley & Forster, 1987; Forster, 1990; Forster, 1989). The effects of frequency on auditory lexical processing were robust with the two groups. In studies involving adults as well as in a limited number of studies with children imageability influenced RT when visual stimuli were used (e.g. Akin, 1989; McMullen & Bryden, 1987). As expected, the effects of imageability were found for both groups. The combined effects of the two factors of imageability and frequency influenced children's auditory lexical decisions. However, the patterns were different for the children with SLI when compared to the control group. These patterns have not been reported in the literature.

Although the pattern of increased RT for words that were low in imageability and frequency was the same in both groups, the magnitude was considerably greater with the

SLI group. As predicted, there was an interaction of frequency and imageability with the SLI group. The combined effects of imageability and frequency resulted in a synergistic pattern for this group. The increased RT for low imageability/low frequency words could be accounted for by the independent influence of each factor only for the NL children. This finding expands the literature on SLI children's lexical processing abilities.

The present research also contributes to our understanding of the general response speed of children with SLI. There have been frequent reports of generally slow responses by children with SLI during processing tasks (e.g. Edwards & Lahey, 1996; Edwards & Lahey, 1993; Kail, 1991). Response slowness observed in these studies was suspected to be independent of the children's linguistic abilities (Kail, 1994). Previous research has used nonlinguistic stimuli such as tones to compare motor or general response speed to speed of processing linguistic stimuli. In the present research, lexical stimuli were used in the lexical decision task and in a simple reaction time task in order to have a more congruous comparison. The children with SLI in this research exhibited responses on the simple reaction time task that were not consistent with previous reports of response slowness. Motor or otherwise, their reaction times were faster than NL controls.

The results of this research has implications for assumptions about the role of imageability in models of lexical access, our understanding about the nature of SLI, and efforts towards developing effective treatments for management and remediation of the SLI sequelae. Future research expanding on the findings reported in this study is recommended.

Lexical access: The role of imageability

Auditory word recognition involves pre-access, access, and post access components (e.g. Whaley, 1978). In a search model of the lexicon, pre-access processes are composed of

mechanisms that interact with the acoustic and phonetic properties of words. For auditory word recognition to take place, the acoustic pattern of the word must be retrieved and the phonological encoding of what was heard must be analyzed. In this model of lexical access, frequency acts so as to make the retrieval of a match for phonetic input more efficient. More frequently used words are represented early in the search path, and are therefore retrieved more quickly (Bradley & Forster, 1987; Forster, 1990; Forster, 1989). Lexical access takes place after a match for the phonetic string occurs.

In addition to a word's phonetic, acoustic and frequency representation, there may be associated information represented influencing word recognition. This information may include stored experiences about a word such as images associated with the word's referent. The imageability of the word's referent is not part of the initial information guiding word recognition. However, it may be part of the post access mechanism that leads to a decision that the stimulus heard was a word. Figure 4 provides a linear schematic of processes involved in auditory word recognition. As illustrated in the figure, a spoken word is composed of a phonetic structure. This provides the input for auditory word recognition. The word frequency guides the access phase of word recognition. Imageability may influence a lexical decision during the post-access period. It may be part of an integration of information that contributes to determining whether the phonetic input heard was a word or pseudoword.

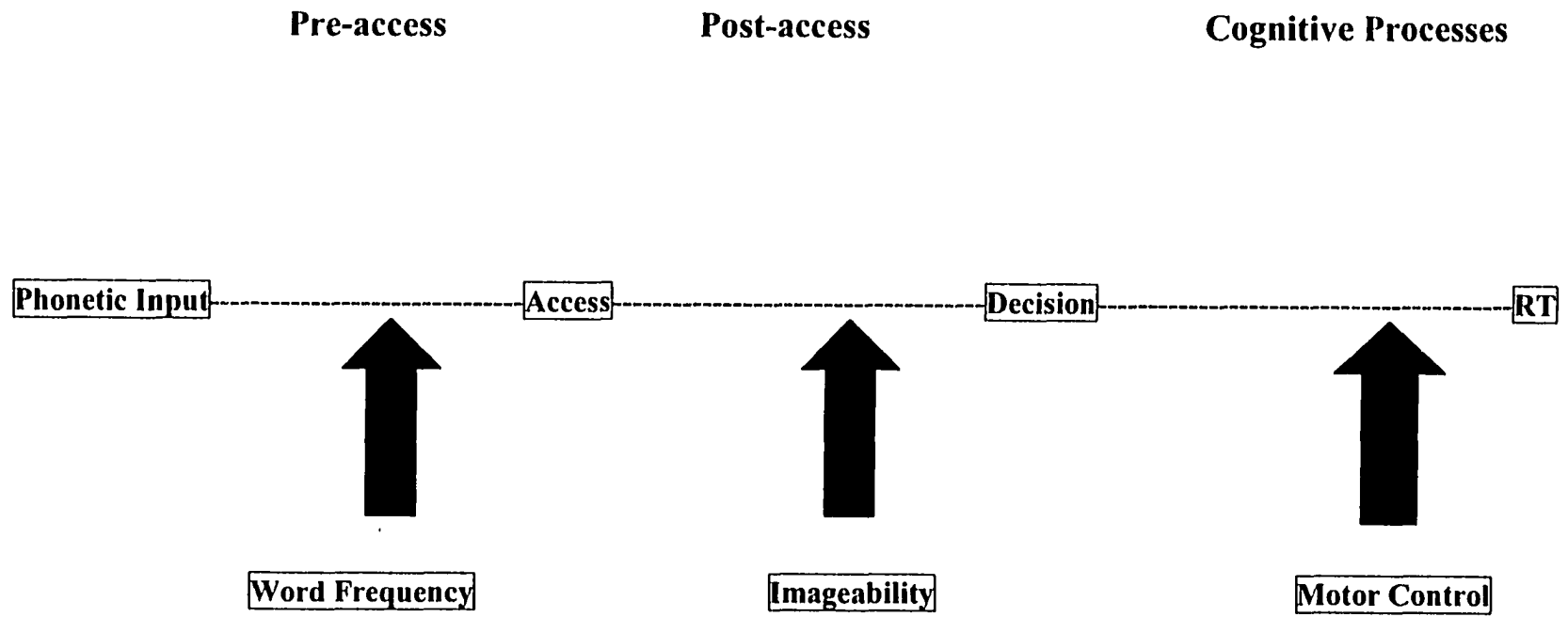


Figure 4: Factors affecting auditory lexical decision

In experiments using visual recognition of words, the effect of imageability on lexical access has been explained in three ways. The dual-coding approach maintains that language has a sign/symbol component and an image component. Concrete words are associated with images and with sensorimotor experiences. Abstract words have less association with images and sensorimotor experiences. The theory assumes that simultaneous processing of the imagistic aspects of a word's referent is responsible for concrete words being processed faster than abstract words (Paivio, 1968, 1971). Another explanation concerns the contextual availability of words. This explanation suggests that when words have contextual information available, they are processed more quickly than words with less associated context (Schwanenflugel, Harnishfeger & Stowe, 1988; Schwanenflugel & Shoben, 1983; Schwanenflugel & Stowe, 1989). Therefore context, rather than concreteness, is the critical factor in speed of recognition. When contextual factors are controlled concrete/abstract differences among words will disappear. A third explanation is that there are developmental patterns in the use of imagery. Younger children may demonstrate a stronger tendency to use images to assist comprehension than older children (Kosslyn, 1974). These explanations are based on lexical decision responses to *visual* stimuli. We cannot presume that the same assumptions apply when the stimuli is *auditory*. Although listening and reading may share processing components, the processing routes may not be entirely identical. In sum, none of the explanations described adequately address lexical access for isolated auditory word stimuli.

The present research provides empirical evidence that the image component of the word's referent is an important influence on latency reaction time for auditory stimuli. How this information is represented and stored remains a question. This information may be part of a separate storage system, as the dual-coding approach suggests, or it may be part of

post-access mechanisms. If it is part of a separate storage system, it may be simultaneously processed during lexical processing. If imagistic information, is part of post-access mechanisms, then it may be sequentially processed after the acoustic/phonetic aspects of the word.

The role of imageability and frequency in SLI children's lexical decision

The children with SLI were influenced by an interaction of imageability and frequency. There are two interpretations of this pattern. If children with SLI have global language deficiencies, then it is not unusual that they would demonstrate less efficient language skills than their peers across all dependent measures, including lexical decision. A greater processing load, that would occur due to low frequency and imageability levels, would result in more time needed to obtain access and make a decision. Although increased latency was demonstrated by the NL children, for low frequency/low imageability words, the difference in msec for children with SLI was greater. The effect of imageability could be interpreted as having no special connection to the way these children process information. Any decreased information about a word might result in an increased processing load and an increased RT. However, the fact that the SLI children were similar to the NL children in their responses to all stimulus sets with the exception of low imageability/low frequency words makes a general increase in processing load a less than adequate explanation. For these children an alternative explanation for the elevated RT with low frequency/low imageability words is that they have specific processing deficits with words that contain sparse information because their own lexical entries may be underrepresented.

Representational difficulties of children with SLI have been described with regard to their grammatical abilities (e.g., Leonard, 1997; Schwartz, Leonard, Messick, Chapman, 1987). The literature demonstrations that at least for some subgroups of children with SLI,

grammatical difficulties are insufficient when their skills are compared to their NL peers (e.g. Rice & Wexler, 1996). If children with SLI have lexical entries that are grammatically underrepresented, then the auditory word recognition of lexical forms may be compromised. One explanation of how children manage lexical decisions when their lexical entries are underrepresented is that these children use associated information about the lexical entry to facilitate processing. The associated information may be obtained from other aspects of the cognitive system such as an imagistic storage system. For example, if a fully represented entry were not available in storage for a phonetic string to be evaluated, then post access information might be used to facilitate the decision process. Figure 5 illustrates how this might occur. Imageability of the word referent is presented as part of the post access information applied to the phonetic input being evaluated. Images be used by children with SLI in a compensatory manner to facilitate processing of lexical items that have sparse information. When image information is not readily available and the frequency of the word is low, the input is sparse. There is no possibility of compensation. When underrepresented lexical entries have imageable referents, imagistic information may be used to facilitate their processing. Therefore the decision time post access results in a faster RT. When underrepresented lexical items are less imageable, imagistic information may not be available to facilitate processing. Therefore the decision time post access is longer and RT is slower.

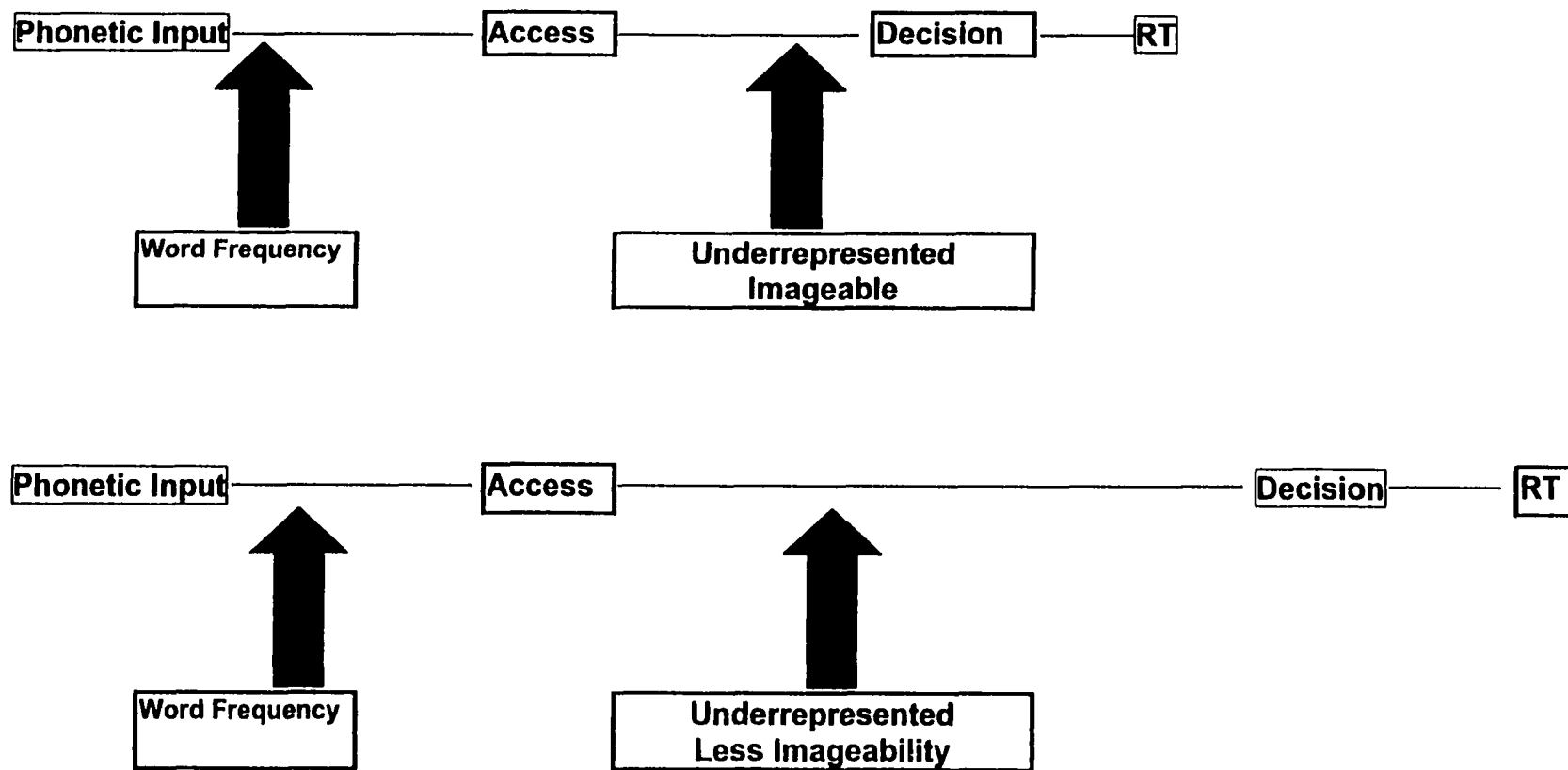


Figure 5: The influence of imageability in lexical decisions with underrepresented lexical entries

Word frequency factors that impose constraints on search models of lexical processing similarly affect children with SLI and their NL peers. High frequency words are processed faster than low frequency words. This is explained by a search model of lexical access. The representation of more frequently occurring words is at the beginning of the search path in this model. On this level SLI children's processing organization may be similar to their peers. The frequency would affect all lexical representations regardless of their completeness. However, if SLI children make use of referent imageability information to support form processing, the literature on imageability deficits and symbolic representation deficits with SLI children must be explained.

Defining SLI: The role of imageability

SLI children have difficulties with symbolism in early childhood (e.g., Roth & Clark, 1987). We know that nouns predominate in the first 100 words that a child acquires and that the acquisition of syntax precedes from reference to predication and then finally, to grammar. Several studies of early learning have focused on how young children learn the extent of the referent, that is, the range of association of the word heard with what it is referring to. The earliest words are usually referential. Given the role of reference in early linguistic learning and the child's early cognitive development that centers around sensorimotor experiences, it is not unreasonable that words with referents that can be imaged would play an important role in the language. SLI children have been documented to differ from their peers in symbolic relations in their early play and later in their ability to relate symbolically to objects. Difficulties in imaging in older SLI children could be a later component of these early characteristics of the SLI sequelae. The early developmental

difficulties with symbolic play may be part of a weakness acquiring and storing representations.

The present research suggests that SLI children may actually use non-linguistic symbolic information to facilitate processing of lexical entries that may have less than optimal linguistic form representation. That SLI children may have specific areas of linguistic underrepresentation; phonetic, semantic, morphological, syntactic or some combination that has been proposed in the literature (e.g., Leonard, Bortolini, Caselli, McGregor & Sabbadini, 1992). It is possible for SLI children to have difficulties from deficits with symbolism and still benefit from imagistic symbolic information since imageability is a multifaceted process.

That SLI children may have deficits with symbolic representation, in the form of mental imagery, has been proposed in the literature. The types of mental imagery deficits observed have included *anticipatory imagery*, recognition of an object's identity when its orientation is physically changed (Johnston, Ellis Weismer, 1983; Savich, 1984). Another deficit concerns haptic recognition, matching the shape of one object with that of another object that has been felt but not seen (Kamhi, Catts, & Lewis, 1984). SLI children have also demonstrated problems with recognizing a complete picture from unassembled pieces or recognizing what a complete picture would look like when a portion of the picture is missing (Whitmere & Stone, 1991). These examples of deficits suggest problems forming the internal representation or imaging abilities needed to make decisions about some externally presented form. However, mental representation of an image involves a variety of processes. It is possible for children to have facility with some aspects of the process and not others.

Kosslyn (1988) cautioned against an oversimplification of the mental imagery process. Although our intuition may suggest that images are a simple uninterrupted whole, the actual ability to form images may be a conglomeration of parts. He suggested that there are two classes of processes that are involved in the ability to form images taking place in the right and left hemispheres. These processes involve activating stored memories about the appearance of parts and arranging imaged parts of objects in appropriate configuration. This suggests that imagery is a multicomponent information process. If more than one single ability is involved with imagery, it is possible for SLI children to have varying abilities with some aspects as opposed to others.

Visual mental images are generated from stored information. Kosslyn (1988) proposed that similar physiological mechanisms are involved in visual mental imagery and in visual perception. The actual object may not be present, but we use sensory information to form a perception of the object without its physical presence. Visual areas of the brain are activated when visual mental imagery takes place. For right-handed individuals, it is generally accepted that the left hemisphere of the brain dominates the comprehension and production of language. Kosslyn's research found that this hemispheric domination could not be as generally categorized with mental imageability. He found a dissociation between the processes of activating images and the processes of arranging images. The left cerebral hemisphere was superior in arranging images. Although his studies were with atypical subjects, his findings have implications for subjects such as SLI, who are atypical in their language skills and suspected to be atypical in their neurocognitive disposition as well (Condino, Im-Humber, & Stark, 1990; Johnston & Ramstad, 1983; Kamhi, 1981; Restro, Swisher, Plante, & Vance, 1992; Swisher, Plante, & Lowell, 1994; Swisher & Plante, 1993; Savich, 1984; Stark, & Tallal, 1981). Studies presenting data from positron emission

tomography (PET) lend support to the multifaceted aspects of processing words and images (Posner, Petersen, Fox, & Raichle, 1988). PET scan observations of single word visual reading have found that no single brain area or cerebral hemisphere is involved. However, there was a difference in cerebral involvement between generating an image and scanning an image once it had been generated. Studies with split brain patients found left hemisphere superiority in generating an image, and right hemisphere contributions to scanning an image once it had been generated.

These studies suggest that evidence from physiological sources together with data from behavioral sources such as reaction time measures in lexical decision would help to delineate the consequences of selective processing and representational deficits in these children.

Directions for future research

The lexical decision paradigm provides behavioral measures of children's RT for recognizing words and pseudowords while listening to them. Typical studies of word recognition in children examine success or failure. They tell us little about the related underlying brain processing. Analysis of the brain activity accompanying the processing of these stimuli could provide converging evidence of SLI children's lexical processing difficulties.

Electrophysiology measures can provide information on brain activity as it relates to anatomical structures and processing of cognitive, phonemic and linguistic information (Steinschneider, Kurtzberg, & Vaughn Jr., 1992; Garnsey, 1993). These measures of cortical responses can provide a continuous record of neural activity as lexical stimuli are presented. Because these measures give information about the time course of lexical processing, they can contribute to our understanding of SLI children's lexical decisions.

Word imageability effects on lexical/semantic processing have been studied using behavioral and electrophysiological methodology. Behavioral studies of word imageability have focused primarily on the interactions between imageability and visual fields. The stimuli are written words used in a lexical decision task (Ferazzo, Conte & Gentilomo, 1993; Kounios & Holcolmb, 1994; McMullen & Bryden, 1987). One goal of such studies is to determine the relationship between imageability and lexical representation in the right and left cerebral hemispheres in adult subjects.

These studies have demonstrated with adult subjects, relationships between word imageability, hemispheric differentiation, and waveform patterns. Among the peak waveforms that has become associated with lexical/semantic processing is N400 (Curran, Tucker, Kutas & Posner, 1993). Kounios, & Holcolmb (1994), were able to detect N400 differences for the lexical processing of concrete and abstract words using visual stimuli. They investigated whether the dual-coding model of processing present as N400 differences in the two cerebral hemispheres. Concrete words, with advantages for both imagistic and linguistic representation, if this model were supported, would show different scalp distributions of the N400 negativity. A narrow interpretation of left hemisphere and right hemisphere processing would suggest that the imagistic system would be located in the right hemisphere. Abstract words, being limited in imagistic properties would have limited representation in the right hemisphere. Therefore, larger differences in processing concrete and abstract words would occur in the right hemisphere. Using two semantic processing experiments with visual stimuli, they found an N400 advantage for concrete words over abstract words in the right hemisphere. Abstract words produced larger effects in the left hemisphere. Repetition effects found were attributed to an increase of contextual information (after repetition, differences between the words were less). They conclude that

the dual-coding model as opposed to a context availability model where processing occurs in one coding system, best explains differences in scalp distribution of N400 presentation. However, they do note that abstract words may be associated with imagistic information but not to the same degree as concrete words. As Kosslyn, suggests, mental image representation is a multifaceted process. There may not be a single physiological explanation for how SLI children process the relative imageability of word referents.

There is preliminary research that suggests that there are cerebral hemispheric differences and electrophysiological differences between SLI children and age matched peers (Plante, Swisher, Vance & Rapcsak, 1991; Kinsbourne & Hiscock, 1990; Mills, Coffey-Corina, & Neville, 1993). There is limited research however, on the event related potentials in children that accompany presentations of auditory semantic stimuli (Friedman, Putnam, & Sutton, 1990). Using visual word stimuli is problematic for SLI children. Some children with SLI have difficulties with reading. However, their reading difficulties are varied. It is difficult to separate decoding problems from lexical/semantic problems using this methodology.

Taken together, evidence from behavioral measures and electrophysiology can lead to expanded understanding of the organization of the mental lexicon in SLI children. However, developing stimuli that will accommodate the constraints of both methodologies is a challenge. Electrophysiological measurement requires several constraints on stimuli composition and number that are not as critical to behavioral measures. This measurement is most effective when the acoustic and phonetic composition of the stimuli have minimal variation. An example of this would be word stimuli of the same acoustic duration. Behavioral experiments generally restrict repetition of stimuli in order to minimize effects on RT from exposure and learning. The number of stimuli needed is also critical to

electrophysiology experiments. At least 30 to 40 stimuli per stimulus type is common for these types of experiments. Finally, stimuli, in electrophysiology is generally repeated in order to have enough data to average. In behavioral experiments however, frequency of stimulus presentation is limited because of the possibility that repetition effects will impact on learning.

If the behavioral and electrophysiological methodologies were utilized in order to obtain converging data then attention must be given to differences in stimulus requirements. Using passive physiological measures such as electrophysiology may be the only way to determine SLI children's language competence without observing their language performance. Behavioral measures can help determine the functional impact of physiological differences so that reasonable directions for intervention can be determined. These measures could also be used to help differentiate subgroups of SLI children identified from behavioral data.. This applied clinical use has been demonstrated by Miles & Stelmack (1994), who used these types of measures to differentiate children's learning disability subtypes.

Intervention and SLI: The role of imageability

Visualization and imagery has long been a component of the literature on learning development, reading development and effective reading instruction (e.g. Pressley, & Levin, 1977; Reese, 1970; Reese, 1972; Vellutino & Scalon, 1985). Imagery has been claimed by some researchers to be a tool for coding and storing meaning during reading. If some subgroups of SLI children use images to facilitate their linguistic processing then intervention that encourages visualization skills as compensatory strategies is appropriate.

Diagnostic probes using imageability as a factor may help to sort out those subclasses of SLI children who have representation problems. However, representation

problems of these children, needs further investigation. For example, linguistic underrepresentation may occur on the phonetic level. Underrepresentation in the phonetic component of a word's lexical entry may compromise the efficiency of lexical processing in a manner similar to grammatical underrepresentation.

Based on clinical descriptions of their speech production in early childhood, children with SLI in this study had histories both of phonological disruption and seemingly normal phonological development. Some had early histories of unintelligible speech. Others did not have any reported history of speech impairment. We cannot make assumptions about the phonetic representations of these children since available information is descriptive and based solely on production data. Whether these children's phonetic representation is adequate to support efficient lexical processing remains a question. A larger sample size focusing on separating these two subgroups may help to differentiate those who have phonetic representation problems from those who do not. As other researchers have suggested, auditory lexical decision measures that record "gated" responses, would help to uncover the phonetic processing and/or phonetic representation abilities of these children (e.g. Edwards & Lahey, 1996; Elliot, Hammer, & Evan, 1987). In a gating lexical decision task, subjects indicate whether they think the stimulus is a word or not as the word is acoustically deployed. However, RT measures from this methodology would be more interpretable if the subjects were first subcategorized by their present and past phonetic abilities. Children with phonetic representation deficiencies may need phonological based intervention in addition to compensatory training using imagistic information.

Summary

This research has implications for the explanation and identification of the SLI sequelae. The assertion that there is a single source of the SLI sequelae is false. The children with SLI in this study did not have modality specific impairments nor did they present with a generalized slowness. Their auditory recognition reaction time was directly affected by the sparseness of the lexical input. The combined effects of imageability and frequency factors as they changed from high to low resulted in lexical input that was sparse in linguistic and imagistic representation. The consequence for auditory word recognition with these children was burdened lexical processing and therefore, a slower RT. However, on the simple reaction time task, that did not depend on lexical information RT was not negatively affected. These findings suggest that children with SLI are not slower in their processing but that they have more difficulty processing words with improvised representations. Children with SLI may use imagistic information to facilitate lexical processing when a word's linguistic information is unavailable or underrepresented. Therefore, pictorial tests that depend on vocabulary words that can be imaged may overestimate the word recognition abilities of these children.

Appendix A
Normal language group demographic information

<u>SUBJECT</u>	<u>GENDER</u>	<u>AGE</u>	<u>ETHNIC GROUP</u>	<u>SOCIAL ECONOMIC STATUS</u>	<u>MOTHER</u>	<u>SOURCE OF LANGUAGE INFLUENCE SOCIAL ENVIRONMENT</u>
NL 1	male	10	Caucasian	high		
NL 2	male	10.4	Afr. American	high	Jamaican Creole	
NL 3	male	10	Caucasian	high		
NL 4	male	10.2	Caucasian	high		
NL 5	male	9.7	Caucasian	high	Trinidadian Creole	
NL 6	male	9.6	Caucasian	high		
NL 7	female	10.9	Caucasian	high		
NL 8	female	10.2	Afr. American	low	Dominica Creole	
NL 9	female	9.1	Caucasian	high		
NL 10	female	10.5	Caucasian	mid		
NL 11	female	10.4	Afr. American	low		African American English
NL 12	male	10.3	Caucasian	high		
NL 13	male	10.2	Caucasian	high		
NL 14	male	10.7	Caucasian	mid		
NL 15	male	8.9	Afr. American	low		African American English

Appendix B
Specific Language Impaired group social and developmental information

<u>SUBJECT</u>	<u>GENDER</u>	<u>AGE(YRS.)</u>	<u>ETHNIC GROUP</u>	<u>SES</u>	<u>SOURCE OF LANGUAGE INFLUENCE</u>			<u>OMP</u>	<u>PHON</u>	<u>RX</u>	<u>FAMILY INCIDENCE</u>
					<u>MOTHER</u>	<u>FATHER</u>	<u>S.E.</u>				
SLI 1	male	10	Afr. American	low			AAE				2 female siblings
SLI 2	male	10.3	Afr. American	low			AAE				
SLI 3	male	10.1	Afr. American	mid			AAE		P		2 male siblings
SLI 4	male	10.2	Afr. American	low			AAE		P		
SLI 5	male	9.7	Afr. American	low	Guyana	Jamaica					
SLI 6	male	9.7	Caucasian	high					P	P	1 male sibling
SLI 7	female	10.11	Caucasian	mid							2 male siblings
SLI 8	male	10.3	Caucasian	high							
SLI 9	female	9	Afr. American	high							
SLI 10	male	10.6	Hispanic	high							
SLI 11	female	10.7	Afr. American	low			AAE				
SLI 12	male	10.2	Caucasian	high							1 female sibling
SLI 13	male	10.1	Afr. American	high	Jamaica					P	2 male siblings
SLI 14	male	10.6	Caucasian	mid						P	
SLI 15	male	8.2	Caucasian	low				P			1 female sibling

- Notes:
- SES Social Economic Status based on local norms
 - S.E. Language influence from the social environment
 - OMP 5 or more incidents of otitis media per year before kindergarten
 - PHON-P History of phonological disability in early childhood, described by a speech language pathologist as unintelligible
 - RX-P Diagnosis of Attention Deficit Disorder, medical monitoring by a physician with drug intervention
 - Family Incidence Number and gender of siblings diagnosed with Specific Language Impairment

Appendix C
Normal language group educational and language testing

<u>SUBJECT</u>	<u>CTBS TESTING</u>						<u>LANGUAGE TESTING</u>		
	<u>YEAR 1</u>		<u>YEAR 2</u>		<u>YEAR 3</u>		<u>PPVT-R</u>	<u>TOLD</u>	<u>DETROIT</u>
	<u>READING</u>	<u>MATH</u>	<u>READING</u>	<u>MATH</u>	<u>READING</u>	<u>MATH</u>			
NL 1	99	99	90	81	73	75	25	50	41
NL 2			55	47	50	43	61	53	33
NL 3	90	76	68	81	60	77	53	52	44
NL 4	68	81	75	64	58	63	47	52	48
NL 5	90	99	80	75	81	76	81	57	26
NL 6			58	56	48	53	32	50	44
NL 7	64	65	58	62	58	54	84	52	26
NL 8	56	56	50	61	46	66	81	50	37
NL 9	68	90	80	99	77	83	95	73	27
NL 10	54	62	76	87	69	72	34	60	37
NL 11	99	78	62	53	50	53	55	49	30
NL 12			71	59	72	69	91	67	41
NL 13			57	70	51	56	96	53	37
NL 14	77	73	62	65	66	62	55	49	37
NL 15			55	64	80	56	96	86	33
<u>M</u>	77	78	66	69	63	64	66	57	36
<u>SD</u>	17	15	12	14	12	11	30	11	7

Notes: Some test scores were not available for students transferred from other schools.
 Values for the Comprehensive Test of Basic Skills (CTBS) represent the normal curve equivalent.
 Values for the Peabody Picture Vocabulary Test (PPVT-R) represent percentiles.
 Values for the Test of Language Development (TOLD) represent the grand mean for percentiles.
 Values for the Detroit Test are for subtest XI. They represent percent correct of all stimuli.

Appendix D

Specific Language Impaired group testing and educational program placement

SUBJECT	CTBS TESTING						C.T. K-BIT	LANGUAGE TESTING			PLACEMENT	
	YEAR 1		YEAR 2		YEAR 3			PPVT-R	TOLD	DETROIT	1	2
	READING	MATH	READING	MATH	READING	MATH						
SLI 1	99	99	90	81	73	75	110	1	25	30	SEC	SEC
SLI 2			55	47	50	43	92	12	25	30	R/RR	R/LD
SLI 3	90	76	68	81	60	77	102	12	15	37	SEC	R/LD
SLI 4	68	81	75	64	58	63	112	1	15	56	SEC	SEC
SLI 5	90	99	80	75	81	76	88	39	25	22		R/RR
SLI 6			58	56	48	53	107	27	25	30	SEC	SEDS
SLI 7	64	65	58	62	58	54	118	16	25	30	R/RR	R/RR
SLI 8	56	56	50	61	46	66	122	39	25	26	R/RR	R/LD
SLI 9	68	90	80	99	77	83	116	58	12	41	R/LD	R/LD
SLI 10	54	62	76	87	69	72	118	3	10	30	R/RR	R/RR
SLI 11	99	78	62	53	50	53	112	10	25	22	R/RR	R/RR
SLI 12			71	59	72	69	104	10	25	35	R/RR	R/LD
SLI 13			57	70	51	56	112	27	34	30	R/LD	R/LD
SLI 14	77	73	62	65	66	62	103	39	16	30	R/LD	R/LD
SLI 15			55	64	80	56	118	1	11	41	R/LD	R/LD
<u>M</u>	77	78	67	68	63	64	109	20	21	33		
<u>SD</u>	17	15	12	14	12	11	10	18	7	9		

Note: Some test scores were not available for students transferred from other schools.

C.T. represents cognitive testing

Placement refers to educational school program placement. "1" indicates placement prior to experiment.

"2" indicates the program the child participated in at the time of the experiment.

The programs listed are as follows: SEC- special education class, SES-special education school, R/RR- regular class with remedial reading, R-LD- regular education class with learning disabilities resource room.

Appendix E

Written instructions for teacher ratings of word exposure and familiarity.

Please rate the following words for student exposure and understanding. Please rate all words. Base your answers on your teaching experiences with normal learning children in your current teaching grade. The rating scale ranges from 0 to 4. A rating of 4 is the highest score for a word, meaning students have had a great deal of exposure to it. The numbers correspond to the following descriptions:

- 0 Children I teach definitely have never been exposed to this word.
- 1 Children I teach are unlikely to have had any exposure to this word.
- 2 Children I teach may have been exposed to this word but are unlikely to be familiar with its meaning.
- 3 Children I teach have had exposure to this word and have some understanding of it.
- 4 Children I teach have been exposed to this word and definitely understand what it means.

Appendix F

Verbal instructions for children's word imageability ratings.

We are going to play a word game together. It's called "Is there a picture?" Some words are easier to think of a picture for than others. For example, you can probably think of a picture in your head for the word *bear*. This may be easy because you have seen a real bear, like at the Bronx Zoo. Some words may be harder to think of a picture for, like the word *truth*. You know what truth means, but you can't see it, feel it, or taste it, so that makes it hard to picture it in your head.

Let's try some words together. I'll tell you some words, and you say whether a picture comes into your head right away, whether you have to think about it a little, or whether you don't get a picture at all. Give the words a score. *3* is the top score. It means a picture comes into your head right away, without thinking. *2* means a picture comes into your head, but you have to think about it. *1* means you have to think a long time before you can get a picture in your head. *0* means you can't get a picture. Write the number for each word on your paper. Ready? "ship" (examiner waits for a response, then opens a discussion about the ratings), "cot" (examiner waits for a response, then opens a discussion about the ratings, "mercy" (examiner waits for a response, then opens a discussion about the ratings.)

Now I want you to do some on your own. I will read the word, then I will give you time to give the word a score. Remember, *3* is the top score. It means a picture comes into your head right away without thinking. *2* means a picture comes into your head, but you have to think about it. *1* means you have to think a long time before you can get a picture in your head. *0* means you can't get a picture. There are no right or wrong answers. Give all the words a score.

Appendix G

Children's imageability ratings: percentage of children rating the word as difficult to image(n=30)

<u>High Imageability</u>		<u>Low Imageability</u>	
(not difficult to image)	% of children	(difficult to image)	% of children
house	0	fact	67
door	0	today	43
water	0	moment	47
girl	7	unit	43
body	0	problem	37
woman	3	life	40
dog	0	rule	27
sand	3	voice	30
food	3	time	30
man	3	power	30
rag	10	law	37
bush	3	month	37
coin	0	unit	33
salad	0	habit	37
chin	0	deed	43
jelly	7	moral	60
cigar	7	fault	57
math	7	mood	43
toy	7	noun	33
lip	0	god	23
<u>M</u>	3 (3)		40(11)

Appendix H - Word Frequency values

<u>Word</u>	<u>Frequency</u>	<u>Categorization</u>	<u>Word</u>	<u>Frequency</u>	<u>Categorization</u>
house	67	high	law	58.4	low
door	64.6	high	month	58.5	low
water	70.8	high	hint	49.6	low
girl	62.9	high	habit	53.5	low
body	64.7	high	deed	45.7	low
woman	61	high	moral	48.9	low
dog	63.6	high	fault	52.3	low
sand	60.4	high	mood	54.5	low
food	66.7	high	noun	58.2	low
man	69.9	high	rag	47.1	low
fact	62.4	high	bush	44.7	low
today	65.6	high	coin	52.7	low
moment	61.5	high	salad	45.4	low
unit	60.5	high	chin	52.3	low
problem	62.6	high	jelly	51.3	low
life	66.5	high	cigar	46.5	low
rule	60	high	math	43.2	low
voice	63.2	high	toy	53.8	low
time	72.1	high	lip	48.2	low
power	62.7	high	god	53.2	low
<u>M</u>	64.435		<u>M</u>	50.9	
<u>SD</u>	(3.42)		<u>SD</u>	(4.64)	

Lower case frequency selected only.

Note:

HI/HF	High Imageability/High Frequency
HI/LF	High Imageability/Low Frequency
LI/HF	Low Imageability/High Frequency
LI/LF	Low Imageability/Low Frequency

Appendix I
Experimental Pseudowords

[bapi]	[gɔɪm]	[mɛf]	[sɪmp]
[bɛtʃ]	[heʃ]	[mɪm]	[salɪk]
[tʃam]	[hɪpɪd]	[mob]	[sokəʌ]
[daek]	[hʌnd]	[nʊm]	[tɔ]
[don]	[dʒaɪmi]	[naʊwəʌ]	[ten]
[dʌp]	[kaʊn]	[nʌnf]	[tɪpo]
[fɪsk]	[laɪ]	[pɔlə]	[vʊz]
[fog]	[lɛk]	[pʌɪbɪŋ]	[wɛndɪ]
[folp]	[loɪ]	[ɹɪv]	[wʌgl]
[gaek]	[maenʌlt]	[rʌp]	[jomi]

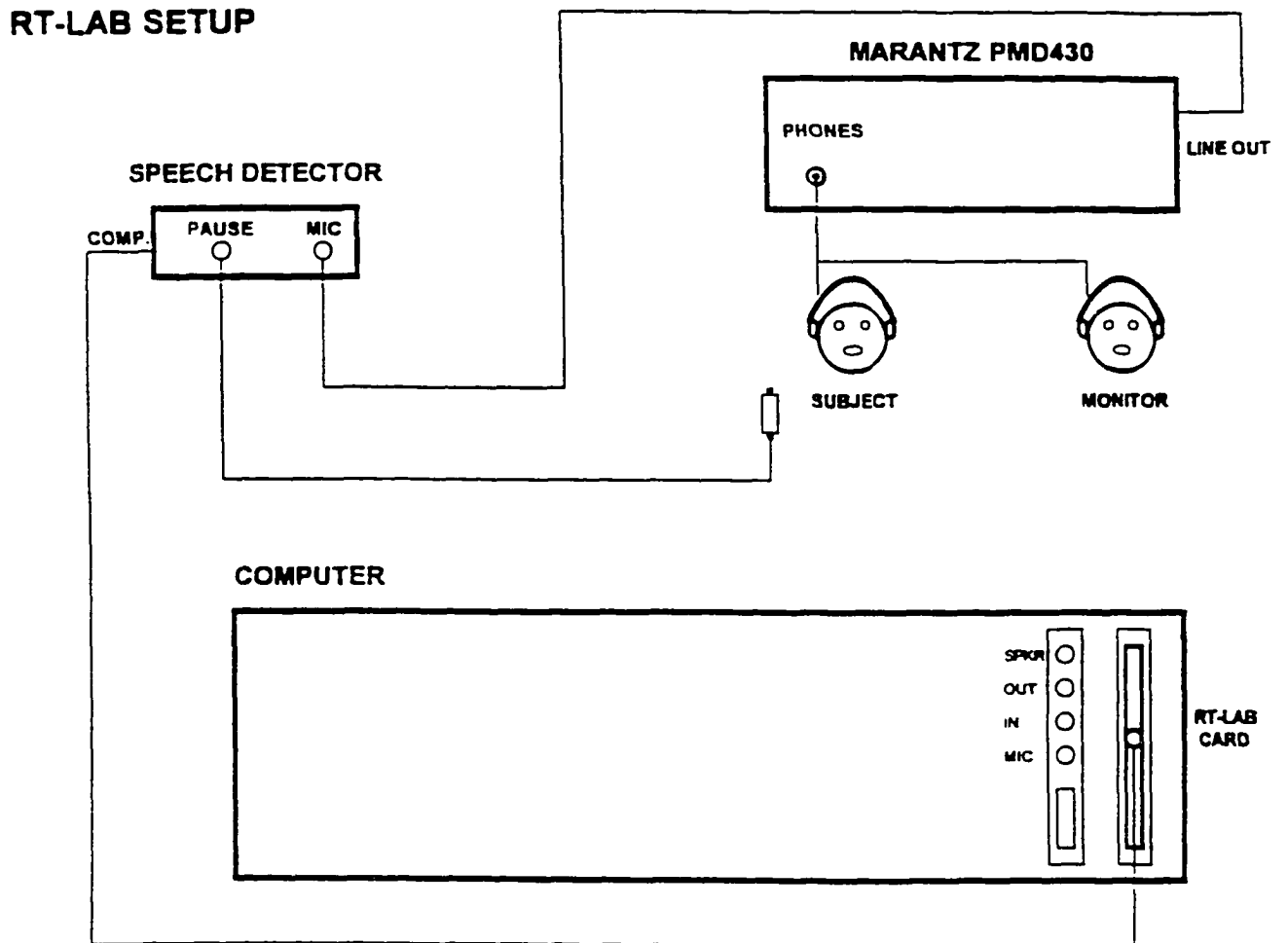
Appendix J

Acoustic durations (in msec) of experimental words grouped by stimulus category

<u>HI/HF</u>	<u>msec</u>	<u>HI/LF</u>	<u>msec</u>	<u>LI/HF</u>	<u>msec</u>	<u>LI/LF</u>	<u>msec</u>
house	641	rag	702	fact	678	law	765
door	646	bush	566	today	673	month	685
water	669	coin	*1152	moment	814	hint	529
girl	526	salad	824	unit	750	habit	664
body	652	chin	627	problem	763	deed	753
woman	717	jelly	555	life	*1080	moral	832
dog	783	cigar	861	rule	705	fault	871
sand	774	math	843	voice	789	mood	919
food	894	toy	687	time	664	noun	794
man	813	lip	613	power	718	god	660
<u>M</u>	712		698		728		747
<u>SD</u>	106		119		54		116

Note: * These values are suspected to contain experimental artifacts.

Appendix K
Schematic of the experiment instrumentation



Appendix L
Individual subject lexical decision latency (RT in msec) for word stimuli in the lexical task

Subject	HI/HF	HI/LF	LI/HF	LI/LF	Subject	HI/HF	HI/LF	LI/HF	LI/LF
NL-1	1266	1419	1381	1369	SLI-1	956	1143	1087	1214
NL-2	1149	1248	1333	1372	SLI-2	1441	1215	1600	1566
NL-3	1201	1168	1387	1480	SLI-3	981	1096	1171	1100
NL-4	930	1082	1094	1124	SLI-4	1353	1221	1508	1829
NL-5	1242	1111	1214	1233	SLI-5	1297	1380	1468	1751
NL-6	1165	1133	1266	1246	SLI-6	954	1066	1166	1625
NL-7	929	1057	1058	1059	SLI-7	1034	1352	1303	1426
NL-8	1020	1133	1198	1357	SLI-8	1079	1391	1296	1586
NL-9	869	950	904	1203	SLI-9	1102	1235	1180	1305
NL-10	992	1063	1221	1672	SLI-10	1084	1054	1249	1375
NL-11	1085	1186	1172	1194	SLI-11	1051	1000	1120	1063
NL-12	1100	1341	1322	1158	SLI-12	1146	1270	1299	1779
NL-13	1407	1569	1638	1754	SLI-13	1269	1291	1265	1407
NL-14	1107	1315	1153	1296	SLI-14	981	1001	984	1218
NL-15	1159	1305	1296	1430	SLI-15	1424	1514	1422	1851
<u>M</u>	1108	1205	1242	1330	<u>M</u>	1144	1215	1275	1473
<u>SE</u>	37	42	69	79	<u>SE</u>	69	40	43	107

Note:

HI/HF High Imageability/High Frequency
 HI/LF High Imageability/Low Frequency
 LI/HF Low Imageability/High Frequency
 LI/LF Low Imageability/Low Frequency

Appendix M

Normal language and specific language impaired subject's RT (in msec) sorted by experimental word

<u>HI/HF</u>	<u>NL</u>	<u>SLI</u>	<u>HI/LF</u>	<u>NL</u>	<u>SLI</u>	<u>LI/HF</u>	<u>NL</u>	<u>SLI</u>	<u>LI/LF</u>	<u>NL</u>	<u>SLI</u>
house	1050	1141	rag	1594	1509	fact	1411	1473	law	1312	1458
door	1131	1242	bush	1166	1194	today	949	969	month	1244	1537
water	1012	1180	coin	1150	1106	moment	1209	1138	hint	1148	1192
girl	952	983	salad	1302	1321	unit	1290	1356	habit	1407	1562
body	1142	1028	chin	1196	1172	problem	1293	1231	deed	1379	1678
woman	1097	1151	jelly	844	1092	life	1361	1471	moral	1337	1465
dog	1268	1214	cigar	1254	1281	rule	1439	1367	fault	1224	1468
sand	1141	1264	math	1272	1376	voice	1128	1213	mood	1476	1817
food	1017	1063	toy	1029	1040	time	1024	1088	noun	1505	1607
man	1269	1185	lip	1273	1126	power	1454	1641	god	1182	1329
<u>M</u>	1107.9	1145.1		1208	1221.7		1255.8	1294.7		1321.4	1511.3
<u>SE</u>	33	29		61	46		55	65		39	55

Note:

- HI/HF High Imageability/High Frequency
- HI/LF High Imageability/Low Frequency
- LI/HF Low Imageability/High Frequency
- LI/LF Low Imageability/Low Frequency

Appendix N
Individual subject lexical decision latency (RT in msec) for word stimuli in the simple reaction time task

<u>Subject</u>	<u>HI/HF</u>	<u>HI/LF</u>	<u>LI/HF</u>	<u>LI/LF</u>	<u>Subject</u>	<u>HI/HF</u>	<u>HI/LF</u>	<u>LI/HF</u>	<u>LI/LF</u>
NL-1	1193	1117	1164	1187	SLI-1	604	631	537	757
NL-2	1398	1336	1386	1253	SLI-2	1125	1179	1305	1224
NL-3	1365	1306	1383	1381	SLI-3	477	574	605	661
NL-4	1111	1067	1108	1055	SLI-4	1035	1110	1063	1011
NL-5	974	907	872	945	SLI-5	1181	1236	1219	1219
NL-6	391	371	413	405	SLI-6	884	914	968	1015
NL-7	1037	981	1022	1041	SLI-7	839	668	771	897
NL-8	1136	1087	1012	1076	SLI-8	952	967	1028	997
NL-9	1078	1130	1189	1239	SLI-9	551	592	635	672
NL-10	1221	1408	1291	1371	SLI-10	825	859	1141	1063
NL-11	992	1098	1062	1077	SLI-11	789	933	1016	1022
NL-12	935	869	937	923	SLI-12	1008	1275	1094	1329
NL-13	1367	1137	1031	1095	SLI-13	1070	1144	1055	1051
NL-14	1219	1225	1145	1285	SLI-14	823	1027	814	976
NL-15	1228	1131	1176	1180	SLI-15	1099	1044	1218	1011
<u>M</u>	1110	1078	1079	1100.9	<u>M</u>	884.13	944	965	994
<u>SE</u>	64	63	61	61	<u>SE</u>	55	61	61	49

Note:

HI/HF High Imageability/High Frequency

HI/LF High Imageability/Low Frequency

LI/HF Low Imageability/Low Frequency

LI/LF Low Imageability/Low Frequency

Appendix O
Individual subject lexical decision latency (RT in msec) for pseudowords in the simple reaction time task

<u>Subject</u>	<u>Words</u>	<u>Pseudowords</u>	<u>Subject</u>	<u>Words</u>	<u>Pseudowords</u>
NL-1	1162	1112	SLI-1	638	661
NL-2	1341	1234	SLI-2	1210	1241
NL-3	1342	1335	SLI-3	569	600
NL-4	1082	1054	SLI-4	1051	1076
NL-5	924	901	SLI-5	1214	1191
NL-6	393	424	SLI-6	950	954
NL-7	1020	1027	SLI-7	804	931
NL-8	1078	1093	SLI-8	988	990
NL-9	1156	1911	SLI-9	612	654
NL-10	1323	1337	SLI-10	973	1059
NL-11	1059	1088	SLI-11	939	905
NL-12	914	947	SLI-12	1168	1068
NL-13	1157	1180	SLI-13	1080	1095
NL-14	1219	1185	SLI-14	914	965
NL-15	1182	1213	SLI-15	1092	1071
<u>M</u>	1110	1136	<u>M</u>	946.8	944
<u>SE</u>	61	79	<u>SE</u>	53	50

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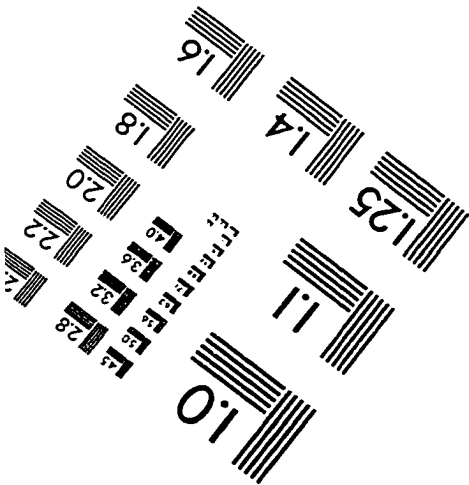
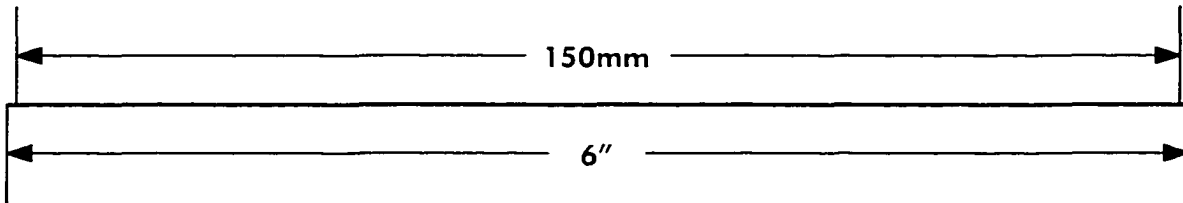
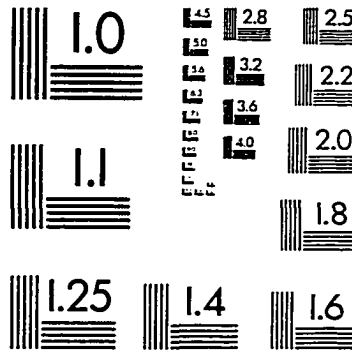
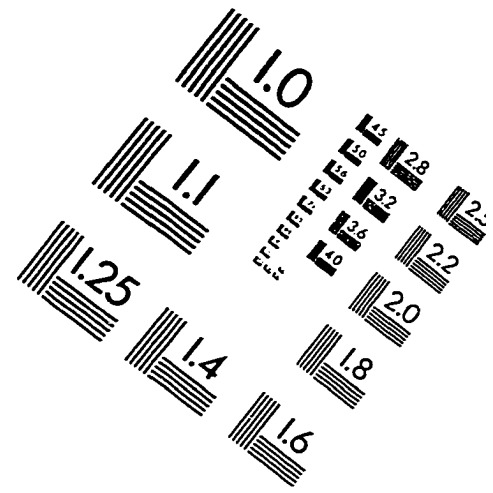
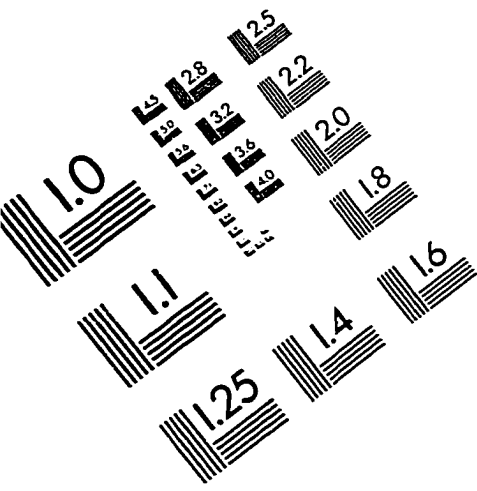
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IMAGE EVALUATION TEST TARGET (QA-3)



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