

DIVIDED ATTENTION IN CHILDREN
WITH AND WITHOUT SLI
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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

2007

UMI Number: 3245071



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Abstract

Divided Attention in Children with and without SLI

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Attention is the ability to maintain focus on a particular stimulus. Selective attention permits an individual to concentrate on one stimulus while ignoring others. If opposing stimuli come into the attentional field, attention to the primary stimulus is reduced. When attention is divided, resources are allocated to two or more competing stimuli. The aspect of attention most related to the allocation of processing resources is divided attention (DA). There are finite resources available for processing and storage (Pashler, 1999).

The present study investigated recall of words and nonwords in children with and without specific language impairment (SLI) when there was an additional, competing task. The children with typical language development (TLD) ranged in age from 8;2 to 10;8. Six children with SLI ranged in age from 9;4 to 14;9. The DA encoding phase required listening to stimuli while executing a secondary visual-motor task. Each child was then asked to recall the stimulus items. DA at the retrieval phase required listening to the stimuli followed by recall while executing the secondary task.

Children with TLD children demonstrated different response patterns compared to adults. Word recall for DA attention tasks consumed more resources. The SLI children were able to accomplish all tasks presented and performed similarly to the TLD group. The percent of items correct on all measures, however, was lower for SLI children. As with adults, the encoding

condition was most detrimental to recall for all participants. Performance on the secondary task suffered on both DA conditions for all children. The children with SLI were more similar to an adult study of older subjects aged 60 and 70 (Anderson, Craik, Naveh-Benjamin, 1998), who allocated more resources for retrieval than was required by younger adults.

DA at encoding caused a decrease in memory performance with some reduction in reaction time for the secondary task. Memory was less affected by DA at the retrieval stage. More costs to memory recall were incurred at the encoding stage because the secondary task interfered with a controlled process. Conversely, memory recall at retrieval appeared to be automatic suffering less from interference (Anderson et al., 1998; Craik et al., 1998).

Acknowledgements

Many people contributed to this dissertation. I wish to thank all of those who listened to my concerns, spent time reviewing tapes of subject performance and in reading drafts of this paper.

I am grateful to Dr. Martin Gitterman's encouragement during many difficult times. Special thanks to Dr. Richard Schwartz for his perseverance throughout this process. Thanks also to Dr. Helen Cairns and Dr. Valerie Shafer for participating on my committee. Dr. Peter Feigenbaum must also be acknowledged for his help with the statistics as well as Dr. Frances Scheffler who agreed to be my outside reader.

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DIVIDED ATTENTION IN CHILDREN WITH AND WITHOUT SLI

CHAPTER 1: INTRODUCTION

Attention and memory are important in the acquisition and use of language. From infancy children attend to various aspects of language. The elements that are selected and processed determine the type of information to be stored in memory (Gomes, Molholm, Christodoulou, Ritter, & Cowan, 2000). Language components such as lexical items must be learned (encoded) and be available for future use (retrieval). This study examined the effects of divided attention on lexical recall in children with typical language development (TLD) and in a smaller group of children with specific language impairment (SLI).

Studies of TLD children have investigated an extensive number of language components. These contributions generated guidelines outlining general milestones of development (Lane & Molyneaux, 1992, Owens, 1988; Reich, 1986). In order to attain these milestones, the ability to attend is crucial. Once attention has been directed towards speech and various components of language (e.g., phonology, morphology, syntax, lexicon), the target must be learned then stored in memory for retrieval. Both attention and memory play interlocking roles in the acquisition of linguistic skills and the use of those previously learned (Lane & Molyneaux, 1992; Cowan & Saults, 1995).

Children with SLI have a performance IQ within a normal range, a normal range of hearing acuity, adequate orofacial structure and oral functioning, no frank neurological dysfunction, or evidence of physical or social impairments. They have language test scores that are at least 1.25 standard deviation or more below the mean and who may be at risk for social devalue (Leonard, 1998). A number of current proposals regarding the underlying cause and nature of SLI in

children point to limitations in perception, speed of processing and processing resource capacity limitations (Ellis Weismer, Evans, & Hesketh, 1999; Ellis Weismer, Tomblin, Zhang, Buckwalter, Chynoweth, & Jones, 2000; Fazio, 1998; Gathercole & Baddeley, 1990; Gillam, Cowan, & Day, 1995; Kail, 1994; Marton, K., 1998; Miller, Kail, Leonard & Tomblin, 2001; Montgomery, 1995a; Montgomery, 1995b; Windsor & Hwang, 1999). However, none of these proposals have provided a complete and fully satisfactory explanation of the origins and maintenance of SLI. Although children with SLI demonstrated many of these deficits, limitations in resource capacity have not been fully explained. One basic cognitive process that may underlie all of these deficits is attention.

Attention

Attention is the ability to maintain focus to a particular stimulus. Selective attention allows concentration on one stimulus while ignoring others (Gomes et al., 2000). If opposing stimuli come into the attentional field, attention to the primary stimulus is reduced. When attention is divided (DA), resources are allocated to two or more competing stimuli. Some researchers suggest that attention is shared (e.g., partial attention to each) while others prefer the theory that attention is shifted alternately (Gomes et al., 2000; Pashler, 1999). How these processes operate may be dependent on individual strategies as well as the type of tasks involved and modality or modalities employed (Pashler, 1999). If, for example, the same modality for primary and secondary tasks is utilized (i.e., visual/visual or auditory/ auditory), there would be a serial rather than a simultaneous sequence of processing (Pashler, 1999). Such single-channel tasks are likely to cause a bottleneck effect decreasing performance.

In bimodal attention paradigms, two (or more) tasks, often auditory and visual, have been used. Although various experiments have been conducted in this manner with informative results, the way in which subjects process multimodal stimuli has not been fully addressed (Pashler, 1998, 1999). Task selection has proved critical because performance depends on the amount of processing resources required. If a primary task is well-practiced, this automaticity requires fewer resources. As a result, additional space is available for the competing task. Interference usually associated with dual-task performance can, therefore, be reduced or eliminated. Conversely, similarity of input or response can hamper performance because it is more difficult to separate related features. For example, it would be more difficult to separate sets of semantic input than to separate a semantic group and a tone group (Pashler, 1999). If tasks are performed concurrently the degree of interference is measurable by noting decrements caused by the secondary task (Guttentag, 1998).

How attention is assigned and how efficiently the stimuli are processed is dependent upon the amount of effort required. Factors such as developmental level, task instruction, motivation, ability to sustain attention, and individual strategies can also contribute to the overall success of attentional control and stimulus processing (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Gomes et al., 2000; Leonard, 1998; Pashler, 1999).

Memory

Memory requires space for storage and space for processing information and, therefore, operates on several levels. Short-term memory (STM) is transient occurring when a signal is received or an individual thinks of something. STM holds a limited amount of information. Task performance or problem solving is accomplished in working memory, a practical aspect of STM.

When input is verbal, it is stored in phonological working memory (PWM). PWM has the capacity to code verbal input and can keep it available for further processing through reactivation (Cowan, 1996; Gillam & van Kleeck, 1996).

Gathercole & Baddeley (1993) offered a model of working memory that has been the basis for a large body of research. This modular model included the central executive, the visuospatial sketchpad, and the articulatory loop. The phonological store and a rehearsal mechanism are subcomponents of the articulatory loop. This loop can temporarily hold a limited amount of verbal information in a phonological store. Spoken items gain access to the phonological store automatically. Operating in real time this information leaves traces that are held until no longer discriminable and are lost through decay that occurs in approximately two seconds. For use after this period, information requires rehearsal to refresh the memory trace. The STM capacity is determined by the limitations of this verbal trace (Gupta & MacWhinney, 1995; Schweickert, Guentert, & Hersberger, 1990). The Gathercole & Baddeley (1993) model addresses the limited capacity issue but does not consider how attention affects the type and amount of information entering the phonological store, what information is retained for rehearsal, or what factors disrupt the process.

Cowan (1993) proposed a model of memory that consists of nested subsets. The largest subset was long-term memory (LTM). Embedded within LTM is a smaller subset called the activated memory followed by the smallest subset, attentional focus. Separation of the subsets

was less distinct than that of a modular model. The human memory systems (abstract, motor, sensory) operate according to similar principles (Cowan & Saults, 1995). Features in current

attentional focus (motor, sensory, phonological, or abstract types) share storage space. Memory for speech, for example, utilizes the same acoustic memory system as other auditory stimuli and shares a phonological memory mechanism with other linguistic stimuli, internal or external in nature. Any stimulus would be subject to decay or would suffer interference from a subsequent representation that shared similar features. The model assumed that all sensory information input to the brain left an afterimage of several hundred milliseconds. An automatic activation of some pertinent features stored in long-term memory occurred and includes some modality-specific components. Features were analyzed more completely and activation endures longer if either the stimulus or the afterimage enters the focus of attention (Cowan & Saults, 1995; Pashler, 1999). Attention is, therefore, necessary to register information into the memory system.

Children's Working Memory

Both TLD and SLI children showed superiority for auditory over visual presentation of words. Auditory stimuli are thought to have direct access to the phonological loop whereas visual stimuli required an additional step to produce a phonological code (Gathercole, Adams, & Hitch, 1994; Gillam, Cowan, & Marler, 1998; Gillam, Hoffman, & vanKleeck, 1998).

Researchers asked children to attend to multiple components even when the task was not intended to examine DA. These tasks purported to examine memory storage, recall, and scanning abilities yet often involved simultaneous attention to various stimuli. Real word recall draws upon the lexicon and both TLD and SLI children have demonstrated the ability to tap this resource (Montgomery, 1995b; Montgomery, 1999). In free recall, TLD children (mean age 6;9) and SLI children (mean age 8;5) could remember from four to six words. Both groups had high accuracy for true/false judgment of factual material. Both groups also followed sentence-length

directions accurately. Memory and comprehension, therefore, appeared adequate. Additional processing steps caused problems for the SLI children. When asked to take a list of items and group them by size or category, they performed more poorly than their typically developing peers. The SLI children had difficulty using factual information inferentially and were unable to perform two commands presented dichotically. Cognitive limitations have been suggested to explain these differences (Campbell & McNeil, 1985; Ellis Weismer, 1985; Ellis Weismer et al., 1999; Gaulin & Campbell, 1994; Montgomery, 2000a; Montgomery, 2000b). Another plausible explanation should be considered. Children with SLI may have more trouble with allocation and control of attentional resources. It is necessary to hold given information in memory, scan to analyze and formulate a credible proposition (i.e., perform multiple operations). The question remains as to whether the problem is a limitation of capacity or an inability to assign resource. Gomes et al. (2000) argued that the ability to control the focus of attention rather than increases in capacity is the primary factor responsible for maturational improvement. The etiology of these deficiencies remains unknown.

Nonword repetition is a sensitive measure of phonological working memory (e.g., Gathercole & Baddeley, 1993). Investigators have reported varied results. TLD children (6 to 11) demonstrated limitations when nonwords were added to real word sentences or when used as distractors. When nonwords were placed at the end of sentences or series of digits, the extraneous suffixation apparently interfered resulting in faulty recall. SLI children showed even greater deficits (Gillam, Cowan, & Day, 1995; Marton, 1998). Most children discriminated nonwords of 1- to 4-syllables (Dollaghan & Campbell, 1998; Marton, 1998), but repetition of

these materials revealed discrepancies between the TLD and SLI groups (Ellis Weismer et al., 2000). All children had more difficulty as nonwords increased in length (Montgomery, 1995a). SLI children, however, made more segment errors and substitution errors supporting the theory that the phonological representation itself was poorer and may be contributing to general WM deficits (Gathercole & Baddeley, 1990; Marton, 1998; Montgomery, 1995b).

Although errors have been attributed to a limited capacity for phonological information (Montgomery, 1996), the inability to control focus of attention may be a related factor. The aspect of attention that is most related to the allocation of processing resources is DA. There are finite resources available for the processing and storage of stimuli. Many factors influence how this limited capacity is used. Understanding the multifaceted aspects of working memory, its relation to language abilities, and attention allocation are important to the explication of language acquisition in children demonstrating typical language development (TLD). This information can be used to compare performances of SLI children.

Attention Tasks

Information processing is modality specific. Visual information is organized spatially and has a relatively long duration when compared to auditory input that is temporally organized and

relatively brief (Gomes et al., 2000). Both modalities have been used in DA paradigms.

Developed to assess problems in selective or focused attention, the Stroop test is an example of a single-channel task that consisted of a visual task with visual interference (Pashler, 1999). When subjects were asked to read a color word (e.g., “red” written in blue print), there was no interference. If color naming became the primary task interference occurred. Most normal

individuals exhibited interference because reading is a highly automatic operation, whereas recalling a color label required attentional control. Picture-word interference was a variation of this procedure. Pictures were superimposed with semantically related or with unrelated distractor words. Picture naming was required while ignoring the printed word. Normal adults demonstrated the greatest number of errors for semantically-related stimuli although unrelated stimuli also caused interference when compared to the control condition, (Kingma, Heig, Fasotti, & Eling, 1996; Monahan, 2001; Pashler, 1999).

Dichotic listening is a single modality task in the auditory mode. In dichotic listening a different stimulus is presented to each ear simultaneously. Although the competing stimuli are both auditory, each ear can be affected differently. When dichotic tasks are presented without procedural instruction, most adult subjects tended to report groupings by ear. Pashler (1998) reported studies by Broadbent (1954) who presented three digits to each ear simultaneously and found that subjects preferred to report by what was heard in one ear, followed by what was heard in the other. Subjects were able to report the first digit heard in the right ear and the first heard in the left ear, followed by the second digit from each ear, then the third pair. Pair wise reports, however, were less accurate than ear-grouped reports.

Normal adults attained higher recognition scores for the right ear (RE) when linguistic stimuli were presented dichotically. By eight to eleven years of age, children also demonstrated this RE advantage (Keith, 2000). SLI children showed this right ear advantage although it was less robust (Cohn, Riccio, & Hynd, 1999). This RE advantage was thought to result from left hemisphere dominance for speech and language processing (Mueller, 1985).

Dichotic listening tasks have been used successfully to study selective attention.

Investigators such as Alain & Arnott (2000) found that subjects were able to separate concurrent stimuli if they could group them in some way. The more distinctive the groups of sounds, the easier it became to focus on only one. Additionally, attention could be diverted from the target stimuli. For example, during prose, attention was redirected to the unattended ear by inserting an item such as the subject's name. This suggests that information of interest caused an attentional shift.

In bimodal tasks, two or more sensory systems receive stimuli simultaneously. Tasks were developed that required memory recall of digits or words presented auditorily or visually. Detection of targets, card sorting or finger-tapping were employed as secondary tasks (Craik et al., 1998; Pashler, 1999). Results were varied as proficiency was dependent upon the amount of resources required and task difficulty (Gomes et. al, 2000; Pashler, 1999).

One bimodal study with adults was designed to investigate memory processes during encoding and retrieval of verbal material in adults. During both encoding and retrieval divided attention (DA) tasks were introduced to determine what impact dual-processing had on recall (Craik et al., 1998). These tasks involved auditory input with verbal output as well as visual input with manual output. Prior to recall, the subject was asked to add "3" to randomly presented numbers. This distractor was employed to reduce the recency effect. The concurrent reaction time task (CRT) utilized a manual response to visual stimuli presented on a computer screen. Subjects were required to monitor an asterisk that appeared randomly in one of four boxes. By pressing the corresponding key on the computer keyboard the subject shifted the asterisk to another box. The amount of time required to move the asterisk successfully was measured. The

verbal recall task was administered without interference to establish a baseline for each subject. The secondary CRT task was also performed independently for 96 seconds; the same time was allowed for performance at the encoding and retrieval conditions. Baseline measures were gathered for this task. Dual task performance was measured at both encoding (learning) and retrieval (recall) to substantiate similarities and differences between these processes. At the encoding phase, the subject heard the word list while performing the secondary task. The distractor task followed and then the list was recalled. All accurately recalled words were accepted regardless of order (free recall). At the retrieval stage, the subject listened to the list of words, performed the distractor task, and then recalled the words while performing the secondary task.

DA at encoding caused a decrease in memory performance as well as some reduction in reaction time for the secondary task. In contrast, memory was unaffected by DA at the retrieval stage and the CRT was minimally affected. Costs to memory recall were those incurred at the encoding stage because the CRT interfered with a controlled process. Conversely, retrieval appeared to be automatic remaining impervious to interference (Anderson et al., 1998; Craik et al., 1998).

In a series of additional experiments, various manipulations were studied. Craik et al. (1996) investigated the effect of task emphasis on performance using a similar paradigm as previously described. Subjects were told to concentrate on either the memory or CRT portion or to divide attention equally between tasks. DA and task emphasis altered performance at the encoding stage with an increase in the emphasized area and a decrease in the other. DA and task emphasis had little effect on memory performance during the retrieval phase.

Naveh-Benjamin, Craik, Guez and Dori (1998) changed the type of stimuli used for the recall tasks. High and low frequency words were presented in a paired-word paradigm. Word pairs were presented orally at the rate of one pair every six seconds. At retrieval, the first word of the pair was presented and subjects were required to retrieve the appropriate paired word within six seconds. Another modification was included. The voice used to present stimuli at the retrieval phase was either the same or different from the voice used to deliver the words at the encoding stage. The asterisk CRT task was used for the DA conditions of encoding and recall. Results indicated that high frequency words were remembered better and use of the same voice at both encoding and retrieval improved recall. Familiarity enhanced memory skills. A significant effect of DA at encoding was seen. As in previous studies, when attention was divided at encoding, memory was decreased. At retrieval, DA had little impact on recall. Analyses of the CRT secondary task indicated that DA at encoding and at retrieval showed significance only in regard to faster reaction time for high frequency words (Anderson et al., 1998; Craik et al., 1998).

Subject age was another variable that affected performance. Older adults (late 60's, early 70's) were recruited. This group exhibited similar DA patterns to those of the college-age subjects for recognition and free-recall memory tasks. When performance was compared with younger adults, all tasks were more resources consuming. CRT costs were somewhat higher during the encoding phase and the retrieval phase was also more demanding with CRT slowing by a greater degree (Anderson et al. 1998).

Despite subject age or procedural manipulations, the general trend remained. When DA was imposed during encoding a significant decrease in memory recall occurred. Conversely, CRT was affected more at the retrieval phase. These results implied that substantial resources were also allocated during the retrieval phase and

appeared independent from the number of words recalled. DA for memory tasks was more detrimental during the encoding phase with DA at retrieval impinging upon the CRT task. It was theorized that the ability to encode material required processing at the time of presentation. Once information was stored, its recall used attentional resources, but this process was automatic. The individual might then be able to allocate resources as required to retrieve information while reserving sufficient resources for the secondary task. Attentional control and use of attentional resources are separable processes. This was clearly evident during task emphasis manipulations. Although familiar stimuli required fewer resources, encoding continued to require attentional control (i.e., conscious focus).

DA studies with children are limited in number. Campbell & McNeil (1985) compared DA in 10-year olds with language disorders and concomitant convulsive disorders to that of age-matched typically developing children. The children were asked to carry out directions taken from the Revised Token Test as a primary task. The secondary task was similar using different colors and items. Two protocols were included in this experimental design. The first consisted of two sentence-length commands presented simultaneously at a normal speaking rate. The primary command was spoken by a man and the secondary by a woman. Children were

instructed to listen to both commands but to carry out the man's direction first. For the second DA task, the rate of presentation for the primary command was slowed by 75 percent. The secondary command remained at a normal speaking rate. All children performed better on the primary task under both protocols although the TLD group reached a higher percentage. Results indicated that slowing the rate of presentation was beneficial to both groups of children. With slowing the primary task was executed better. The secondary task performance also improved when compared to other protocols within the study. These findings supported the theory that

resources used for a primary task deplete resource availability for the secondary task when resources are shared.

Several modalities were utilized in a study designed by Hoffman & Gillam (2004). Nine-year olds with and without SLI were given tasks to determine their ability to recall verbal or spatial information. Stimuli were presented on a computer screen. Digits were shown then the child was asked to recall them verbally. For the spatial recall, Xs appeared then the child was asked to point to the location of the Xs on grids provided. More complex tasks were designed to provide a greater processing challenge. Digits were presented in color (three colors were used) and the child was asked to identify the color during the sequence presentation. Following the presentation the child was asked to name the digits. Another variation required the child to point to a colored circle matching that of the number shown during presentation. This was followed by recall of the number sequence. The spatial paradigm paralleled the verbal recall format. All experimental tasks were given at both a fast and a slow presentation rate. All children were more accurate when the presentation and recall were in different modalities (verbal with pointing or spatial with naming). Less information was remembered when the same modality was used for presentation and recall. When the secondary color identification was introduced, the groups demonstrated a different performance pattern. Children with SLI recalled significantly less for both verbal and spatial tasks than their TLD peers. The SLI children's poorest performance was seen when pointing was paired with color identification. A main effect for presentation rate was found but there were no significant group interactions. These researchers noted that children with SLI had deficits beyond the verbal domain. They had difficulty processing various types of information as the amount increased. The SLI children appeared to allocate available resources

differently than the TLD children.

These two examples demonstrate that children with and without SLI differ in their ability to process multiple stimuli. Task selection is critical and sometimes changes the results. Although these findings provide some insight into the nature of attention deficits in SLI, many questions remain unanswered. Bimodal tasks similar to the adult studies of Craik and colleagues have not been presented to children. The format used by Craik, et al.(1998) provided insight into several aspects of DA. It is unknown if children perform in a similar manner as young adults or are more vulnerable to interference as were the older adults. How children with and without SLI respond on a DA task of this type will provide valuable information about attentional control and the use to available processing capacity.

Purpose and hypotheses

The purpose of this study was an examination of children's recall ability when their attention was divided. Many researchers have provided information about the processing abilities of children while attending to multiple stimuli. None have fully answered the question regarding the amount of interference that takes place during these tasks. The current study was modeled on studies by Craik, et al. (1996) and Naveh-Benjamin, et al. (1998). These investigators utilized word lists presented auditorily and a secondary task that required visual monitoring and movement of an asterisk presented on a computer screen. The DA conditions varied. At encoding the subject was required to listen to the stimulus list while performing the secondary task. At retrieval, the process was reversed. The subject listened to the word list then performed the secondary task while recalling the stimuli.

This study required modification of the adult paradigm for use with children. Memory

span for lists of unrelated monosyllabic words were approximately four to five words for TLD children aged eight to nine (Gathercole, 1995, Gathercole et al., 1994, Henry, 1991). The lists contained six words each. The distractor task was replaced by a 16-second silent interval. A concurrent visual/motor task was presented on a computer requiring only a space bar press. An encoding phase and a retrieval phase were developed similar to those used by Craik et al (1996) and Anderson et al. (1998). Nonwords were included in this study because they have the potential to reveal something about the effect of DA on phonological memory. Because the memory span for nonwords is shorter than for real words our stimulus lists consisted of four items (Gathercole & Baddeley, (1990). Additionally, each nonword was pronounced for the child and he/she was asked to repeat it. The procedure for nonword recall and DA was identical to the word tasks.

All tasks were expected to be more resource consuming for children than for adults. During the full-attention baseline tasks, some children were expected to reach ceiling for recall of both words and nonwords. Performance on the secondary task without interference was also expected to show high accuracy and speed. Children should require more attentional resources than adults to encode material, thereby disrupting the secondary task to a greater degree during DA task. The TLD children were expected to follow the adult trend of poorer recall performance during the DA at encoding condition than the retrieval phase. Disruption was also predicted for the secondary task during both DA conditions. The SLI children should show greater discrepancies in all tasks than the TLD group. Recall for the SLI group should be less accurate for both words and nonwords at the baseline measure. DA at both encoding and retrieval was

anticipated to be more resource consuming for the SLI group, decreasing recall and further slowing the secondary task.

CHAPTER 2: METHOD

TLD Participants

Eighteen girls ($M=9;1$, $SD=8;1$ months) and thirteen boys ($M=9;5$, $SD=10;1$ months) considered TLD participated. No child had a history of hearing impairment or current otitis media and all passed a hearing screening. IQ was in the within average range as indicated by their school files. No child with motor impairments was included. Vision was within the average range as determined by school vision screening or was corrected to average. All children were English monolinguals. Each child scored within the average range or above on the Clinical Evaluation of Language Fundamentals Third Edition Screening Test (Semel, Wiig, & Secord, 1996) and 70% or higher on the Nonword Repetition Task (Dollaghan & Campbell, 1998).

SLI Participants

Six SLI children ranging in age from 9;4 to 14;9 participated. No child had a history of hearing impairment or current otitis media and all passed a hearing screening. IQ was in the average range as indicated by their confidential files. No child had motor impairment and vision was within the average range as determined by school vision screening or was corrected to average. All children were English monolinguals. Each of these children had language test scores of at least one standard deviation below the mean on a minimum of two of the three subtests on both the receptive and expressive clusters of the Clinical Evaluation of Language Fundamentals Third Edition (CELF-3) (Semel, Wiig, & Secord, 1995) as determined by a licensed speech pathologist.

Materials

The following hardware was utilized: laptop computer, a headset with attached microphone a tape player for stimuli presentation, a tape recorder for acquiring response data. Verbal stimuli for recall were drawn from two sources.

Words.

A pool of monosyllabic high-frequency words was selected (Hall, Nagy, & Linn, 1984). These words were phonological consonant-vowel-consonant forms (CVC). Six words were chosen from the pool for each list. These six words were not semantically or phonologically similar. Each word was 1s in duration and the words were presented at the rate of one word every 2s. Stimulus lists were different for each of the full attention (FA), encoding, and retrieval conditions. Five lists were used for each condition. One list (or more if deemed necessary) was used for practice (28 lists were developed. See Appendix A). These lists were counterbalanced.

Nonwords.

To provide a different list of nonwords for each condition, a pool of monosyllabic nonwords was developed. These nonwords were phonological consonant-vowel-consonant forms (CVC). Lists were compiled with four nonwords each. These nonwords were not phonologically similar. Each nonword was 1s in duration and was presented at the rate of one every 4s. Stimulus lists were different for the FA, encoding, retrieval conditions. Five lists were used for each condition with one additional list for practice (additional if deemed necessary). Thirty lists were developed (see Appendix B). These lists were counterbalanced.

Visual/Motor (VM) Task.

The LocuTour Multimedia High Level Attention program titled “Stimulus Field Attention” was presented on the computer screen (Scarry, & Scarry-Larkin, 2001). This task was presented continuously during encoding or recall in DA conditions. The task involved a series of screens, each with two shapes. Each screen presented either two circles, or one circle and one triangle. The child was instructed to press the space bar when two circles appeared and to ignore (do nothing) when a circle and a triangle appeared. The ratio of 60% response screens and 40% inhibit screens was chosen. Forty screens were presented over 20s. This presentation time matched the time required to present the verbal stimuli. Scoring was reported in percentages done automatically by the program. When a correct decision was made (space bar pressed on two circles) it was reported as correct. If incorrect decision was made (space bar pressed for a circle and a triangle) it was recorded as an error.. Misses were screens where no action was taken when a correct space bar press was required. Speed of response was also calculated. When two

circles were presented in the center of the screen (twenty samples) this screen was held until the space bar was pressed. This averaged response time was recorded as seconds on center.

Procedures

All preliminary evaluations were administered individually in a quiet room. A practice session was conducted the same day in the same room. The primary task was verbal recall. Stimuli were presented auditorily through a headset and required a verbal response that was recorded. The secondary visual/motor component was presented on the computer. The child practiced with the microphone/headset. A real word list was presented and the child was asked to recall and say the words in order. A nonword list was presented. Each nonword was spoken for the child and he/she was asked to repeat it. The list was then heard using the headset. The child was asked to recall and say the nonwords in order. The V-M task (computer game) was demonstrated and practiced. The following conditions were presented the day after initial evaluation and practice session.

Full attention (baseline) condition.

The FA portion was presented first. Each task (words, nonwords, and V-M) was presented without any interference. The children were reminded of the procedure employed in the practice session. The children were told that they would again hear six real words presented through the headset. It was reiterated that they would be asked to remember and repeat the words in order a few seconds (16s) after hearing them. The four nonwords were read to the child one at a time and he/she was asked to repeat each. The nonwords were then presented using the headset in the same manner as the real words. Responses were accepted for words or nonword if they were recalled within 30 seconds.

The child was asked to do the V-M task as quickly and as accurately as possible. Each of the three baseline tasks was preformed five times. Word recall, nonword recall and the V-M task were counterbalanced.

Divided attention conditions.

Two DA conditions were presented and were counterbalanced. The child was reminded of the procedures previously used.

Encoding phase.

The children were told that this time they would hear the words while playing the computer game (V-M task). When the words and game ended, a few seconds would pass (16s) before they could say the words that they remembered. Five performances were done during the word encoding phase.

When a nonword list was the primary stimulus, each word was said aloud and the child was asked to repeat it. The remainder of the presentation procedure was the same for nonword as for words. Nonword encoding was also completed five times.

Retrieval phase.

The children were told that this time they would first listen to the word list and after a few seconds (16) they would be asked to say the words remembered while playing the V-M task .A total of five performances was gathered for the word retrieval phase.

Nonword sets were read aloud and practiced by the child. Nonwords were then presented identically as described for the real words. Again, this task was administered five times.

Scoring

Every child performed five FA baseline tasks, five encoding tasks and five retrieval tasks. Verbal recall raw scores for each group of five tasks were summed and converted to percentages. This was done for correct, error, and miss categories.

Each word or nonword was scored as correct if recalled exactly as presented. A V-M screen chosen when two circles were presented was scored as correct. Percentages for the number

correct on FA baseline recall were compared with percentages for the DA at encoding, and DA at retrieval. The two DA task conditions were also compared.

Stimulus items could be correct, incorrect, or missed and these were examined separately. A response was scored as an error if an attempt was made at word or nonword but the response was inaccurate. A V-M error resulted when a screen that contained two different shapes was selected. A word or nonword that was not recalled at all was scored as a miss. A V-M miss resulted when a screen with two circles was not acted upon. Errors and misses in percentages were compared in the same manner as correct responses.

Additional analyses examined the number of consonants and vowels that were remembered in word and nonword recall. Credit was given for any consonant (total consonants) that was in the test list regardless of its placement. Vowels were also counted if they were within the list. The consonants were analyzed in greater depth by considering those remembered in initial and final position. The scores for the five performances for each condition were summed and converted to percentages correct for comparison.

Because the order of recall was also of interest, we used the scoring procedure that Gillam,

Cowan & Day (1995) employed. For the conservative analysis, any item recalled in the exact serial position received credit. The liberal method of scoring gave credit for items recalled in a serial order even if not in the exact presentation position. We also scored items a third time, giving credit for any item from the stimuli list regardless of list position (free recall). In this way, we could see how position affected recall. Both words and nonwords were analyzed in this manner.

CHAPTER 3: RESULTS

Means with standard deviations were calculated for all responses. Because each participant performed all three conditions (full attention for baseline, encoding, retrieval), repeated measures ANOVAs (group x condition) were used consistently throughout to analyze the responses. The baseline condition was compared with the encoding condition as well as with the retrieval condition. The two DA attention tasks of encoding and retrieval were also compared. The data obtained for the SLI sample group were included.

An initial analysis divided the TLD children into two age groups (8;2 to 9;0 and 9;1 to 10;7). No significant differences were found between groups. Additionally, the groups were divided by gender with no significant differences seen between groups. All significant differences were between conditions. Analyses were, therefore, performed on the TLD group as a whole.

Word Recall

Word recall, the primary task, was scored as the percent of words recalled accurately and those that contained errors. When an item was skipped, it was considered a miss. Means for word recall are listed on Table 1. Significant differences were found among the experimental

conditions and the baseline (Table 2). For both groups of children fewer words were recalled correctly for retrieval than baseline. Recall dropped more during the encoding when compared to baseline. A significant difference was also found between the two DA conditions. Errors and misses followed a similar pattern. There were no significant interactions found. All children had

poorer recall for both DA conditions when compared with the baseline measure. Encoding difference reached a higher level of significance for the SLI group.

Table 1

Means for word recall (percents) children with typical language development versus children with specific language impairment

| | | Correct | | Error | | Misses | |
|-----------|-----|---------|------|-------|------|--------|------|
| Group | | Mean | SD | Mean | SD | Mean | SD |
| Baseline | TLD | 65.5 | 10.9 | 10.0 | 7.5 | 25.1 | 10.3 |
| | SLI | 47.3 | 21.8 | 18.5 | 20.6 | 28.6 | 10.8 |
| Encoding | TLD | 46.3 | 14.8 | 19.1 | 10.7 | 33.8 | 10.5 |
| | SLI | 30.9 | 9.7 | 28.3 | 12.1 | 35.6 | 12.6 |
| Retrieval | TLD | 51.2 | 11.3 | 16.6 | 10.3 | 32.0 | 10.6 |
| | SLI | 42.2 | 17.6 | 20.2 | 13.3 | 31.6 | 8.4 |

Table 2

Words F's for repeated measures MANOVAs (group x condition)

| | Within- Subject Effects | Between Subject Effects | Interaction Effects | Post-hoc Analyses | | |
|-----------------|-------------------------------|-------------------------------|------------------------|-------------------|------------|----------|
| | | | | B vs. E | B vs. R | E vs. R |
| | | | | <hr/> | | |
| Percent Correct | | | | | | |
| Total | 16.42 *** | | 1.14 | 29.78 *** | 6.52 ** | 11.26 ** |
| TLD vs. SLI | | 9.14 *** | | 5.84 *** | 284.19 *** | 7.74 *** |
| Percent Error | | | | | | |
| Total | 6.80 *** | | 0.69 | 12.40 ** | 2.55 | 4.76 * |
| TLD vs. SLI | | 3.58 | | 5.04 * | 2.32 | 2.33 |
| Percent Missed | | | | | | |
| Total | 5.81 *** | | 0.37 | 8.87 ** | 2.55 | 1.81 |
| TLD vs. SLI | | 0.19 | | 0.47 | 2.32 | 0.03 |

Note: df = group: 1, 35; frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

The following figures graphically display the results for word recall between the groups.

The percent correct, percent of errors and the percent of misses are presented.

Figure 1. TLD word recall.

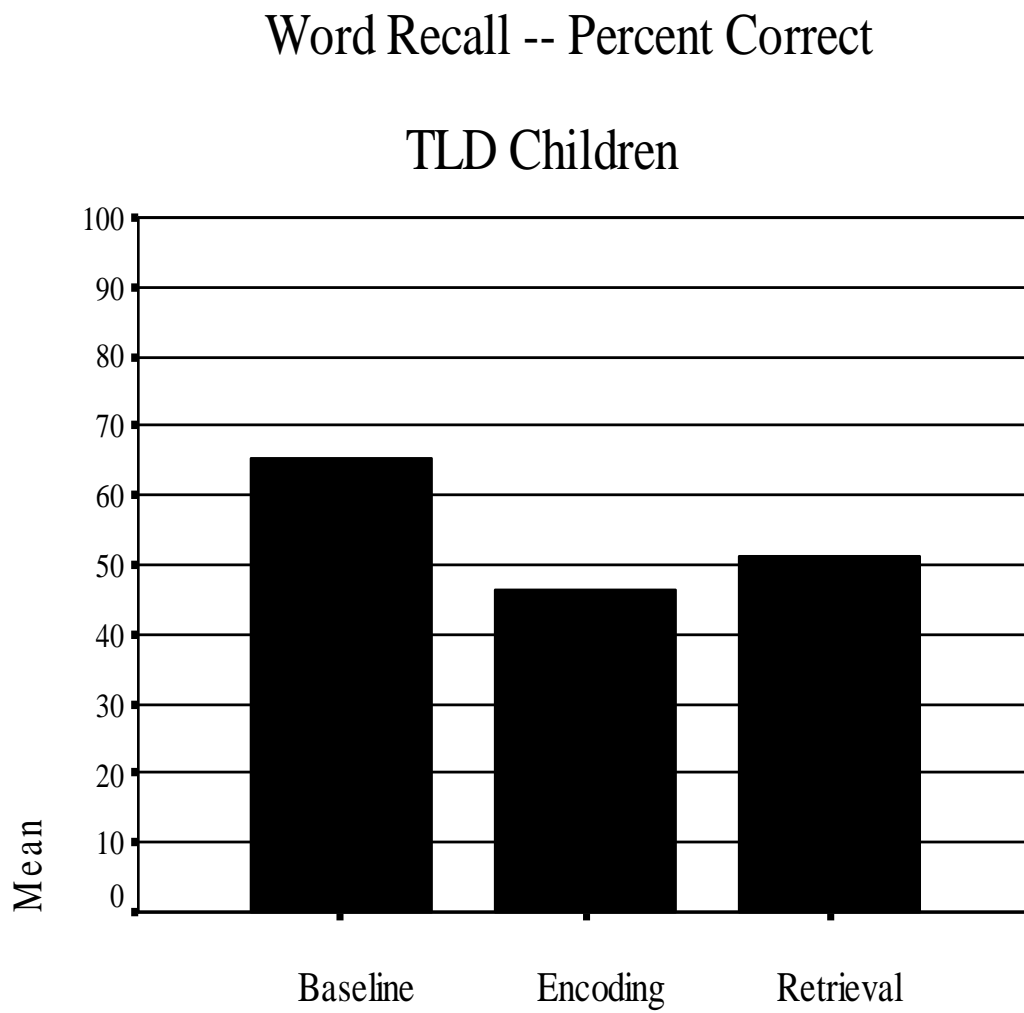


Figure 2. SLI word recall.

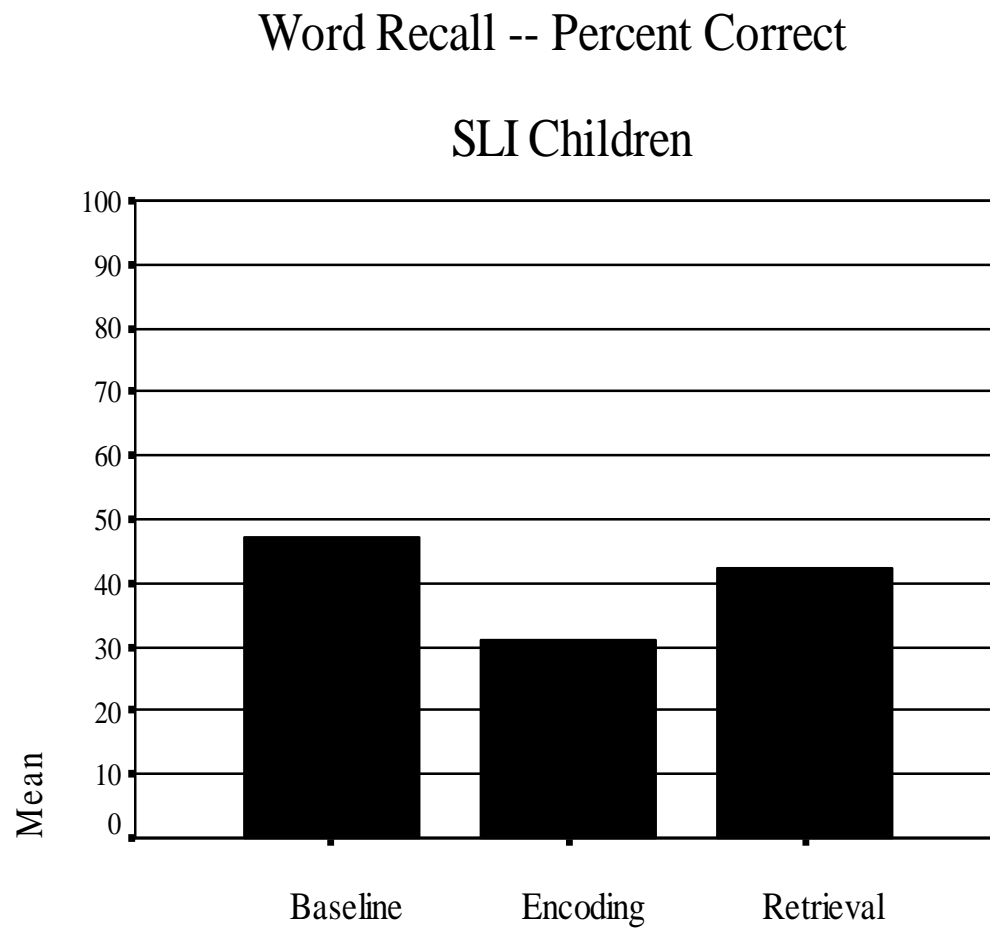


Figure 3. TLD word errors and misses.

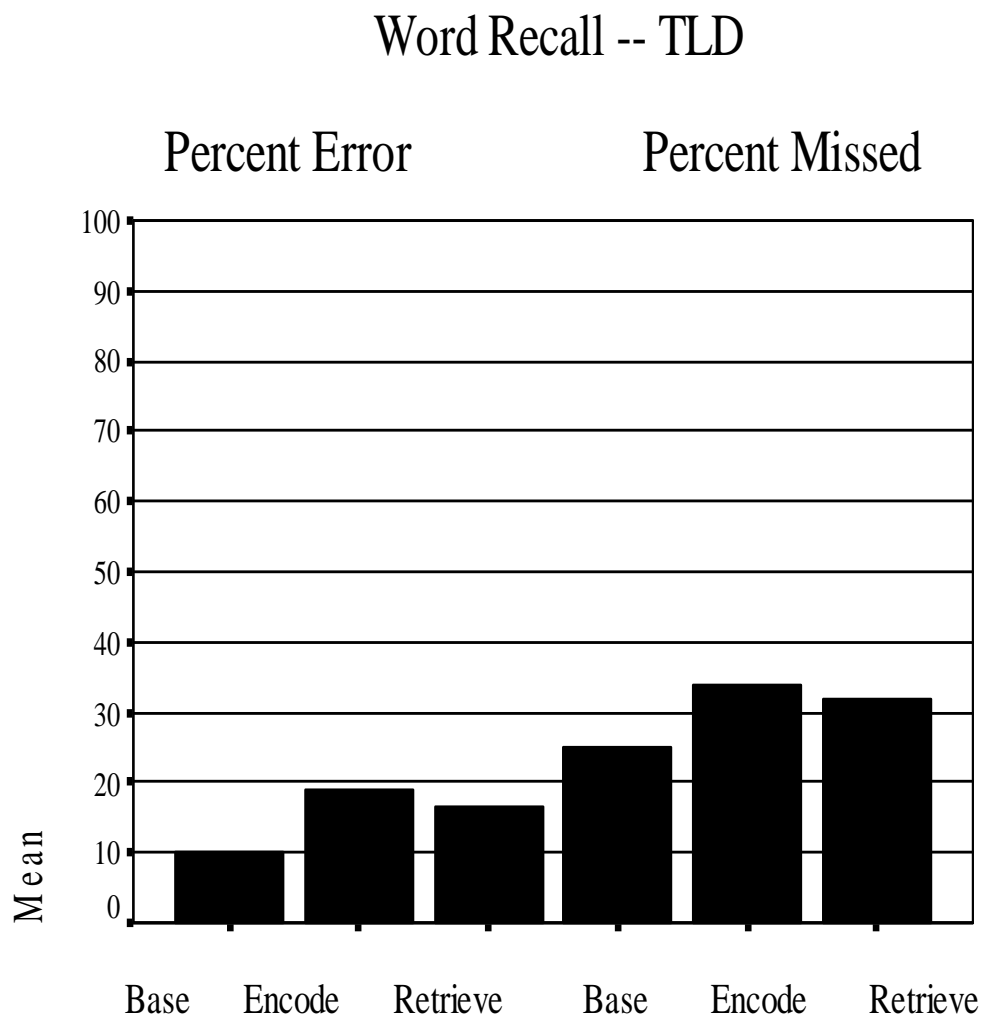
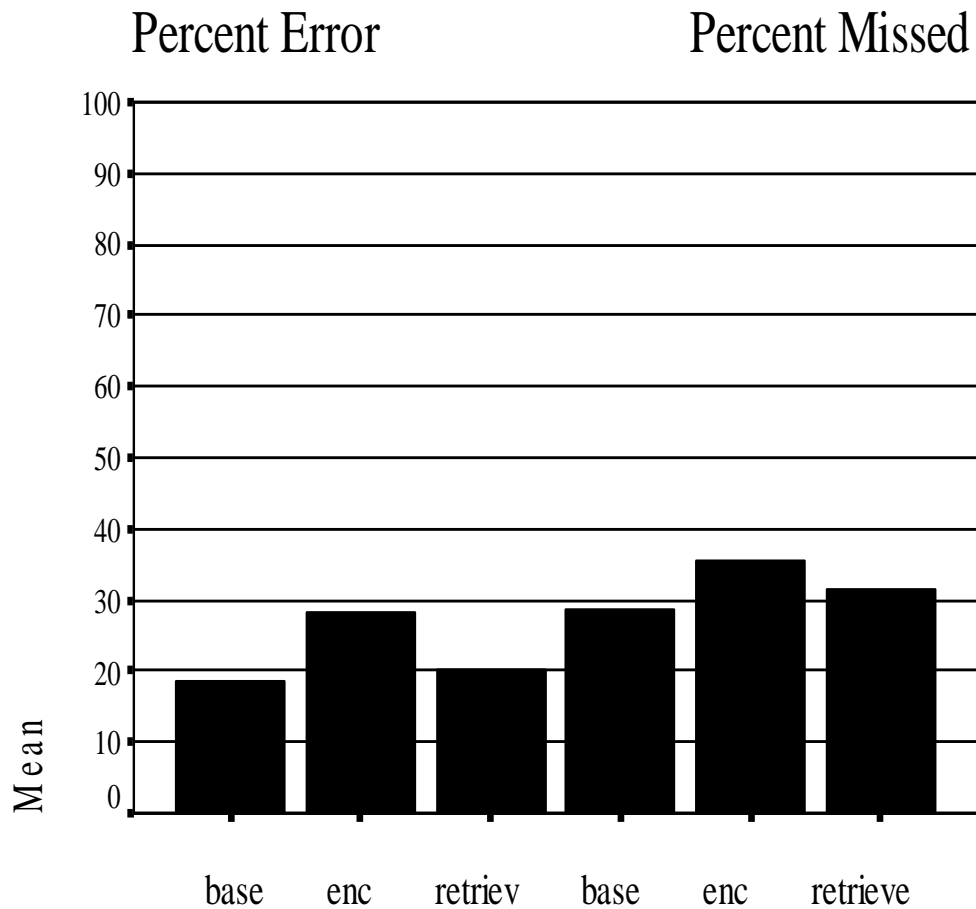


Figure 4. SLI word errors and misses

Word Recall -- SLI



The V-M task was performed alone to establish a baseline. This was the secondary task used in DA with word recall. These measures were scored in the same manner as word recall.

Means were established for this component (see Table 3). Compared with baseline the percent of correct items for both DA tasks were reduced significantly. The two DA tasks showed minimal differences between them. Misses were higher for the TLD children at baseline than for the SLI children. Errors increased with both DA tasks. Statistical analyses were applied (see Table 4). Both groups performed less efficiently with DA

Table 3

Means for visual-motor performance with words (percent) children with typical language development versus children with specific language impairment

| Group | | Correct | | Error | | Misses | |
|-----------|-----|---------|------|-------|------|--------|-----|
| | | Mean | SD | Mean | SD | Mean | SD |
| Baseline | TLD | 82.6 | 7.2 | 7.1 | 3.6 | 11.4 | 9.3 |
| | SLI | 87.5 | 4.5 | 5.0 | 2.0 | 10.8 | 7.6 |
| Encoding | TLD | 77.1 | 8.2 | 11.1 | 6.9 | 11.9 | 8.2 |
| | SLI | 68.7 | 33.1 | 13.3 | 12.6 | 7.7 | 5.2 |
| Retrieval | TLD | 77.7 | 9.6 | 9.9 | 7.6 | 12.4 | 7.6 |
| | SLI | 70.6 | 32.2 | 8.5 | 9.7 | 12.4 | 5.7 |

Table 4

Visual-motor performance F's for repeated measures MANOVAs (group x condition)

| | Within- Subject Effects | Between Subject Effects | Interaction Effects | <u>Post-hoc Analyses</u> | | |
|-----------------|-------------------------------|-------------------------------|------------------------|--------------------------|---------|---------|
| | | | | B vs. E | B vs. R | E vs. R |
| <hr/> | | | | | | |
| Percent Correct | | | | | | |
| Total | 9.43 *** | | 2.85 | 11.57 ** | 9.70 ** | 0.44 |
| TLD vs. SLI | | 0.63 | | 0.23 | 0.08 | 1.49 |
| Percent Error | | | | | | |
| Total | 7.47 *** | | 0.04 | 13.45 ** | 3.16 | 5.31 * |
| TLD vs. SLI | | 1.12 | | 0.00 | 0.70 | 0.02 |
| Percent Missed | | | | | | |
| Total | 0.73 | | 0.57 | 0.40 | 0.22 | 2.41 |
| TLD vs. SLI | | 0.01 | | 0.54 | 0.00 | 0.49 |

Note: df = group: 1, 35; frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

One additional component of the V-M task considered the speed of performance, reported

as seconds on center. Means are reported in Table 5. A significantly slower performance occurred for the encoding phase and retrieval when compared to the baseline. The SLI groups demonstrated dramatic slowing under both DA conditions (Table 6).

Table 5

Means for seconds on center with words children with typical language development versus children with specific language impairment

| Group | Baseline | | Encoding | | Retrieval | |
|-------|----------|------|----------|-------|-----------|------|
| | Mean | SD | Mean | SD | Mean | SD |
| TLD | 0.43 | 0.07 | 0.39 | 0.11 | 0.41 | 0.09 |
| SLI | 0.48 | 0.06 | 6.44 | 14.80 | 3.84 | 8.41 |

Table 6

Seconds on center with words) F's for repeated measures MANOVAs

(group x condition)

| Group | Within-Subject Effects | Between-Subject Effects | Interaction Effects | Post-hoc Analyses | | |
|-------------|------------------------|-------------------------|---------------------|-------------------|---------|---------|
| | | | | B vs. E | B vs. R | E vs. R |
| Total | 5.62 ** | | 5.79 * | 5.62 * | 5.57 * | 5.69 * |
| TLD vs. SLI | | 5.92* | | 5.96 * | 5.99 ** | 5.87 * |

Note: df = group: 1, 35; frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

Nonword Recall

Nonword and V-M correct responses were compared across conditions in the same manner as used with words. Tables 7 and 8 display the means derived and the repeated measures

MANOVA results for nonword recall. The areas of significance for percent correct and percent of errors followed that seen for words. The percent of misses was insignificant.

Table 7

Means for nonword recall (percents) children with typical language development versus children with specific language impairment

| Group | | Correct | | Error | | Misses | |
|-----------|-----|---------|------|-------|------|--------|------|
| | | Mean | SD | Mean | SD | Mean | SD |
| Baseline | TLD | 55.6 | 13.0 | 34.7 | 11.0 | 11.8 | 11.4 |
| | SLI | 41.7 | 12.5 | 42.5 | 15.1 | 15.8 | 12.0 |
| Encoding | TLD | 36.9 | 16.4 | 49.2 | 14.0 | 14.8 | 14.1 |
| | SLI | 23.3 | 11.7 | 59.2 | 25.4 | 18.3 | 16.9 |
| Retrieval | TLD | 44.4 | 12.7 | 44.7 | 12.0 | 11.3 | 8.8 |
| | SLI | 37.5 | 24.6 | 45.0 | 28.5 | 16.7 | 16.3 |

Table 8

Nonword recall F's for repeated measures MANOVAs (group x condition)

| | Within- Subject Effects | Between Subject Effects | Interaction Effects | Post-hoc Analyses | | |
|-----------------|-------------------------------|-------------------------------|------------------------|-------------------|---------|---------|
| | | | | B vs. E | B vs. R | E vs. R |
| | | | | <hr/> | | |
| Percent Correct | | | | | | |
| Total | 12.36 *** | | 2.85 | 23.60 *** | 4.16 * | 8.95 ** |
| TLD vs. SLI | | 5.60 * | | 7.17 * | 4.54 * | 3.05 |
| Percent Error | | | | | | |
| Total | 10.54 *** | | 1.10 | 23.11 ** | 7.68 ** | 2.97 |
| TLD vs. SLI | | 1.37 | | 2.73 | 0.68 | 0.68 |
| Percent Missed | | | | | | |
| Total | 0.52 | | 1.08 | 6.01 | 3.16 | 1.14 |
| TLD vs. SLI | | 1.09 | | 8.04 ** | 0.74 | 0.78 |

Note: df = group: 1, 35; frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

These results are presented graphically in the following figures.

Figure 5. TLD nonword recall.

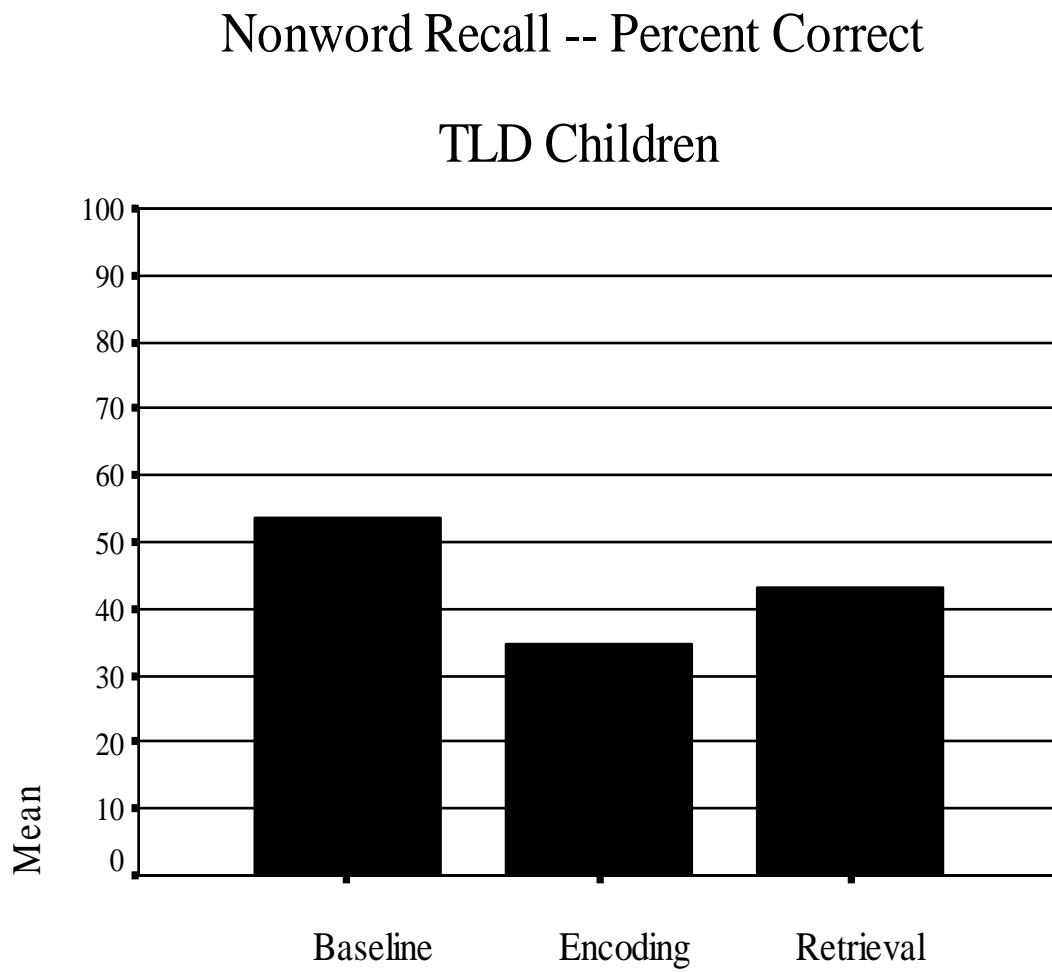


Figure 6. SLI nonword recall

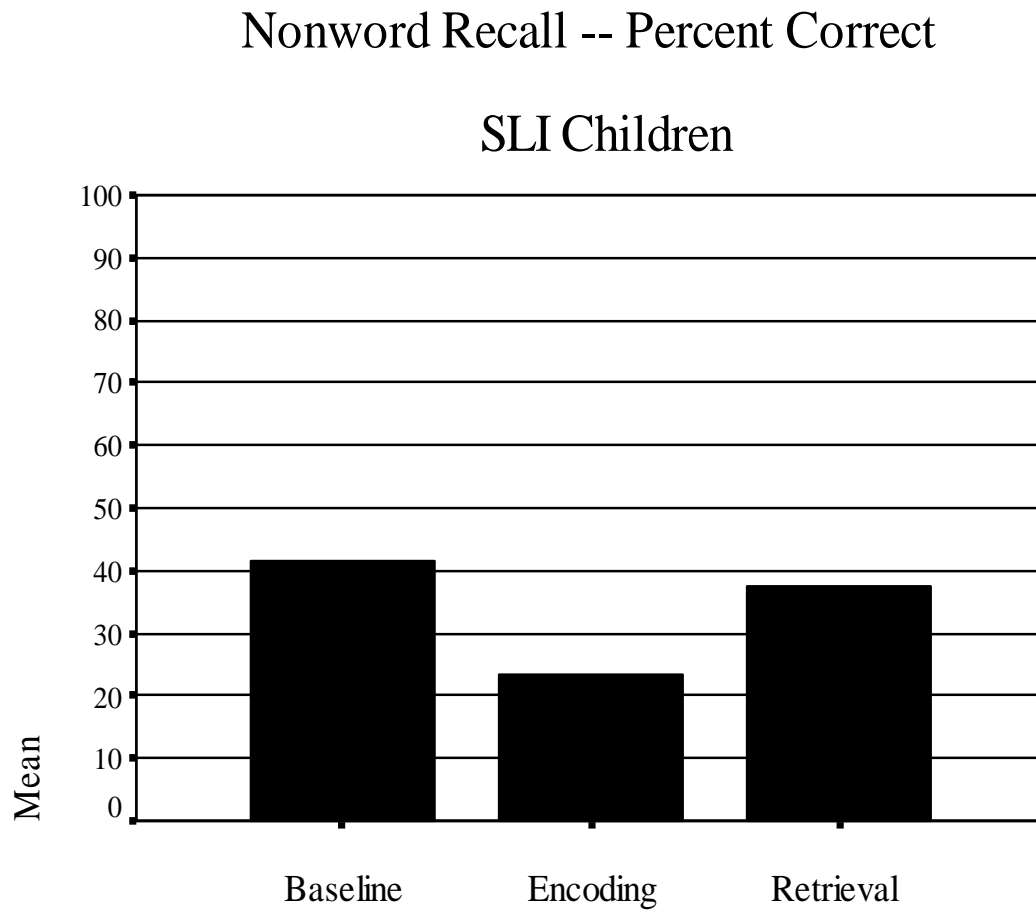


Figure 7. TLD nonword errors and misses.

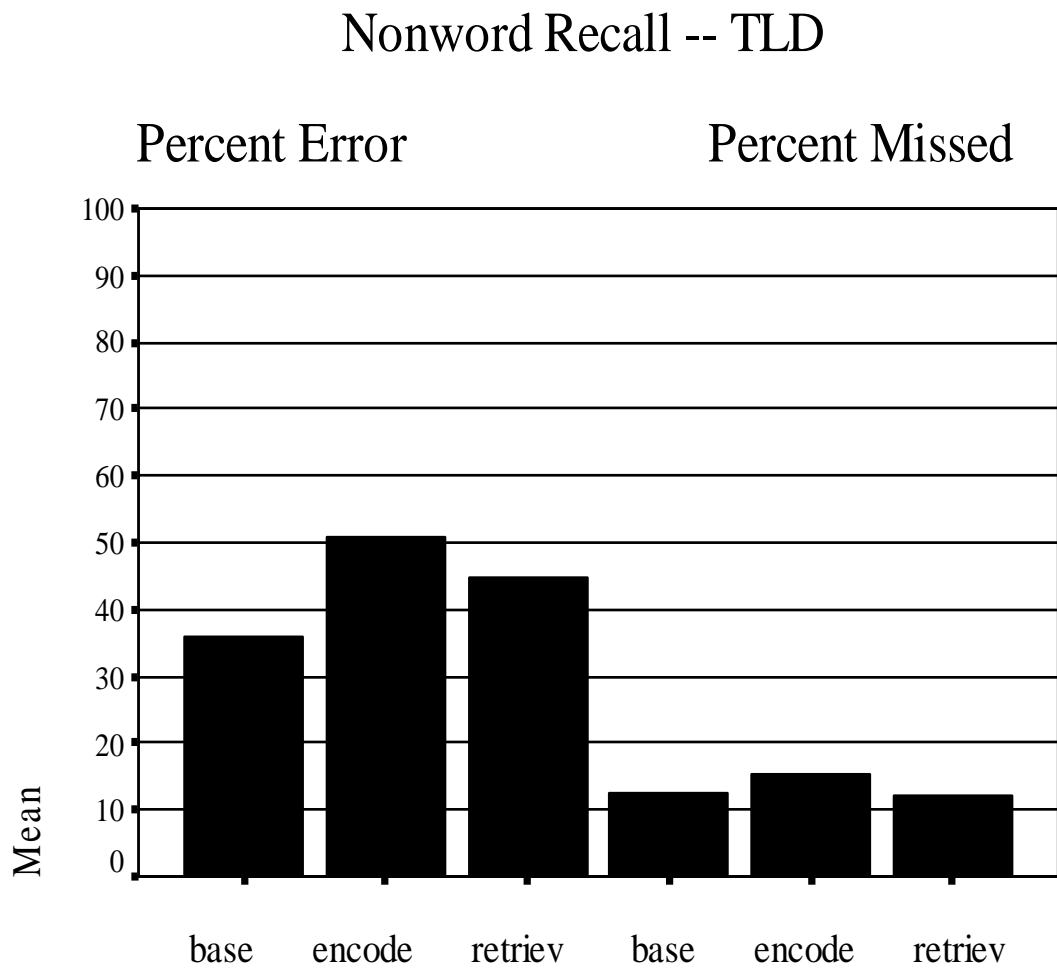
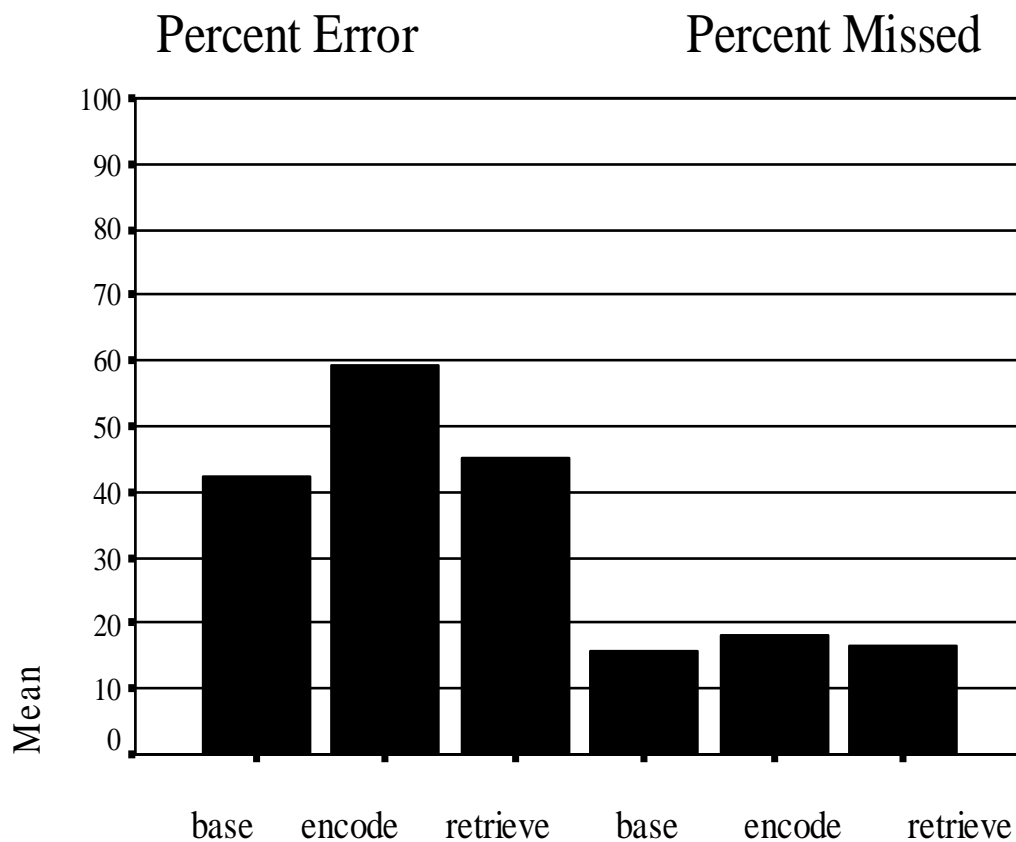


Figure 8. SLI nonword errors and misses

Nonword Recall -- SLI



The V-M task was analyzed considering the percent correct, the percent of error and the percent of misses. Analyses of errors and misses revealed interesting differences. A main effect was seen as well as significance between the baseline and encoding conditions. Means (Table 9)

and results of MANOVAs are reported (Table 10). No significance was reached for the percent of errors and the percent of misses between baseline and encoding. Performance between groups did not differ significantly.

Table 9

Means for visual-motor performance with nonwords (percents) children with typical language development versus children with specific language impairment

| | | Correct | | Error | | Misses | |
|-----------|-----|---------|-----|-------|-----|--------|------|
| | | Mean | SD | Mean | SD | Mean | SD |
| Baseline | TLD | 82.6 | 7.2 | 7.2 | 3.6 | 32.5 | 21.2 |
| | SLI | 87.5 | 4.5 | 5.0 | 2.0 | 10.8 | 7.6 |
| Encoding | TLD | 76.7 | 8.2 | 11.0 | 7.4 | 12.6 | 9.0 |
| | SLI | 79.7 | 9.1 | 10.2 | 8.0 | 11.2 | 4.5 |
| Retrieval | TLD | 78.9 | 9.3 | 9.0 | 7.1 | 13.3 | 7.2 |
| | SLI | 84.7 | 5.3 | 7.0 | 6.5 | 9.8 | 4.9 |

Table 10

Visual-motor performance with nonword F's for repeated measures MANOVAs (group x condition)

| | Within- Subject Effects | Between Subject Effects | Interaction Effects | Post-hoc Analyses | | |
|-----------------|-------------------------------|-------------------------------|------------------------|-------------------|---------|---------|
| | | | | B vs. E | B vs. R | E vs. R |
| | | | | | | |
| <hr/> | | | | | | |
| Percent Correct | | | | | | |
| Total | 5.37 ** | | 2.79 | 8.37 ** | 3.16 ** | 0.44 |
| TLD vs. SLI | | 0.22 | | 0.23 | 0.08 | 1.49 |
| Percent Error | | | | | | |
| Total | 4.92 ** | | 0.14 | 8.38 ** | 1.03 | 1.03 |
| TLD vs. SLI | | 0.56 | | 0.51 | 0.12 | 0.12 |
| Percent Missed | | | | | | |
| Total | 4.00 * | | 3.78 * | 3.68 | 4.72 * | 1.10 |
| TLD vs. SLI | | 6.63 * | | 6.59 * | 7.23 * | 1.17 |
| <hr/> | | | | | | |

Note: df = group: 1, 35; frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

The additional component of speed of performance for the V-M task, reported as seconds on center, was computed when the V-M task was done with and without interference. Means are reported in Table 11. Results from analyses of these measures can be seen on Table 12. Unlike the pattern seen for words, V-M with nonwords reached significance between the baseline and both DA conditions. Groups did not differ significantly.

Table 11

Means for seconds on center with nonwords children with typical language development versus children with specific language impairment.

| Group | Baseline | | Encoding | | Retrieval | |
|-------|----------|------|----------|------|-----------|------|
| | Mean | SD | Mean | SD | Mean | SD |
| TLD | 0.41 | 0.09 | 0.37 | 0.10 | 0.39 | 0.08 |
| SLI | 0.46 | 0.06 | 0.35 | 0.12 | 0.40 | 0.16 |

Table 12

Seconds on center with nonwords F's for repeated measures MANOVAs (group x condition)

| Group | Within-Subject Effects | Between-Subject Effects | Interaction Effects | Post-hoc Analyses | | |
|-------|------------------------|-------------------------|---------------------|-------------------|---------|---------|
| | | | | B vs. E | B vs. R | E vs. R |
| | | | | | | |

| | | | | | |
|-------------|----------|------|-----------|--------|------|
| Total | 8.30 *** | 0.64 | 20.06 *** | 5.37 * | 2.6 |
| TLD vs. SLI | | 0.06 | 0.03 | 0.43 | 0.01 |

df = group: 1, 35; frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

Consonant and Vowel Recall for Words

The total number of consonants and vowels recalled were counted. Total consonants were divided into initial consonants and final consonants for a finer-grained analysis. Means were established and the results of a repeated measures ANOVA (group x condition) were used for these analyses. No significant differences were found between initial and final consonant recall. Vowel recall was nonsignificant. These results parallel those seen for the word recall lists and are not reported separately.

Consonant and Vowel Recall for Nonwords

Consonants and vowels were counted in the nonwords and were considered using the same measures as outlined for words. Results of these analyses were also consistent with the nonword recall list and, therefore, are not reported here.

Serial Order

The following analyses compared performance across the three conditions (FA baseline,

encoding, and retrieval) with regard to list position. Three scoring criteria were utilized: conservative, liberal and free recall. Both words and nonwords were investigated.

Words

Means of percent correct for position order for words can be found in Tables 13, 14 and 15. Three scoring methods are outlined. As the scoring method becomes more lenient, the means increase. The conservative rating demonstrated positions 1 through 6 in declining order for all conditions. Using liberal scoring, a primacy and a small recency effect was noted. Free recall provided the best insight into primacy and recency effects. Repeated measures MANOVAs found areas of significance for word position. These results are presented on Table 16 for all conditions and scoring methods.

Table 13

Means for order recall of words conservative scoring (percents) children with typical language development versus children with specific language impairment

| | | Baseline | | Encoding | | Retrieval | |
|----------|-------|----------|----|----------|----|-----------|----|
| Position | Group | Mean | SD | Mean | SD | Mean | SD |

| | | | | | | | |
|---|-----|-------|-------|-------|-------|-------|-------|
| 1 | TLD | 60.65 | 32.86 | 38.71 | 31.81 | 43.87 | 35.18 |
| | SLI | 50.00 | 35.21 | 40.00 | 30.98 | 50.00 | 35.21 |
| 2 | TLD | 45.18 | 32.65 | 25.91 | 26.82 | 23.87 | 21.55 |
| | SLI | 36.67 | 29.44 | 16.67 | 15.06 | 36.67 | 23.38 |
| 3 | TLD | 34.19 | 25.92 | 20.0 | 25.82 | 15.48 | 19.81 |
| | SLI | 15.67 | 19.66 | 3.33 | 8.17 | 20.00 | 17.89 |
| 4 | TLD | 17.42 | 19.83 | 7.10 | 13.22 | 7.10 | 15.10 |
| | SLI | 3.33 | 8.17 | 6.67 | 10.33 | 13.33 | 16.33 |
| 5 | TLD | 6.45 | 14.04 | 1.29 | 5.00 | 2.58 | 8.55 |
| | SLI | 6.67 | 10.33 | 3.33 | 6.17 | 3.33 | 8.17 |
| 6 | TLD | 3.23 | 11.68 | 1.29 | 5.00 | 1.94 | 6.01 |
| | SLI | .00 | .00 | .00 | .00 | .00 | .00 |

Table 14

Means for order recall of words liberal scoring (percents) children with typical language development versus children with specific language impairment

| Position | Group | Baseline | | Encoding | | Retrieval | |
|----------|-------|----------|-------|----------|-------|-----------|-------|
| | | Mean | SD | Mean | SD | Mean | SD |
| 1 | TLD | 71.61 | 26.22 | 44.52 | 33.35 | 50.97 | 30.48 |

| | | | | | | | |
|---|-----|-------|-------|-------|-------|-------|-------|
| | SLI | 56.67 | 36.70 | 46.67 | 32.66 | 56.67 | 32.04 |
| 2 | TLD | 60.65 | 26.07 | 30.97 | 28.88 | 35.13 | 20.93 |
| | SLI | 50.00 | 27.57 | 20.00 | 12.65 | 46.67 | 27.33 |
| 3 | TLD | 51.61 | 28.65 | 29.68 | 30.93 | 30.97 | 24.68 |
| | SLI | 33.33 | 32.66 | 13.33 | 16.33 | 33.33 | 16.33 |
| 4 | TLD | 30.32 | 19.91 | 24.52 | 25.55 | 25.80 | 18.76 |
| | SLI | 26.67 | 30.11 | 6.67 | 10.95 | 30.00 | 24.50 |
| 5 | TLD | 32.90 | 27.10 | 30.97 | 31.34 | 40.00 | 25.82 |
| | SLI | 13.33 | 16.33 | 10.00 | 10.95 | 20.00 | 25.30 |
| 6 | TLD | 42.58 | 30.87 | 45.81 | 36.95 | 30.97 | 28.68 |
| | SLI | 26.67 | 24.22 | 13.33 | 16.33 | 20.00 | 21.91 |

Table 15

Means for order recall of words free recall scoring (percents) children with typical language development versus children with specific language impairment

| Position | Group | Baseline | | Encoding | | Retrieval | |
|----------|-------|----------|----|----------|----|-----------|----|
| | | Mean | SD | Mean | SD | Mean | SD |

| | | | | | | | |
|---|-----|-------|-------|-------|-------|-------|-------|
| 1 | TLD | 85.16 | 20.84 | 52.26 | 29.06 | 67.74 | 25.13 |
| | SLI | 66.64 | 32.66 | 63.33 | 29.44 | 63.33 | 26.58 |
| 2 | TLD | 71.61 | 24.10 | 35.48 | 25.15 | 48.45 | 23.88 |
| | SLI | 66.67 | 37.24 | 36.67 | 19.66 | 50.00 | 30.33 |
| 3 | TLD | 62.58 | 29.09 | 38.71 | 27.78 | 43.23 | 25.87 |
| | SLI | 43.33 | 38.82 | 20.00 | 12.65 | 46.67 | 20.66 |
| 4 | TLD | 51.61 | 23.54 | 37.42 | 27.20 | 34.19 | 21.41 |
| | SLI | 43.33 | 34.45 | 13.33 | 10.33 | 33.33 | 27.33 |
| 5 | TLD | 51.61 | 25.70 | 45.16 | 27.79 | 53.55 | 23.88 |
| | SLI | 33.33 | 27.33 | 23.33 | 15.06 | 23.33 | 23.38 |
| 6 | TLD | 69.03 | 24.13 | 69.03 | 26.75 | 56.13 | 29.85 |
| | SLI | 56.67 | 29.44 | 36.67 | 29.44 | 30.00 | 37.42 |

Table 16

Word order F's for repeated measures MANOVAs (group x condition)

| Type | Group | Within- Subject Effects | Between Subject Effects | Interaction Effects | Post-hoc Analyses | | |
|------|-------|-------------------------------|-------------------------------|------------------------|-------------------|---------|---------|
| | | | | | B vs. E | B vs. R | E vs. R |

Conservative

| | | | | | | |
|-------------|-------------|---------|------|---------|--------|--------|
| | Total | 4.77 * | 2.43 | 7.14 * | 4.60 * | 0.16 |
| | TLD vs. SLI | | 0.27 | 0.61 | 0.16 | 1.05 |
| Liberal | | | | | | |
| | Total | 4.77 * | 0.11 | 6.07 * | 4.80 * | 0.02 * |
| | TLD vs. SLI | | 0.07 | 0.01 | 0.06 | 0.20 |
| Free Recall | | | | | | |
| | Total | 4.44 ** | 1.76 | 22.03 * | 4.40 * | 0.35 |
| | TLD vs. SLI | | 0.03 | 0.09 | 0.08 | 0.65 |

Note: df = group: 1, 35 frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

Nonwords

Means for percent correct for the three scoring conditions of conservative, liberal and free recall for the nonword were also computed. These are shown on the following tables (Tables 17, 18 and 19). Again significances were found for all conditions and for all scoring methods (Table 20).

Table 17

Means for order recall of nonwords conservative scoring (percents) children with typical language development versus children with specific language impairment

| Position | Group | Baseline | | Encoding | | Retrieval | |
|----------|-------|----------|-------|----------|-------|-----------|-------|
| | | Mean | SD | Mean | SD | Mean | SD |
| 1 | TLD | 50.32 | 30.49 | 48.39 | 28.65 | 50.32 | 30.93 |
| | SLI | 40.00 | 41.95 | 32.33 | 23.38 | 30.00 | 27.57 |
| 2 | TLD | 37.42 | 24.63 | 24.52 | 22.34 | 27.74 | 16.67 |
| | SLI | 23.33 | 32.04 | 10.00 | 16.73 | 13.33 | 16.33 |
| 3 | TLD | 28.39 | 24.64 | 16.77 | 22.57 | 20.65 | 23.94 |
| | SLI | 3.33 | 8.17 | 6.67 | 10.33 | 3.33 | 8.17 |
| 4 | TLD | 38.71 | 28.25 | 24.52 | 24.61 | 24.52 | 27.18 |
| | SLI | 16.67 | 19.66 | 10.00 | 16.73 | 6.67 | 16.33 |

Table 18

Means for order recall of nonwords liberal scoring (percent) children with typical language development versus children with specific language impairment

| Position | Group | Baseline | | Encoding | | Retrieval | |
|----------|-------|----------|-------|----------|-------|-----------|-------|
| | | Mean | SD | Mean | SD | Mean | SD |
| 1 | TLD | 50.97 | 29.59 | 33.55 | 27.51 | 38.71 | 26.80 |

| | | | | | | | |
|---|-----|-------|-------|-------|-------|-------|-------|
| | SLI | 36.67 | 42.74 | 26.67 | 43.21 | 26.67 | 24.22 |
| 2 | TLD | 40.00 | 22.51 | 21.94 | 20.88 | 27.10 | 20.36 |
| | SLI | 26.37 | 30.11 | 3.33 | 8.17 | 10.00 | 16.73 |
| 3 | TLD | 33.55 | 25.50 | 17.42 | 22.36 | 23.23 | 25.87 |
| | SLI | 13.33 | 16.66 | 3.33 | 8.17 | 10.00 | 10.95 |
| 4 | TLD | 52.26 | 32.12 | 31.61 | 25.18 | 37.42 | 25.16 |
| | SLI | 23.33 | 23.38 | 13.33 | 20.66 | 16.67 | 15.06 |

Table 19

Means for order recall of nonwords free recall scoring (percents) children with typical language development versus children with specific language impairment

| Position | Group | Baseline | | Encoding | | Retrieval | |
|----------|-------|----------|-------|----------|-------|-----------|-------|
| | | Mean | SD | Mean | SD | Mean | SD |
| 1 | TLD | 56.77 | 27.86 | 38.71 | 26.80 | 45.81 | 29.75 |
| | SLI | 43.33 | 36.70 | 23.33 | 23.38 | 40.00 | 33.47 |

| | | | | | | | |
|---|-----|-------|-------|-------|-------|-------|-------|
| 2 | TLD | 45.16 | 25.28 | 23.23 | 19.39 | 27.74 | 16.67 |
| | SLI | 30.00 | 27.57 | 3.33 | 8.17 | 33.33 | 24.22 |
| 3 | TLD | 37.42 | 21.13 | 19.35 | 20.32 | 28.39 | 24.10 |
| | SLI | 26.67 | 24.22 | 10.00 | 10.95 | 20.00 | 30.98 |
| 4 | TLD | 61.94 | 25.49 | 39.35 | 22.79 | 45.16 | 23.65 |
| | SLI | 53.33 | 16.33 | 13.33 | 16.33 | 30.00 | 30.33 |

Table 20

Nonword order F's for repeated measures MANOVAs (group x condition)

| Type | Group | Within- | Between | Interaction | Post-hoc Analyses | | |
|--------------|-------------|---------|---------|-------------|-------------------|---------|---------|
| | | Subject | Subject | | B vs. E | B vs. R | E vs. R |
| | | Effects | Effects | Effects | | | |
| Conservative | | | | | | | |
| | Total | 3.35 * | | 1.50 | 5.25 * | 3.18 | 0.22 |
| | TLD vs. SLI | | 8.09 ** | | 5.48 * | 8.14 ** | 7.16 * |

Liberal

| | | | | | |
|-------------|------|---------|--------|--------|------|
| Total | 1.65 | 0.07 | 3.60 | 0.49 | 1.24 |
| TLD vs. SLI | | 8.27 ** | 7.28 * | 6.42 * | 6.77 |

Free Recall

| | | | | | |
|-------------|--------|--------|--------|--------|------|
| Total | 4.23 * | 1.13 | 9.71 * | 0.85 | 3.52 |
| TLD vs. SLI | | 8.94 * | 0.47 | 5.97 * | 4.09 |

Note: df = group: 1, 35 frequency: 1, 35

B = baseline E = encoding; R = retrieval

*p < .05 ** p < .01 *** p < .001

The above analyses demonstrated that SLI children recall fewer words and nonwords than the TLD children, especially during DA tasks.

Comparison of children matched by baseline recall scores

To further explore the similarities and differences between children with and without SLI, three children from each group who had matching baseline recall scores for words were compared. The children with TLD were ages 9;4, 9;11 and 10;1 and the children with SLI were 9;4, 11;9 and 14;9. Although the baseline was matched, the children with SLI recalled fewer words in the encoding condition than their TLD matches. Performance was similar between groups for the retrieval condition. The difference between the encoding and retrieval conditions was greater for the children with SLI than for the children with TLD. The percent of errors and

the percent of misses were greater for the children with SLI during encoding. The general trend remained, that is, poorer recall during the encoding phase than retrieval for all children (see Table 21).

The V-M task performance for these three matched pairs also revealed some differences from the larger analyses. The children with SLI had a greater mean for percent of correct responses in all conditions. Both groups had fewer correct responses in the encoding condition. The children with SLI may have had more computer experience or may have shifted their attention from the recall task to the V-M task (see Table 22). The additional measure, speed of performance (seconds on center), presented in Table 23 was similar for both groups with the exception of encoding for the TLD children. This task reduced speed of performance to a greater degree than the other conditions.

Table 21

Means for word recall (percents) 3 children with typical language development versus 3 children with specific language impairment

| Group | | Correct | | Error | | Misses | |
|----------|-----|---------|-----|-------|-----|--------|-----|
| | | Mean | SD | Mean | SD | Mean | SD |
| Baseline | TLD | 65.6 | 1.9 | 7.8 | 3.8 | 26.7 | 3.3 |
| | SLI | 65.5 | 1.9 | 10.0 | 3.3 | 24.4 | 3.8 |

| | | | | | | | |
|-----------|-----|------|------|------|------|------|------|
| Encoding | TLD | 61.1 | 10.7 | 7.8 | 10.7 | 31.1 | 7.7 |
| | SLI | 32.2 | 1.9 | 23.3 | 14.5 | 44.4 | 10.4 |
| Retrieval | TLD | 56.7 | 8.8 | 12.2 | 3.8 | 31.1 | 12.6 |
| | SLI | 53.3 | 14.5 | 13.3 | 3.3 | 33.3 | 11.5 |

Table 22

Means for visual-motor performance with words (percent) 3 children with typical language development versus 3 children with specific language impairment

| | | Correct | | Error | | Misses | |
|-----------|-----|---------|------|-------|-----|--------|------|
| Group | | Mean | SD | Mean | SD | Mean | SD |
| Baseline | TLD | 81.7 | 7.5 | 7.3 | 4.0 | 11.7 | 5.5 |
| | SLI | 88.3 | 3.8 | 4.3 | 2.9 | 7.7 | 4.0 |
| Encoding | TLD | 72.3 | 7.0 | 12.3 | 8.7 | 15.3 | 10.0 |
| | SLI | 81.3 | 2.9 | 9.7 | 6.5 | 8.0 | 5.6 |
| Retrieval | TLD | 77.0 | 12.5 | 5.7 | 1.8 | 17.1 | 12.0 |

| | | | | | | |
|-----|------|-----|-----|-----|------|-----|
| SLI | 84.7 | 3.1 | 4.7 | 5.5 | 10.8 | 3.9 |
|-----|------|-----|-----|-----|------|-----|

Table 23

Means for time on center with words 3 children with typical language development versus 3 children with specific language impairment

| Group | Baseline | | Encoding | | Retrieval | |
|-------|----------|------|----------|-----|-----------|------|
| | Mean | SD | Mean | SD | Mean | SD |
| TLD | 0.45 | 0.09 | 0.46 | 0.9 | 0.42 | 0.08 |
| SLI | 0.47 | 0.06 | 0.42 | 0.9 | 0.46 | 0.14 |

For nonword recall baseline scores five matches were found. These five TLD children ranged in age from 8;5 to 10;5 and the five SLI children were between 8;9 and 14;9. Both groups exhibited a decrease in recall for encoding compared with baseline. The percent of error and the percent of misses increased during encoding for both groups when compared to baseline. More misses also occurred during the encoding than the other conditions. The groups demonstrated similar performances for nonword recall (see Table 24).

The five SLI children made more errors when encoding compared with baseline differing from the five TLD children whose error rate was consistent over conditions. Both groups demonstrated more missed during encoding compared with the other conditions (see Table 25).

Speed of performance slowed from baseline to retrieval. The greatest slowing, however, was seen for encoding. Again, there was little difference noted between groups (see Table 26).

The V-M task revealed performance discrepancies in percent correct for all children when baseline and encoding were compared. Recall for retrieval was also somewhat lower than for baseline. The SLI children made more errors than their TLD matches, however, The TLD children missed more than the SLI children (Table 25. Speed of performance slowed from baseline to retrieval, however, the greatest slowing was seen for encoding. Again, there was little difference noted between groups.

Table 24

Means for nonword recall (percent) 5 children with typical language development versus 5 children with specific language impairment

| Group | | Correct | | Error | | Misses | |
|----------|-----|---------|------|-------|-----|--------|------|
| | | Mean | SD | Mean | SD | Mean | SD |
| Baseline | TLD | 45.0 | 10.6 | 45.0 | 7.9 | 14.0 | 11.9 |
| | SLI | 45.0 | 10.0 | 37.0 | 7.6 | 18.0 | 12.0 |

| | | | | | | | |
|-----------|-----|------|------|------|------|------|------|
| Encoding | TLD | 29.0 | 21.0 | 52.0 | 16.0 | 22.0 | 24.9 |
| | SLI | 27.0 | 8.4 | 54.0 | 24.6 | 20.0 | 18.4 |
| Retrieval | TLD | 43.0 | 20.8 | 42.0 | 20.2 | 14.0 | 11.9 |
| | SLI | 44.0 | 21.0 | 37.0 | 23.1 | 18.0 | 17.9 |

Table 25

Means for visual-motor performance with nonwords (percent) 5 children with typical language development versus 5 children with specific language impairment

| Group | Correct | | Error | | Misses | | |
|----------|---------|------|-------|-----|--------|------|------|
| | Mean | SD | Mean | SD | Mean | SD | |
| Baseline | TLD | 87.4 | 5.6 | 6.4 | 4.0 | 6.2 | 3.4 |
| | SLI | 88.0 | 2.9 | 4.8 | 2.2 | 9.3 | 7.5 |
| Encoding | TLD | 81.0 | 10.1 | 6.4 | 5.5 | 12.4 | 11.6 |

| | | | | | | | |
|-----------|-----|------|-----|------|-----|------|-----|
| | SLI | 79.8 | 6.4 | 11.4 | 8.2 | 10.0 | 3.9 |
| Retrieval | TLD | 83.4 | 3.8 | 7.0 | 4.1 | 9.6 | 5.1 |
| | SLI | 85.8 | 5.1 | 7.0 | 7.2 | 9.0 | 4.9 |

Table 26

Means for time on center with nonwords for 5 children with typical language development versus 5 children with specific language impairment

| Group | Baseline | | Encoding | | Retrieval | |
|-------|----------|------|----------|------|-----------|------|
| | Mean | SD | Mean | SD | Mean | SD |
| TLD | 0.41 | 0.08 | 0.35 | 0.11 | 0.38 | 0.09 |
| SLI | 0.46 | 0.06 | 0.34 | 0.13 | 0.40 | 0.18 |

Although these comparisons were made on a small number of children it was evident that DA affects recall in children. DA during the encoding condition was the most detrimental to recall. SLI children performed more poorly during the encoding condition than the TLD children. The underlying reason has not been answered here.

CHAPTER 4: DISCUSSION

The results of this study supported the hypothesis that divided attention affects children as well as adults. The overall patterns demonstrated the same trend, that is, more disruption to recall during encoding than during retrieval when compared with baseline measures (Anderson et al., 1998; Craik et al., 1998). The tasks were administered 31 children with TLD and 6 children with SLI. Means were compiled and repeated measures ANOVAs (groups x condition) were used in all of the statistical analyses. The TLD and SLI performances were compared on all measures.

Word Recall

The main focus of this study was recall. The children with TLD and the children with SLI were able to remember four to six words at baseline. The ability to draw from their lexical store may have aided these children (Montgomery, 1995b; Montgomery, 1999). These measures were used for comparison with DA conditions. As expected, in the retrieval condition the TLD group showed fewer words recalled than at baseline. Encoding, however, resulted in the poorest recall. Differences were not noted between the two DA conditions indicating that the ability to divide attention was challenging regardless of the protocol imposed. The SLI group exhibited a similar profile with the greatest decrement in the encoding condition. The SLI group recalled fewer words than the TLD group in all conditions. These findings exhibit a pattern similar to those found in adults.

The SLI group demonstrated a higher percentage of errors for encoding than for the baseline or the retrieval. Their percent of errors on the encoding condition was also elevated when compared with the TLD children. The number of misses was similar for both groups.

Gomes, et al. (2000) suggested that maturational improvement was due to an increase of control rather than an increase of capacity. Both TLD and SLI children in this study were able to control their focus of attention. The noticeable difference was the number of words recalled correctly.

The adult studies (Anderson et al., 1998; Craik et al., 1998) reported reaction time for the secondary task. These authors found that a reduction in reaction time occurred on the secondary task during encoding. Minimal disruption was seen during the retrieval phase. The V-M secondary task performance was analyzed for speed of performance as well as the number of correct choices, number of errors and number of misses. The TLD children demonstrated more

misses and fewer errors at baseline than the SLI children. This may indicate that the TLD groups concentrated more on avoiding errors, thereby letting some screens pass. This pattern was not evident during the DA conditions suggesting that resources were allocated differently. For the TLD subjects, there were significant differences when attention was divided for the number of correct, errors and misses. Accuracy diminished, errors increased and more screens were missed. The V-M task differences were not as dramatic as the differences in word recall, however, decrements were noted for both DA tasks. For the V-M task the baseline performance for percent of correct screens for the SLI children was better than the TLD group and there were fewer errors and misses at baseline. It must be remembered that there were only six participants and the age range was broader. The children with SLI showed a greater drop in percent correct than did the TLD children for both DA tasks. When speed of performance was considered, both groups were slower for the encoding condition. The SLI group, however, had greater discrepancies for both DA tasks. This demonstrated that the word recall was more demanding for them than for the TLD children dramatically reducing speed on the secondary task.

DA during retrieval resulted in fewer words recalled compared to baseline and some reduction in the secondary task for all children. DA during encoding showed the greatest differences amongst measures. These results are in line with those of Campbell & McNeil (1985) who supported the theory that resource availability is reduced for the secondary task when resources are shared.

Nonword Recall

The adult studies that served as our model did not include nonwords. We chose to include

nonwords to investigate how phonological memory might be impacted during DA tasks. Each nonword list was four items, two shorter than the word lists. In addition, the children heard and repeated each stimulus. No child had difficulty repeating the nonwords given one at a time and of only one syllable in length. Despite this procedure, DA did affect nonword recall in a pattern similar to that for words for all children. Both the encoding and retrieval conditions depressed recall. At encoding, a higher percent of words were missed than nonwords, however, this may be due to the differences in list length. Performance on all measures of nonword recall paralleled that of word recall.

The secondary V-M task baseline measures were used to compare DA performances. The children with TLD demonstrated more misses and fewer errors at baseline than the children with SLI. Again this pattern was not evident during the DA conditions. When attention was divided during encoding, the percent of correctly chosen screens decreased and errors increased, however, dividing attention at retrieval had little effect on this secondary task. Percentage for misses was similar for both DA conditions. The SLI children had more correct responses than the TLD children under all conditions. V-M processing speed with nonwords was different than that seen with words. Although the challenge of remembering unfamiliar material may have caused some slowing, it was far less than that caused by word recall. List length lessened burden on capacity and allowed more resources to be allocated for secondary task execution. There were some differences between the groups but they did not reach a significant level. It was again demonstrated that sharing resources between a primary and secondary task inhibit performance on both (Campbell & McNeil, 1985).

Consonant and Vowel Recall

Words

The TLD and the SLI subjects were compared on this measure. The total number of consonants recalled was examined. This total was also divided into those remembered in the initial position and those remembered in the final position. The pattern seen for phoneme recall paralleled that of the word recall because those words were analyzed. The same significant differences were seen. Of interest in looking at phoneme recall was to determine if the position in the CVC format influenced recall. Some children from both groups made errors by substituting one phoneme for another although both were contained in the list. Both groups of children remembered the majority of words as presented. Words recalled incorrectly did not significantly alter the number of consonants and vowels recalled correctly.

Nonwords

The groups were also compared on this measure. As with words, the nonword consonant and vowel reflected the nonword recall measures. Both groups recalled these phoneme sequences with good accuracy although the children with TLD had a higher percentage of recalled nonwords than the children with SLI. The significances between conditions were the result of the overall nonword recall, not the individual components, per se. The occasional real word substitution did not alter the consonant or vowel recall significantly.

Serial Order

Words

All scoring methods (conservative, liberal, free recall) used the same sets of recall. As expected, the more stringent method of scoring resulted in a lower percentage for word position. A primacy effect can be seen for baseline and retrieval in all scoring methods. This was greatly

reduced for the encoding condition. This is likely due to the demands of that condition. Recency effects were seen in the free recall scoring. If a child recalled part of the list, for example, words 1, 2, 6, 3 and 4 conservative scoring would only count words one and two because they were in the exact position as the presentation. The liberal scoring would count 1, 2, 3 and 4 because they were presented in a sequence and free recall would count all words. One child with TLD consistently recalled stimuli in reverse order resulting in no correct word positions or sequencing.

The conservative scoring method masked recency effects. Free recall has the advantage for this aspect of the analysis. Overall, the primacy effect was prevalent.

Nonwords

Free recall yielded the highest percentage as it should since neither exact position nor sequential order was required. There were fewer stimuli for nonwords and this affected the scoring to some degree making it more difficult to judge primacy or recency effects. One exception was noted. On free recall during the retrieval phase, the nonword in position 3 was least recalled.

General Discussion

As seen in the adult studies, DA at encoding caused a decrease in memory performance as well as some reduction in reaction time for the secondary task. Memory was less affected by DA at the retrieval stage. More costs to memory recall were incurred at the encoding stage because the secondary task interfered with a controlled process. Conversely, memory recall at retrieval

appeared to be automatic suffering less from interference (Anderson et al., 1998; Craik et al., 1998).

Word and nonword recall demonstrated similar patterns for the children with TLD. DA during encoding resulted in poorer recall than for retrieval. The percentage of words missed was greater for words than nonwords. This may be the result of list length. There were several examples of children recalling the nonwords as words indicating that items stored in their lexical memory were accessed and caused interference. Throughout the study many of the means had large standard deviations. It was hypothesized that this was a result of the children's ages. When piloting this study, some younger children (8 years old) were recruited. The divided attention tasks were too demanding for them. Most were able to do only one of the tasks at a time. Specifically, during the DA conditions they hurried through one task then did the other. Some recalled first then played the V-M game, others did the reverse. The ability to control attentional resources improves with maturation (Gomes et al., 2000). Future studies should explore other age groups to determine at what age results become less variable.

The SLI group had a limited number of participants and the age-range was greater than the TLD group. This small sample, however, demonstrated that the SLI group could do all tasks presented. The profiles are similar to the TLD profiles although the percentages on all measures were less for the SLI group. The children with SLI could divide their attention much like the children with TLD with some differences in the number of errors and misses on all measures. This study supports the hypotheses that children with SLI have limited resource capacity. Despite this limitation, these children were able to perform DA tasks exhibiting their ability to

use attentional control. The SLI group was more similar to the adult study of older subjects. The older adults required more resources for retrieval implying that more resources needed to be allocated for this task than that required by younger adults (Anderson et al. 1998). Our SLI children allocated resources differently than the TLD children.

Future directions

Future research is needed with a larger group of SLI children to further explore these findings. The similarities in performance between children with SLI children and younger TLD children is another area that warrants further investigation. Studies of word recall using different paradigms have demonstrated that children with SLI perform more like younger TLD than TLD chronological age peers (Gillam, Cowan, & Day, 1995; Montgomery, 2000a). This study although limited, shows this trend.

Because this study used a silent interval between presentations of items for recall, some children may have used strategies such as rehearsal to enhance their performance. To eliminate this possibility, this study could be replicated using a distractor task as was used in the adult model. Interviewing the children as to strategies used to enhance recall could provide an interesting comparison between groups. Finally, issues such as the effects of the domains of the secondary task (auditory vs. visual-motor; non-language vs. language) warrant further investigation

Appendix A

CVC word lists:

| | | | | | |
|---------|---------|---------|---------|---------|---------------|
| List 1 | List 2 | List 3 | List 4 | List 5 | List 6 |
| goat | big | bad | book | back | fight |
| jazz | hoop | shave | game | vase | juice |
| wish | thumb | goose | lip | doll | dip |
| bang | can | home | jet | get | rock |
| sock | leave | walk | road | phone | moth |
| rhyme | rice | fell | cheese | push | chain |
| List 7 | List 8 | List 9 | List 10 | List 11 | List 12 |
| ball | foot | hose | buzz | bus | fan |
| shook | noise | jail | loaf | gave | boat |
| nose | pad | peach | chop | tan | room |
| deep | hole | sign | ham | pile | dice |
| roof | gym | fit | wig | deaf | pill |
| mat | cheek | cab | cage | zoom | sheep |
| List 13 | List 14 | List 15 | List 16 | List 17 | List 18 |
| job | dog | mess | wood | sheet | live (long I) |
| mud | shell | rope | bet | win | soap |
| knife | bun | cat | mug | sad | fin |
| sail | wave | bush | chin | hog | web |
| rose | zip | pain | seize | move | hug |
| vet | root | watch | loom | luck | math |

| | | | | | |
|---------|---------|---------|---------|---------|---------|
| List 19 | List 20 | List 21 | List 22 | List 23 | List 24 |
| pig | save | cap | dive | wash | hot |
| chalk | hid | face | nut | rod | fish |
| lose | cheat | join | sell | gum | dig |
| seen | rug | chug | hope | look | check |
| wife | mash | witch | rich | seat | page |
| dot | bike | team | mouth | fake | boss |
| | | | | | |
| List 25 | List 26 | List 27 | List 28 | | |
| bug | fin | leaf | light | | |
| raise | cup | head | soup | | |
| den | mouse | jam | bath | | |
| shout | hall | thin | red | | |
| cheep | give | cape | comb | | |
| joke | buzz | white | jug | | |

Appendix B

CVC nonsense words

| List 1 | List 2 | List 3 | List 4 | List 5 | List 6 |
|---------|---------|---------|---------|---------|---------|
| sef | sate | koge | reev | hef | chag |
| jode | vum | fid | fot | loat | zeep |
| riv | hap | tul | gibe | mib | leb |
| wum | lish | syle | kip | vun | rit |
| List 7 | List 8 | List 9 | List 10 | List 11 | List 12 |
| bot | wib | bim | boodge | bav | jave |
| gup | nake | jav | lig | gobe | heen |
| zode | sote | zep | hase | lup | gid |
| wev | thep | toke | reen | nout | chak |
| List 13 | List 14 | List 15 | List 16 | List 17 | List 18 |
| chot | noof | sep | gop | chav | bool |
| zoov | rhate | dut | kooz | lom | shawk |
| dawp | chog | zafe | hoif | googe | cheen |
| som | vil | boz | cham | neep | seg |
| List 19 | List 20 | List 21 | List 22 | List 23 | List 24 |
| vach | zan | wub | thois | pid | feep |
| jawf | goth | zowth | pof | weef | jaus |
| shoik | vake | mek | voke | hoiz | sem |
| zeep | lowj | geel | gime | mool | nade |

| List 25 | List 26 | List 27 | List 28 | List 29 | List 30 |
|---------|---------|---------|---------|---------|---------|
| lawk | mab | thag | ched | vosh | pune |
| weej | gif | keef | theep | tem | teeg |
| tosh | lage | heb | shafe | nide | bith |
| goom | tov | sudge | mog | faz | loo |

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