VISUAL AND VERBAL CODING STRATEGIES IN CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT

by

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Abstract

A substantial body of research points to the possibility that deficits in verbal memory processes may contribute to the atypical language development of children with specific language impairment (SLI). The current study used a short-term memory task to explore children's use of visual and verbal coding strategies to remember pictures of objects. Participants were 39 children, 13 children with SLI and two normal language control groups of 13 children each, one matched by age (AM) and one by language level (LM) with the SLI children. Subjects performed a memory task in which they were briefly presented with a target picture and then selected its match from an array of three pictures in which the target was either an identical match (identity condition), a basic level category match (category condition), or a visual match (shape condition). Children with SLI showed a pattern of a larger reaction time difference between the category and identity conditions than their AM peers. If it is true that the category condition rewards verbal coding, then relatively slower performance on this condition suggests that the SLI children may not be relying on verbal codes to the same degree as the AM children. A deficit in using verbal codes could explain the learning difficulties experienced by children with language impairment, both in the domain of language and more generally.

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CHAPTER ONE: INTRODUCTION

Visual and Verbal Coding in Specific Language Impairment

The present study was intended to examine memory coding strategies for children with specific language impairment (SLI). While children with SLI have traditionally been described as those whose language delay occurs in the absence of a cognitive deficit (Leonard, 1982), many studies have shown that these children do have difficulties in the cognitive domain (for reviews see Bishop, 1992; Johnston, 1994, 1999). Of late, processing variables, in particular deficits in short-term or working memory, are being looked at as contributing to the atypical language development of these children.

The precise nature of the mechanisms underlying the memory difficulties in children with SLI, however, remains unresolved. Children with SLI have been shown to perform more poorly than their typically developing age peers on many memory tasks (e.g., Edwards & Lahey, 1998; Friel-Patti, 1999), a deficit which often diminishes as the verbal demands of the task are reduced (Johnston, 1994). Hence, one theory that is gaining support suggests that the deficits these children present occur "at the intersection of language and memory" (Gillam, 1996, p. vi). If this is true, then research that has focused on children's abilities at the interface of these two domains may be relevant to understanding the deficits in SLI.

Research relevant to this topic can be broadly grouped into four areas of investigation. *Capacity limitation* explanations of working memory deficits in SLI suggest a difficulty for these children in simultaneously retaining and manipulating multiple pieces of linguistic information (Ellis Weismer, 1996, 1999). Research in *phonological working memory* has examined difficulties that children with SLI have in constructing temporary phonological representations of sequences of auditory information, i.e., speech (e.g., Gathercole & Baddeley, 1990; Gillam, Cowan, & Marler, 1998). *Coding strategy* researchers have studied children with typical language development to determine whether these children use verbal or visual strategies to

remember (e.g., Brown, 1977). Finally, the possibility that the memory deficits in SLI children are specific to *sequential memory processes* have also been an area of research (Tallal, 1976; Tallal & Stark, 1980; Gillam, Cowan, & Day, 1995). It is important to note that these areas of research are not exclusive of one another (e.g., phonological working memory is generally considered to be a capacity-limited system): the organization of the discussion simply reflects the most salient aspects of the theories pertinent to the current study.

One issue in reviewing memory research is the breadth and complexity of the research in this area. In order to focus this discussion more narrowly, two prominent models of working memory will be briefly reviewed and will provide a framework for the subsequent discussion of the research looking at memory and language. Then the research in the areas of capacity limitations, phonological working memory, sequential memory, and coding strategies will be considered, along with some of the conceptual and methodological limitations of this literature. Finally, the purpose of the present study and the experimental task used will be introduced, along with the research questions to be addressed.

Literature Review

Working Memory

Models of Memory

The contemporary concept of working memory grows out of earlier work on short-term memory. While short-term memory was conceived as a temporary storage repository (Atkinson & Shiffrin, 1968), working memory is thought to possess an additional functional component. The term working memory refers to a system in which information can be temporarily stored and manipulated to serve complex cognitive tasks (Baddeley, 1992). In the following section, models of working memory put forward by Daneman and associates (e.g., Daneman &

Carpenter, 1980; Daneman & Merikle, 1996), and by Baddeley (1986) will be briefly discussed to provide an outline of the current conceptualization of memory relevant to the present study.

From the perspective of Daneman and associates (Daneman & Carpenter, 1980; Daneman & Merikle, 1996), working memory for language is viewed as a resource-limited system that includes both storage and processing functions. These functions share a limited pool of resources and, as a result, there is a tradeoff between storage and processing of information when task demands exceed available resources. From the perspective of this model, implications of memory deficits for children with SLI would likely involve limitations in capacity for information when processing demands increase, or vice versa.

One example of this capacity-demands perspective can be seen in the literature that examines speed of processing in SLI. Windsor and Hwang (1999), for example, conducted a meta-analysis of studies that examined the performance of children with SLI compared to chronological age-matched peers on a range of reaction time (RT) tasks. Results indicated that there was a speed-accuracy tradeoff for children with SLI, providing support for the idea of generalized slowing in children with SLI. In another study of processing speed in children with SLI, Miller, Kail, Leonard, and Tomblin (2001) looked at the performance of a group of children with SLI on several different RT measures. Miller et al.'s results paralleled those of Windsor and Hwang, in that children with SLI were consistently slower than typically developing children on many different types of tasks, both linguistic and nonlinguistic. From this perspective, then, deficits underlying the language delays in children with SLI may be the result of limitations in capacity impacting on processing speed.

Baddeley's (1986) phonological loop model of working memory presents working memory as a multi-componential construct, with a central executive, articulatory loop, and a visuo-spatial sketch pad. The central executive serves several functions that include information-flow regulation, information retrieval, and mediating the processing and storage

functions. The capacity-limited articulatory loop maintains and refreshes novel speech material, and is thought to be responsible for forming and temporarily storing phonological representations, particularly while another cognitive task is carried out. The visuo-spatial sketchpad briefly holds visual and spatial information.

While Baddeley (1986) views the articulatory loop as speech-specific, Cowan (1996) has suggested that this might just be a special instance of memory activation, and thus similar to the activation processes that occur in memory for other types of information. So, while it has been suggested that the deficit in memory processes is specific to auditory information, it is also possible that similar deficits in functioning may occur for verbal information more generally.

From the perspective of Baddeley's (1986) model, the memory deficit for children with language impairment is presented as a deficit in phonological working memory (Gathercole & Baddeley, 1990). Deficits in phonological working memory demonstrated by children with SLI may result from (1) difficulty creating phonological representations, (2) difficulty encoding phonological representations, and/or (3) rapid rate of decay of the phonological trace, causing difficulty in translating incoming acoustic information into a phonological code (Cowan, 1996).

Capacity Accounts for the Memory Deficits in SLI

Researchers have long wondered about the possibility that limitations in capacity underlie memory deficits in children with SLI. A substantial body of early research in the area of short-term memory capacity focused on basic measures of memory span, most notably for lists of digits or words. Children with SLI consistently demonstrate reduced short-term or working memory capacities relative to their age peers on a variety of tasks (for an overview see van der Lely & Howard, 1993).

Johnston, Smith, and Box (1997), for example, looked at referential strategies in children with SLI and typically developing age peers. They found that children with SLI were capable of

"communicatively adequate" reference (p. 969), in that they were able to successfully refer to the objects. However, there were differences between groups in their use of referential strategies that were not attributable to group differences in lexical or grammatical knowledge. While capacity was not the initial focus of this study, the authors argued that cognitive capacity limitations may have been responsible for the observed group differences.

Other researchers have used complex paradigms to study capacity issues in children with SLI directly. Ellis Weismer (1996) used a dual task paradigm to study working memory for verbal material in children with SLI and typically developing age-matched children, to determine whether the children with SLI have reduced verbal working memory capacities compared to peers with normal language skills. The task required children to respond to either one verbal instruction (noncompeting condition) or two simultaneous verbal instructions (competing condition), one spoken by a man and one by a woman. While all children had more difficulty responding in the competing condition, the difference between comprehension scores for the noncompeting condition and the competing condition was significantly greater for the children with SLI than the normal language children. Ellis Weismer interpreted these findings as providing tentative evidence for a working memory capacity restriction in children with SLI that makes it "extremely difficult to maintain multiple pieces of linguistic information at the same time." (p. 40).

Ellis Weismer (1999) also examined capacity issues in children with SLI using performance on a Daneman and Carpenter-type verbal working memory task. Participants were two groups of young school-aged children, one group with SLI and one group with typically developing language skills. The children listened to groups of two to six sentences. After each sentence they were required to state whether the sentence was true or false and, after presentation of all the sentences, the children were asked to recall the last word of each sentence. While neither children with SLI nor the normal language group had difficulty with the semantic

judgment part of the task, the SLI children had significantly poorer word recall performance than the children with typical language skills. Ellis Weismer suggests that these findings provide additional evidence for capacity limitations in verbal working memory in children with SLI.

Phonological Working Memory Accounts for the Memory Deficits in SLI

Another focus for memory research in children with SLI has been with respect to deficits in one purported type of memory, phonological working memory. This line of research stems from Baddeley's (1986) phonological loop model of memory described in an earlier section. Children with SLI are thought to have phonological working memory deficits, of which difficulty learning language is one consequence (Gathercole & Baddeley, 1990).

Evidence in support of the link between phonological working memory and the language-learning difficulties of children with SLI has been well-documented (Gathercole & Baddeley, 1989, 1990; Gillam et al., 1998). In one study, for example, Gathercole and Baddeley (1989) assessed a large group of young children on a range of verbal measures. The children's vocabulary knowledge and immediate phonological memory skills were found to be highly related. There was a link between non-word repetition ability at age four, thought to be a measure of phonological working memory, and vocabulary scores one year later. The researchers suggested that these results lend strong support to their hypothesis, that phonological working memory plays an important role in the long-term learning of new words. Those children with reduced short-term phonological coding abilities seem to have more difficulty learning vocabulary at a normal rate.

One concern with research in the area of language development is that the correlational nature of the studies often limits their ability to indicate causal connections between variables. In an attempt to counter this issue, Gathercole and Baddeley (1990) set out to provide specific experimental evidence that children's ability to learn novel words was related to their

phonological working memory skills. They focused on individual variation in young children's ability to learn new vocabulary. Their main assumption was that differences in children's abilities to learn new words reflected differences in their abilities to "construct the temporary phonological specifications of unfamiliar sound sequences in working memory" (p. 440).

Two groups of children participated in the Gathercole and Baddeley (1990) project, both selected from the pool of children who participated in an earlier study (Gathercole & Baddeley, 1989). Participants were selected on the basis of their performance in the earlier study on measures of vocabulary comprehension, non-verbal intelligence, and non-word repetition. The children were then separated into low- and high-repetition groups based on their non-word repetition scores. The authors hypothesized that phonological working memory is the medium for temporarily storing unfamiliar, but not familiar, words. To investigate this possibility, they developed a task that required children to learn familiar words versus novel words as labels for objects. The researchers found that low repetition children were slower than high repetition children at learning phonologically unfamiliar names for toys, but not at learning familiar names for them even when the two groups were matched on non-verbal intelligence scores. The authors suggested that the results experimentally establish a close relationship between phonological working memory skills and the speed at which young children learn new, unfamiliar words to name objects, and thus provide evidence in support of the role of these skills in vocabulary acquisition. They further suggested that phonological working memory deficits are implicated in the impaired vocabulary and language development of language-disordered children.

The findings from these studies provide support for the link between phonological working memory and vocabulary development; however, the process by which phonological working memory contributes to learning new words remains unresolved. One hypothesis put forth is that in order to learn new words, children must first achieve a stable, long-term representation of a sequence of sounds (Gathercole & Baddeley, 1990). And, a logical

prerequisite for the establishment of a long-term representation would be the formation of an adequate temporary phonological representation. One hypothesized medium for the storage of this temporary representation, and for the construction of a stable long-term memory representation, is immediate phonological memory. This is thought to occur in the articulatory loop, where the phonological representation undergoes rehearsal processes. Furthermore, the stability of the long-term representation will likely be related to the adequacy of the temporary representation. If a better short-term representation results in more efficient long-term learning, children with strong phonological working memory skills should be able to learn new words more easily than those children without strong skills in this area.

A similar theoretical explanation for the link between phonological working memory and language skills has been developed in the context of developmental dyslexia. Palmer (2000) compared the performance of three groups of 16 teenagers, one group of children with dyslexia and two groups of controls, one matched by reading age and one by chronological age with the children with dyslexia. The experimental task was a picture span task in which the participants viewed pictures from one of four sets of line drawings, which varied in their visual and/or phonological similarity. The labels of the pictures were all single-syllable words. Phonologically similar labels shared the same vowel (e.g., cat & map), while visually similar items looked alike. The four sets of items were: a practice set and a control set consisting of visually and phonologically dissimilar items, a set of items that were visually similar and phonologically dissimilar, and a set which were phonologically similar and visually dissimilar.

Palmer (2000) found that all three groups of children demonstrated a phonological similarity effect where recall was negatively affected when the picture labels sounded the same, but only the dyslexic group showed an effect for visual similarity. This pattern of results provides evidence that the dyslexic subjects were using a visual recall strategy on the memory task, while reading age-matched and chronological age-matched controls were using a

phonological recall strategy. Palmer hypothesized that for the dyslexic children the task was challenging for two reasons. First, they had to phonologically recode the visual information presented, and second, they had to inhibit the formation of visual representations, which were potentially disruptive. Palmer concluded that children who are relying on visual coding will be at a disadvantage in memory tasks, not only because of their difficulty with phonological coding per se, but also because they formulate visual representations that interfere with their phonological memory. It is possible, then, that there are similar patterns of deficits underlying the delays in children with other language-based impairments, such as SLI.

In an attempt to provide evidence in support of, or counter to, several prevailing theories of the deficit underlying SLI, Gillam et al. (1998) used a modality-effect paradigm to study modality-specific memory mechanisms. Participants were 8- to 11-year-old children with SLI and age-matched children with normal language development. The children were tested using a basic digit span task in which recall and response modality were manipulated. Stimuli were presented either visually, auditorily, or audiovisually, and the response was either a spoken response or pointing response. Overall, both the language-impaired children and the normal-language controls had better recall when stimuli were presented auditorily than when they were presented visually or audiovisually. Gillam et al. suggested that this pattern of performance was due to a greater reliance on phonological coding when auditory information was presented. They suggested that auditory presentation 'forces' the use of a phonological code, since auditory stimuli are not easily codable visually. This finding also supports the theory put forth by the authors that phonological codes provide the best form of representation for storage and recall in working memory.

An additional, unexpected finding in the Gillam et al. (1998) study was that SLI children performed better when a speaking response was required of them than when a pointing response was required. Moreover, worst performance in this group occurred when a visual stimulus was

paired with a pointing response. The authors hypothesized that these findings point to a phonological coding deficit in children with SLI: when phonological coding is not 'forced' through presentation of auditory stimuli or the requirement of a speaking response, children with SLI may employ visual coding strategies, which do not support recall as well as phonological coding. Baddeley and Wilson (1993) further suggested that the phonological coding processes that occur when pictures are presented are similar to those that occur for auditory stimuli. Given the possibility that visual information yields a phonological code only with additional active processing (Salame & Baddeley, 1982), this raises questions about the implications of this capacity tradeoff when children with SLI are presented with pictorial stimuli.

Sequential Memory Accounts for the Deficits in SLI

A large body of research with children with language impairments has pointed to difficulties for these children in dealing with sequential information. While some researchers have described the sequencing difficulties with respect to difficulties in perceiving rapid auditory sequences (e.g. Tallal, 1976; Tallal & Stark, 1980), others have looked to difficulties in memory limited to sequential verbal information. Kushnir and Blake (1996) examined sequential/processing memory in 3- to 5-year-old children with language impairments and non-impaired age-matched children. The authors looked at three possible sources of memory deficits for the SLI children in their study: a general memory deficit, a verbal memory deficit, or a deficit in verbal sequential memory. Kushnir and Blake found that the most significant performance difference between the two groups of children was on performance on the verbal sequential memory task. This task required children to repeat back a list of animal names in order. Kushnir and Blake interpreted the SLI children's lower level performance as pointing to a memory deficit in these children specific to sequential verbal information.

In another study of sequential memory in children with SLI, Gillam, Cowan, and Day (1995) examined serial recall for lists of digits, by children with language impairment and two groups of normally developing controls. The children in the study were presented with lists of digits at one item greater than their memory span. In one condition the children heard a suffix at the end of the list which served to interfere with memory for items at the end of the list. In the other condition the list was presented without the suffix. The results indicated that the list-final suffix interfered with serial recall in children with language impairment but not in typically developing children. And, the interference effect was significant only for serial order information. Gillam et al. concluded that children with SLI may have memory deficits specific to sequential information.

Summary

Studies of capacity limitations and phonological coding deficits have clearly shown children with SLI to have working memory deficits relative to children with typically developing language skills. What many of these studies fail to adequately address, though, is the question of what is happening for these children when they are demonstrating performance deficits on working memory tasks. Capacity or phonological coding explanations of memory deficits in SLI are thus far limited in their ability to detail the process or processes underlying the performance of children with reduced capacity or poor phonological coding ability. While phonological working memory accounts may explain memory for spoken language, it is not clear yet whether they do, in fact, provide comprehensive accounts of all aspects of the memory deficit in children with SLI. And, though deficits in children with SLI specific to sequential information have been clearly documented, these deficits may coexist with other processing impairments in these children.

Coding Strategies

Overview

An examination of differences in use of coding strategies underlying memory processes in children with typical and delayed language development might serve to clarify some of the issues that have been presented thus far. While the primary focus of coding strategy research to date has been in examining adults or children with typical language development, relating the coding strategy research in normally functioning individuals to understanding memory processes in children with SLI might serve to answer some of the questions raised. The discussion to follow will review some early studies of memory in typically developing children and adults, and then will review some of the research specific to visual and verbal coding. This will be followed by a consideration of the implications of this research for understanding the memory deficits in children with SLI. I will also speculate about the possible consequences of an individual's preference for a particular coding strategy and what the basis for such a preference might be.

Typical Development

Memory. Early researchers in memory recognized the importance of strategy use in children's memory development. One model of memory development conceptualized memory in children as progressing through distinct stages (e.g., Blonskii, 1935, cited in Schneider & Pressley, 1997). Infants were thought to rely initially on motor memory and emotional memory. With increasing age, children become more reliant first on visual then verbal memory.

The shift from visual to verbal memory processes was thought to occur at about the time reading is taught. For example, Bruner (1964) demonstrated that preliterate children were better at retaining pictorial stimuli in a pictorial representation and less likely to recode them to a verbal form than older children. Similarly, Kendler and Kendler (1962) showed that older children relied more on verbal representations to aid in recall of pictorial information when compared

with younger children. These studies highlight the shift from the use of visual to verbal memory processes in young children that has been hypothesized to occur.

In a related similar study Maltseva (1948, cited in Smirnov, 1973) compared young school-aged children and a group of college students in their use of visual and verbal stimuli as retrieval cues for encoding and recalling text materials. She found that although overall visual cues were most effective in aiding recall, older subjects benefited relatively more than younger subjects when provided with verbal cues. This points to the increasing importance of the verbal system in memory with age.

Other researchers have also found evidence in support of the increasingly key role of the verbal system with age along with a gradual reduction in the dominance of the visual system in encoding and retrieving information. Farapanova (1958, cited in Smirnov, 1973) studied the recall abilities of school-age children and college students presented with pictures and verbal material. Participants were asked to memorize four different types of stimuli: (1) easily-named pictures; (2) easily-visualized verbal material; (3) difficult-to-name pictorial materials; and (4) difficult-to-visualize verbal material. Recall was best at all ages first for easily-named pictures, followed by visualizable-words. Hard-to-name pictures and hard-to-visualize words were the most difficult for participants to recall. This pattern of findings points to the key role of both labels and visual cues in memory. In fact, both visual and verbal memory seem to have roles in recall but the relative importance of either may be dictated by the materials. Farapanova also found that young school-age children remembered hard-to-label pictures better whereas older schoolchildren and adults did better with abstract words. These findings also support the theory that there is a developmental shift from the use of visual to verbal memory processes.

Visual and verbal coding. Support for the findings from early studies of memory development in children can be found in later studies that focused on visual and verbal memory processes in typically developing children. In one such study, Brown (1977) examined

preschool-aged children's use of visual and verbal coding processes using a pictorial short-term memory task. The children performed a recognition task using four sets of letters that varied systematically in visual or auditory similarity (high visual/high auditory, high visual/low auditory, low visual/high auditory, and low visual/low auditory). Differences in recall under the four conditions were used to infer mode of coding. Results demonstrated that the children showed poorer recall under the high-visual similarity condition, regardless of the auditory similarity of the letters. Brown interpreted this finding as indicating the greater importance of visual coding compared to verbal coding as a means of short-term representation for preschool-aged children.

In a related study, Corsini (1972) looked at differences in kindergarten children's ability to use different types of stimulus information in a recall task. Children were required to perform a task after either listening to a verbal instruction, watching an adult model perform the task, or listening and watching simultaneously. The main finding of interest to the present study is that the children in Corsini's study demonstrated better recall under conditions in which both verbal and nonverbal stimulus cues were available, than when only verbal or visual information was available. The author suggested that for children of this age verbal instructions may have functioned as a cue to code something, but how well the instruction was coded depended upon whether visual information was also available. These findings, again, highlight the importance of both verbal and visual coding processes in memory for young children.

More recent research has looked at the processes underlying visual and verbal recognition memory. Doty and Savakis (1997) studied the performance of adults on a continuous visual recognition task, in order to examine common processes underlying visual and verbal recognition memory. Participants were presented with items sequenced at 5 second intervals and required to identify whether each item in the list was new, a novel word or picture, or old, a previously presented word or picture. Mode of presentation of stimulus items was varied across

the sessions (images or words) as was duration of stimulus presentation (2 seconds or 200 msec). The images were designed such that they would be not easily verbally codable, while the words were four letter, one syllable words. The two variables of interest were accuracy and reaction time. The finding from the Doty and Savakis study most relevant to the present study is that accuracy for words displayed for 200 msec was significantly better than that for images displayed for 2 sec. This finding points to the possibility that, for adults, words may provide a better support for recall than images.

Specific Language Impairment

Implications of Coding Strategy Research for Understanding SLI

Coding strategy research on typically developing children points to the importance of both visual and verbal processes in memory but indicates that a key feature of normal memory development is an increasing reliance on verbal processes with age. Few studies to date, however, have focused specifically on these processes in children with SLI. While it is not clear why a shift from a reliance on visual to verbal processes in typically developing children occurs, it has been hypothesized that words are a more efficient means of storing and recalling information than are visual representations (Gillam et al., 1998). Thus limitations in a child's ability to use verbal coding strategies might have a significant impact on his or her ability to learn new verbal material, one hallmark of children with SLI. One possibility to explain the deficits in SLI, then, might be with respect to coding strategy preference. If this shift to a verbal coding strategy did not occur, impaired language development might result.

Implications of Using Visual or Verbal Coding Strategies

If the deficit in SLI is due to a reduced reliance on verbal coding strategies by these children, this raises the question of what might be different about the use of visual and verbal

representations that would have such a significant impact. That is, what is it that a child is doing when he or she is coding visually versus verbally? Visual representations have depictive properties, whereas a word or label has interpretive, propositional properties. While interpreting a picture in terms of a label or object class means that much detailed visual information, a richness of propositional information is gained. Words or labels can capture relationships between objects or classes of objects in a way that visual representations cannot, hence providing a tool for storing of information in a single 'package' about which some judgments or interpretations have been made. All of these things remain unrealized when a visual representation is made. So it is possible that for children who are coding visually, they are maintaining a detailed, depictive representation but have not taken the next step of making judgments about that representation through attaching a label to it.

There may also be more serious consequences of a difficulty with verbal coding strategies that extend far beyond the immediate effects seen with respect to the language delays of children with SLI. Gillam et al. (1998), among others, suggest that a verbal coding deficit may also have implications with respect to the general learning difficulties experienced by children with SLI. Failure to code verbally might also mean that the children do not have the propositional information required to perform many higher level thinking tasks such as reasoning and problem solving. We might expect that these children would be weak in many areas that require propositional thought. This is, in fact, the case as many studies have demonstrated children with SLI to be weak in areas that require higher level thinking skills including reasoning and problem solving (Johnston, 1992). In support of this possibility, Stothard, Snowling, Bishop, Chipchase, and Kaplan (1998) conducted a longitudinal study in which preschool-aged children with language delays were followed into adolescence. A significant number of these children went on to have academic and learning difficulties, even after their language delays had apparently resolved.

Basis for the Coding Strategy Preference in SLI

Now that we have considered the potential consequences for children who are coding visually versus verbally, we will consider some of the reasons why we could expect children with SLI to rely more on visual rather than verbal coding strategies. Visual input may only yield a phonological code with additional active mental processing (Salame & Baddeley, 1982). From this perspective, then, the SLI children might be using visual coding because of the extra 'cost' in terms of processing resources associated with verbal coding for a poor language user. Faced with a semi-intensive task children with SLI may reserve their mental energy for the task itself. SLI children might prefer to rely primarily on visual coding because this is an area of relative strength, or because language is an area of relative weakness.

Limitations of Past Research

Overview

Thus far I have reviewed past research relevant to visual and verbal coding strategy use by children with language impairments. Caution must be used when interpreting this literature. First, the complexity of the research task involved in studying memory means that researchers have used a wide variety of tasks to study many different aspects of this construct. As a result, comparing the findings from different studies can be complicated and even misleading. An even greater challenge in evaluating the validity of the findings is that many memory studies present conceptual and methodological limitations. These limitations will be considered in the next section. The present study will then be introduced, along with the design and methodological aspects of this study that have attempted to address some of these limitations.

Inferring Underlying Processes from External Variables

In many of the memory studies reviewed earlier, a common assumption was that external variables such as modality of stimulus and response bore a direct relation to underlying processes. In Brown's (1977) study, for example, recall under conditions of visual similarity or auditory similarity of stimuli was used to infer mode of coding. While these kinds of assumptions are intuitively logical, it is also likely that underlying processes will vary between children, and for different tasks and materials. For example, if pictures are recalled better than words, this does not necessarily mean that the participants are using visual rather than verbal coding strategies to remember. It is also possible that they are coding the picture by its verbal label. Similarly, optimal recall of verbal information does not provide conclusive evidence for an individual's use of verbal coding strategies, as he or she may be forming a visual code based on the verbal information. As a result of these issues, interpretations of the findings in terms of the processes underlying task performance remains speculative.

Verbal Demands of Memory Tasks

Another issue of concern when evaluating studies of memory is whether there are 'hidden' verbal requirements, even on non-verbal tasks, which favor those with stronger language skills (Ceci, Ringstrom, & Lea, 1981; Johnston, 1988). These verbal requirements may disadvantage children with SLI either in learning or performing a task. For example, if participants are instructed verbally, the children with SLI receive instructions in a modality that is weak, and hence may not fully understand the task. Misunderstanding the instructions may affect performance differentially across conditions. So, performance differences might reflect a lack of understanding of the task rather differences in ability or use of underlying processes. In summary, performance differences between SLI and normal language children on memory tasks

may result from the stronger language skills of the latter group, rather than underlying differences in memory processes between the groups.

Control Groups

An additional factor to consider in evaluating studies of children with SLI is whether age-matched children should be the only control group against which the performance of language-delayed children is measured. This is an issue because when children with SLI are shown to have performance deficits relative to their age peers, it is possible that the differences reflect the SLI children's limited experience with language or their lower language level rather than their atypical language development per se (van der Lely & Howard, 1993). The inclusion of language-level matched control groups may allow more confident interpretations of the performance differences of SLI children relative to their age peers, in terms of processes that may underlie their delayed language development.

The Present Study

Review of Statement of Purpose and Outline of Experiment

The present study used a short-term memory task to examine visual and verbal coding processes in children with SLI and two groups of children with normal language development, one matched by age (AM) with the SLI group and one matched by vocabulary production level (LM). All participants performed a computerized, picture-matching task in which they briefly viewed a target picture and then selected the correct response from an array of three pictures consisting of two unrelated foils and the correct response item. The dependent variable was RT, measured from the time between the presentation of the choice array and the time at which the child pressed the button corresponding to his or her selection of the correct response.

There were three conditions, which were defined by the relationship between the target and correct response item. In the identity condition the target and correct response were identical; in the category condition the target and correct response were different members of the same basic level category (e.g., a men's dress shoe and a ladies' pump for the item 'shoe'); and, in the shape condition the target and correct response were visually similar (the target and match shared a similar visual outline, but the match was a 'shadow' shape lacking many of the internal details of the original object). The conditions were intended to differentially reward visual and verbal coding strategies. Analysis of the RT patterns across the three conditions should therefore indicate which sort of memory codes each child favored. Note also that each child's preferred coding strategy should be efficient in two out of the three conditions. Thus it was hoped that as trials continued neither coding strategy would be induced by the mere performance of the task.

Task analysis suggests that either visual or verbal coding strategies would be effective in the identity condition, because both can guide selection of the correct item in the response array. However, for the category condition, a visual code could not indicate the correct selection since the 'matching' item in the array is visually different from the original target. For example, a man's shoe does not visually resemble a woman's high-heeled dress shoe, although they are both "shoes". If a child is relying on a visual coding strategy, when confronted with a verbal match to the target the child must recode the visual representation verbally in order to select the correct response from the array. This extra step of recoding is expected to be reflected in longer RT's for visual coders on the category condition relative to the identity condition. A verbal code, on the other hand, could be effective on the category condition since it does not require physical resemblance. If it is true that verbal coding enhances performance on the category condition, then children who are using verbal processes should show a smaller RT difference between the identity and category condition than children who are using visual coding strategies, because the verbal coders should not need to engage in any recoding of their internal representation of the

target stimulus to select the correct response. A similar argument can be made for the shape condition, which was intended to favor visual coding. For verbal coders confronted with a visual match to the target (i.e., shape condition) an extra recoding step may be necessary to identify the correct response in the array resulting in a larger RT difference between the identity and shape trials than for those coding visually.

It was expected that absolute RT would vary between groups due to between group differences in speed of processing. Thus, the analysis of task performance will focus primarily on the pattern of RT across conditions for children in each group. That is, the main variable of interest with respect to determining the children's use of underlying coding strategies will be a within child analysis of pattern of RT across conditions. It is hoped that this comparison will then allow for a between group interpretation of the preferred coding strategies of the children in each group.

Addressing Limitations of Previous Studies

Overview

The task in the present study was modified from a dual-task paradigm study used to explore attentional processes in preschool-aged children (Riddell & Johnston, 1992). Many of the modifications to the task in its version in the present study were undertaken with the intention of eliminating some of the limitations mentioned previously with respect to past memory research. The discussion to follow will highlight some of these efforts.

Inferring Underlying Processes from External Variables

The present study attempted to address the issue of inferring underlying processes from explicit behavior or stimulus characteristics in several ways. All stimuli were pictures of common objects; all responses were inputted through a motor response. Holding modality of

stimulus and response constant across trials serves to reduce the number of external variables that could contribute to group differences in task performance. The present task also differed from many previous memory studies in that the dependent variable was RT, rather than a more commonly used measure such as accuracy of recall, or pattern of recall. It was assumed that all children would, in fact, be able to perform the task at high levels of accuracy. While accuracy was measured in this study, it served to indicate that the task was simple for all the children on all the conditions and that it placed a relatively low burden on the children's memory resources. Thus it was hoped that RT would serve as a measure of subtle differences in task performance which could be interpreted in terms of differences in underling coding strategies rather than any variables external to the child.

Verbal Demands of Memory Tasks

While the children in this study were instructed verbally, steps were taken to reduce any potential disadvantage for the SLI children as a result of being instructed in a modality in which they are weak. All the children received a demonstration of the task and several practice trials. And, since accuracy was not used as the primary dependent variable, an examination of rates of accuracy can indicate whether difficulties with understanding instructions contributed to differences in task performance: if there are significant differences in accuracy between groups or between conditions for the SLI group, this might indicate that these children did not adequately understand the task. However, if there are approximately equal error rates for the groups across conditions then this will likely indicate that the children understood the directions sufficiently.

It is also possible that hidden verbal requirements of a task can negatively influence the performance of SLI children relative to typically developing peers. This is not a problem in the present study as it is these hidden verbal requirements of the task that are the point of interest.

Whether or not the SLI children use visual or verbal coding strategies, they should still be able to perform the task efficiently half of the time so there is no advantage or disadvantage overall to choosing one coding strategy over another.

Control Groups

The primary purpose of this study was to examine memory coding strategies in children with language impairment (SLI group) relative to their age peers (AM group). A younger group of typically developing children matched on vocabulary production level (LM group) was also included to determine whether any differences in preferred coding strategy between the AM group and SLI group could be attributed to the more limited language experience of the SLI children or their atypical language development. Including both AM and LM control groups also permits an examination of developmental trends in use of coding strategies. Thus, having two variously matched control groups will allow for an analysis of group differences in task performance in terms of the children's age (younger versus older) and vocabulary level (higher versus lower), in addition to language status (typical versus atypical).

Research Questions and Hypotheses

Overview

The research questions to be explored in the present study were: (1) Do children with SLI rely less on verbal coding strategies than their typically developing age matched peers? (2) Is the coding strategy preference of children with language impairment similar to that of young, typically developing children matched by language level? (3) Are there developmental differences in coding strategy use between younger and older typically developing children? Two aspects of task performance were examined: (1) mean RT, for each condition and overall,

measured between groups; and (2) pattern of RT across conditions, measured within subjects and compared between groups.

Research Question 1: Are children with SLI less likely to use verbal coding strategies than their typically developing age peers?

It was hypothesized that children with SLI would be less likely to use verbal coding strategies than AM children. If children with SLI are relying primarily on visual rather than verbal coding strategies, they should show a pattern of larger differences in RT between the conditions that reward verbal coding and those that don't. Thus we would expect to see a larger difference in RT for the SLI children on the category condition compared to the identity or shape conditions, than for the typically developing children. If the AM children are using primarily verbal coding strategies, their pattern of responses should be different from the SLI children, with a larger difference in RT for the shape condition relative to the identity and category conditions than the SLI children.

Research Question 2: Is the coding strategy preference of SLI children similar to that of their LM peers?

Few studies of memory processes in children have utilized both AM and LM control groups. And, no studies specific to visual and verbal coding processes in SLI children have compared SLI children with both AM and LM control groups; thus, it was difficult to confidently predict the SLI children's performance relative to the LM children in the present study. In cognitive studies that have compared the performance of SLI with LM and AM control groups, SLI children often demonstrate task performance that falls in between that of AM children and younger, LM controls (e.g., Fazio, 1998; Kamhi, 1981; Terrell, Schwartz, Prelock, & Messick, 1984). Thus, one possible pattern of results for the present study is that the SLI children will

demonstrate performance at a level between that of their LM and AM peers. The SLI children should show smaller RT differences when RT on the category condition relative to the identity or shape conditions is examined, than the younger, LM children. And, they may have larger RT differences between these conditions than the AM children. This pattern of results could be interpreted to mean that children with SLI are less likely to code verbally than their AM peers, but more likely to do so than younger, LM children. In other studies (e.g., van der Lely, 1993), however, SLI children have been shown to perform comparably to their younger, LM peers. So, it is also possible that, in the present study, the SLI children might show a similar pattern of RT across conditions as their LM peers pointing to similar coding strategy use by these groups of children.

Research Question 3: Are there developmental differences in use of coding strategy in children with typical language development?

Based on the large body of previous research with typically developing children, it was expected that LM children would be less likely to use verbal coding strategies than AM children. If this is the case in the present study, the LM children should show a pattern of performance indicating larger RT differences between the category condition and the other two conditions relative to the AM children's pattern of RT's across conditions.

Summary

In the present study, the point of interest in task performance will lie in the pattern of RT's across conditions for each child in each group rather than absolute RT measures. It was predicted that each group of children would perform relatively faster on the conditions which rewarded their preferred coding strategy, and relatively slower on the conditions that did not. Thus the AM children were expected to show a pattern of relatively fast RTs on the identity and

category conditions, and slower RTs on the shape condition. These children should then have a smaller RT difference between the identity and category conditions than the SLI children. For the SLI children, it was thought that the relatively faster RTs would be seen on the identity and shape conditions, and slower on the category condition resulting in a larger RT difference between category and the identity or shape conditions. Finally, the LM group were expected to obtain relatively longer RT's on the category condition than the AM group, and be either similar to the SLI group in pattern of performance or show a larger RT difference between the category condition relative to the shape and identity conditions.

CHAPTER 2: METHOD

Overview of Design

This study was intended to explore the relationship between children's language ability and their use of visual versus verbal coding strategies to remember pictures. Children performed a short-term memory task in which they briefly viewed a target picture, then selected its match (correct response item) from an array of three choices presented after a fixed interval. The conditions varied in the relationship between the target and correct response item. The target and correct response were either identical (identity condition), basic level category matches (category condition), or visual matches (shape condition). It was hypothesized that children with SLI would rely less on verbal coding to perform the task than same age children with age-appropriate language skills. It was also expected that there might be differences in coding strategy use between children with SLI and younger, language-matched peers.

Participants

Grouping Procedures

Participants in this study were 39 children in three groups of 13 each. The experimental group consisted of children with SLI, between the ages of 63 months (5;3) and 90 months (7;6). Appendix A details age and assessment data for all children participating in the study. The two control groups consisted of one group matched by chronological age (AM) with the SLI group and one group matched by vocabulary production level (LM).

The children participated in assessments of language, hearing, and nonverbal intelligence to determine inclusion into, and matching between, the groups. These assessments took place over one, two, or three sessions, depending on the attention and motivation level of the child and the scheduling needs of the parent, teacher, or daycare staff. Each child completed four subtests

of the *Test of Language Development, Primary, 3rd Ed.* (TOLD-P:3; Newcomer & Hammill, 1997), Relational Vocabulary (RV), Grammatic Completion (GC), Grammatic Understanding (GU), and Sentence Imitation (SI). The TOLD-P:3 was selected as the language assessment tool for this project because it provides normative data for children ages four and older, and was therefore appropriate for even the youngest participants. The four subtests used were selected because they are designed to measure different aspects of language development and thus should provide an overall picture of the children's language abilities in different domains of language. The entire assessment was not administered in order to limit the amount of time the school-aged children were removed from their classrooms.

The *Expressive One Word Picture Vocabulary Test, 2000 Edition* (EOWPVT; Gardner, 2000) was used to match children in the SLI and LM groups because this assessment provides normative data for vocabulary production over the age-span of the children in the study. A vocabulary production measure was selected rather than a comprehension measure because many children with SLI show deficits that are limited to language production. In addition, groups defined on the basis of vocabulary production might also differ in use of visual and verbal coding strategies and thus demonstrate performance differences on the experimental task.

Children with SLI

The children with SLI were recruited from the public school system upon referral by their school speech-language pathologists. All were receiving services, either on a direct or consultative basis, for a diagnosed speech and language delay. The speech-language pathologists were asked to forward consent forms to students on their caseloads who fit the criteria for participation in this study. Out of 18 consent forms distributed, 16 were returned consenting to participation in the study. Fourteen of the returned consent forms were from families of children

who met the criteria for inclusion in the study. One child was unable to complete the experimental task and was subsequently dropped from the study, leaving a total of 13 SLI children. For the children with SLI inclusion criteria were:

- standard scores of at least 1 *SD* below the mean (scores of seven or below) on a minimum of two of four subtests of the TOLD-P:3
- standard scores within +/- 1 *SD* from the mean on the *Columbia Mental Maturity Scale, Revised* (CMMS; Burgemeister, Blum, & Lorge, 1972), a nonverbal test of cognitive ability
- English as a first language

Criteria for exclusion were:

- a history of neurological involvement as reported to the school speech-language pathologists in case history information
- a diagnosis of autism, pervasive developmental disorder, or any other known syndrome associated with delayed language or cognitive skills
- hearing impairment

The children in the SLI group were four girls and nine boys, ranging in age from 63 months (5;3) to 90 months (7;6), with a mean age of 76 months (6;4). Table 1 provides individual test and subtest scores for the children in the SLI group, and group means and standard deviations for the children in all groups are detailed in Table 2. As can be seen, five children scored below average on two of the TOLD subtests, five children scored below average on three subtests, and three children scored below average on all four subtests. Note also that four children had a comprehension component to their language delay, as indicated by below average performance on the GU subtest. The other nine children had delays only in language

production. The mean EOWPVT age equivalent score for the SLI group was 59 months, indicating a mean delay of 17 months relative to the mean age of the children in this group.

Control Group Participants

Overview

Control group participants were recruited from public schools (7 children) or daycare centers (14 children), or were children of friends of the experimenter (5 children). For the children recruited through schools and daycare centers, 138 consent forms were distributed. Daycare and school staff were asked to distribute consent forms to families of children who spoke English as a first language, were not currently receiving speech and language services, and were between the ages of 4;0 and 7;6. Of these, 64 consent forms were returned by families consenting to their child's participation in the study, 3 were returned refusing consent to participate, and 71 were not returned.

AM Group

Potential AM group participants were selected out of the pool of children for whom consent to participate was received, if they were a chronological age match within +/- four months of the age of an SLI child. Once a potential age-matched participant was identified, the child participated in a series of assessments to determine whether he or she met the inclusion criteria for the group. Inclusion criteria for the AM group were as follows:

- standard scores within +/- 1 *SD* from the mean (8 to 12) on at least three of four subtests of the TOLD-P:3

Table 1

Language, Vocabulary, and Non-verbal Intelligence Standard Scores for Children with Specific Language Impairment

Child	EOW (SS)	CMMS (ADS)	TOLD (SS)			
			RV	GU	GC	SI
AC	83	87	6	10	6	6
MB	83	92	6	9	6	8
JW	75	94	5	5	5	1
JZ	99	110	6	10	11	6
EP	86	94	6	10	10	7
AW	73	104	6	8	9	7
RM	90	104	6	8	2	1
GP	84	95	7	10	6	7
JP	93	87	6	9	5	4
TE	89	98	6	11	10	6
TF	85	109	5	4	6	4
PC	89	91	3	7	6	4
JD	77	95	2	5	8	3
M	85	97	5	8	7	5

EOW Expressive One-Word Picture Vocabulary Test – 2000 Edition, Standard Score

CMMS Columbia Mental Maturity Scale, Revised, Age Deviation Score

TOLD-P:3 Test of Language Development – Primary, 3rd Edition, Standard Subscale Score

Subtests:

RV Relational Vocabulary

GU Grammatic Understanding

GC Grammatic Completion

SI Sentence Imitation

Table 2

Language, Vocabulary, and Non-verbal Intelligence Group Mean Standard Scores and Standard Deviations

	EOW (SS)		CMMS (ADS)		TOLD (SS)							
					RV		GU		GC		SI	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
SLI	85	7.3	97	7.6	5	1.4	8	2.3	7	2.5	5	2.3
AM	104	7.3	111	7.8	10	2.5	11	2.1	11	1.6	11	2.3
LM	100	2.6	104	7.5	9	1.4	11	1.4	11	1.7	10	1.5

SLI Group	Children with specific language impairment
AM Group	Typically developing children matched by chronological age with SLI group
LM Group	Typically developing children matched by productive vocabulary with SLI group
EOW	Expressive One-Word Picture Vocabulary Test – 2000 Edition, Standard Score
CMMS	Columbia Mental Maturity Scale, Revised, Age Deviation Score
TOLD-P:3	Test of Language Development – Primary, 3rd Edition, Standard Subscale Score
RV	Relational Vocabulary
GU	Grammatic Understanding
GC	Grammatic Completion
SI	Sentence Imitation

- no history of speech and language delay (this requirement was stated in an introductory letter distributed to the family with the consent form and relied on self-disclosure)
- non-verbal intelligence within +/- 1 *SD* from the mean (84 to 116) on the CMMS
- vocabulary production scores within of +/- 1 *SD* (85 to 115) on the EOWPVT
- English as a first language

Children in the AM group ranged in age from 61 months (5;1) to 90 months (7;6), with a mean age of 77 months (6;5), and included six girls and seven boys. Due to a shortage of children who met the participation criteria initially set with respect to CMMS score, four children with scores in the above average range on this test (age deviation scores of 118, 118, 119, and 123) were included in this group.

LM Group

The LM control group children were matched with SLI children by vocabulary production level. Potential LM participants were initially assessed using the EOWPVT. Those whose age equivalent vocabulary production score matched their chronological age within +/- four months were selected for further assessment to determine whether they met the remaining inclusion criteria for the group. If all inclusion criteria were met and the LM child's age equivalent EOWPVT score matched the age equivalent score EOWPVT score within +/- four months of an SLI child, the LM child was chosen to participate in the experimental task. Inclusion criteria were as follows:

- standard scores within +/- 1 *SD* on at least three of four subtests of the TOLD-P:3
- EOWPVT standard scores between 94 and 106, reflecting an age equivalent score within +/- four months of the child's chronological age

- age deviation scores within +/- *SD* (84 to 116) on the CMMS
- English as a first language

Children in the LM group ranged in age from 52 months (4;2) to 75 months (6;3), with a mean age of 60 months (5;0), and were four girls and nine boys. One child was not able to complete the RV subtest, but scored in the average range on all other subtests and measures. One child scored in the above average range on the CMMS, receiving an age deviation score of 118.

Outcomes for Group Defining and Matching Variables

Each SLI child was matched with an AM child by chronological age within +/- four months. Matching between the SLI and LM children was done on the basis of EOWPVT raw scores, intended to match the children by absolute vocabulary knowledge. Table 3 details the mean group values for age and EOWPVT raw score on which the SLI and control groups were matched. As can be seen, a close match was achieved between the SLI and control groups on both of these measures.

It was also expected that the SLI group would be different from both the AM and LM groups on standard scores of language and, possibly, vocabulary production, but that the two groups of typically developing children would not differ significantly from one another on these measures. A one-way ANOVA procedure was used to determine whether the intended group differences had been achieved and whether these differences were significant. As can be seen in Table 2, the intended group differences on the language measures were achieved. Post hoc tests (Scheffe, $p < .05$) indicated that, for standard scores on the EOWPVT, group differences were

Table 3

Means and Standard Deviations for Measures on which Experimental and Control Groups were Matched: Age and Vocabulary Production

Group	Age (months)		EOW (Raw Score)	
	M	*SD*	*M*	*SD*
SLI	75.7	6.8	58.8	8.2
AM	76.6	7.5	83.2	11.0
LM	59.9	8.3	59.0	14.7

SLI Group Children with specific language impairment

AM Group Typically developing children matched by chronological age with SLI group

LM Group Typically developing children matched by productive vocabulary with SLI group

EOW Expressive One-Word Picture Vocabulary Test – 2000 Edition

significant for the SLI and AM groups, and for the SLI and LM groups. The difference in standard scores for the EOWPVT between the two control groups was not significant. As for the TOLD-P:3 subtest scores, post hoc tests (Scheffe, $p < .05$) indicated that there were significant differences between the SLI and AM groups on RV, GC, GU, and SI. Significant differences (Scheffe, $p < .05$) were also found between the SLI and LM groups on all four subtests of the TOLD-P:3. And, while it was intended that there would be no group differences on CMMS age deviation score, a one-way ANOVA was conducted and a main effect was found for Group, Rao R (10, 62) = 7.37; $p < .01$. Post hoc tests (Scheffe, $p < .05$) indicated that the difference in CMMS age deviation score for the SLI and AM groups was significant. No significant differences were found between the SLI and LM groups or the AM and LM groups on CMMS age deviation score.

Stimuli

Word List Development

Description of Stimuli

The stimuli used in this experiment were line drawings of 32 common objects, 8 from each of four categories: animals (cow, duck, frog, lion, pig, rabbit, sheep, squirrel), food (apple, banana, bread, cake, carrot, corn, pear, sandwich), clothing (belt, boot, dress, glove, hat, pants, shoe, sock), and vehicles (airplane, bike, boat, bus, tractor, train, truck, wagon). The pictures selected were controlled and matched on the basis of the following measures of the stimulus label: spoken and written frequency, and objective and subjective measures of age of acquisition (AOA). Appendix B provides detailed data on these measures for the 32 object labels used in this study. While there is diversity in findings from studies of the effect of these factors on naming and recall, each has been shown to influence performance in naming studies (Barry,

Morrison, & Ellis, 1997; Ellis & Morrison, 1998), and recognition and recall studies (Dewhurst, Hitch, & Barry, 1998; Walley & Metsala, 1992). These word-selection criteria were used even though the children were not asked to name the pictures. It was assumed that some of the children would be using overt or covert naming to complete the task and thus stimulus label characteristics that influence RT in naming studies could similarly impact the results of the present study.

Stimulus Parameters

Word frequency. Word frequency has been shown to influence performance in naming studies (Barry et al., 1997). Low frequency words take longer to name and very high frequency words show different naming patterns than medium and low frequency words. One explanation for this pattern is that the frequency with which these words are accessed makes their retrieval more automatic reducing the time required to retrieve the name. The stimuli in this study were chosen based on objective measures of spoken frequency of 494 kindergarten children (Kolson, 1961) and written word frequency, overall, and for a grade one corpus (Zeno, Ivens, Millard, & Duvvuri, 1995).

In terms of spoken frequency of the picture labels, the intent was to select those objects whose labels were neither very high nor very low in frequency. Out of approximately 7500 different words produced by the children in the Kolson (1960) study, approximately 3700 were produced more than seven times out of a total of approximately 99,000 tokens. In order to avoid both the very high frequency and low frequency words, the objects selected for this study had labels which were produced between 9 and 600 times in the Kolson study corpus.

Written word frequency variables for a large set of words are provided by Zeno et al. (1995). For the purposes of the present study the Standard Frequency Index (SFI), a logarithmic

transformation of the raw frequency figures was used as the measure of written frequency of the picture label. Labels of the stimuli used in this study all had SFI values between 43.7 and 60.0, again serving to eliminate the very high frequency words (over 60.0) and low frequency words (below 40.0).

Zeno et al. (1995) also provide written word frequency values in terms of a U value, which is an index of frequency expressed as n per million for each grade level corpus. As some words have much different frequencies in adults and children (e.g., "kitty" is a high frequency word in children but a very low frequency word for adults), these values served to provide frequency values specific to young children. All of the object names in this study except one ('pear') registered a U value of 1 or greater, with the remainder falling between 50 and 450. These data confirm that the labels of the pictures selected for the task are likely to be familiar and accessible to children of the ages of those in the present study.

Age of acquisition. Objective and subjective measures of AOA have also been found to be related to performance in naming studies. Ellis and Morrison (1997) found that objective AOA strongly predicts adult object-naming speed. Earlier AOA corresponds to faster naming times. Controlling for AOA of the object labels in the present study was also important to ensure that the verbal labels of the objects were available to the children. In controlling for this variable, if the children are shown to use visual coding strategies it is not simply because they have not yet learned the word to describe the picture. Morrison, Chappell, and Ellis (1997) provide a list of words with objective AOA ratings which represent the age at which 75% of children have acquired each word. The youngest child participating in this study was four years old and the SLI children all obtained vocabulary production age equivalent scores of at least four years old. Therefore, for the stimuli in this study, all the pictures selected for this study had labels which, according to Morrison et al., are generally acquired by 48 months of age.

Subjective measures of AOA have also been shown to be related to performance on picture naming studies (Walley & Metsala, 1992). Estimates of AOA by 5-year-old children have been shown to correlate closely with estimates made by older children and adults, and both children's and adult's estimates of AOA have been found to predict children's accuracy on a picture naming task. Walley and Metsala found that young children's performance on a picture recognition task varied systematically with the AOA estimates, in that pictures whose labels had lower AOA's were more often recognized. Thus all pictures used in this study had labels with a subjective AOA of between 16 and 55 months. Items with very early AOA's (generally very high frequency words) were not selected for use in this study nor were those words that had late AOA's.

Picture Development

Description of Stimuli

Overview. The stimulus items were constructed from three sets of pictures of the 32 objects listed in the previous section. The first two sets were line drawings of the objects and the third set was a visually altered version of Set 1.

Set 1 pictures. Set 1 pictures were from the Snodgrass & Vanderwart pictures (1980). These pictures were all line drawings of common objects that have been frequently utilized in psycholinguistic studies. This set of pictures served as the source for this study primarily because they were systematically selected and developed, and also because many relevant measures are available for the pictures and their stimulus labels, including those discussed in the previous section. The Snodgrass and Vanderwart set includes only concepts that are unambiguously picturable, are exemplars of common categories, and represent concepts at the basic level of categorization. The pictures were also drawn with several specific guidelines

including amount of detail, correctness (whether or not they were realistic), typicality of the representation of a concept, orientation, and subjective size within categories.

Set 2 pictures. The second set of line drawings were different members of each of the basic level categories represented by the Set 1 objects (e.g., the 'shoe' in Set 1 is a man's dress shoe, while the shoe in Set 2 is a woman's pump). Set 2 pictures were drawn relying as much as possible on the same principles as those used in developing the Snodgrass and Vanderwart set with respect to correctness, amount of detail, and subjective size. One difference, however, was that orientation was manipulated between Set 1 and 2 in order to increase the visual differences between the two pictures (e.g., the cow in Set 1 is pictured in profile whereas the cow in Set 2 is facing forward).

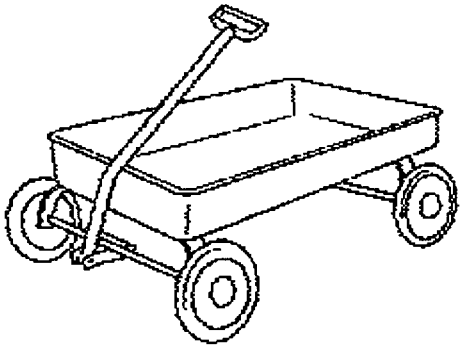
Set 3 pictures. Set 3 pictures were modified from the Set 1 pictures. The development of this set of pictures proceeded as follows: first, all internal details of the picture were removed and the interior was shaded in; then, the outline of the object was smoothed through elimination of small details. The intent of these modifications was to make the Set 3 pictures unrecognizable when presented alone, while still allowing them to be a visual match for the Set 1 pictures. Figure 1 provides examples of Set 1, 2, and 3 pictures.

The success of the Set 3 manipulations were measured by asking 12 adults to name the pictures. Approximately half of the pictures were not immediately recognizable as their intended object while the other half remained identifiable. For the items on which errors were made there were generally two patterns of errors. In some cases the individuals could not name the picture or guess the identity of the object it was representing. In other cases, though, the adults were able to identify the picture after being given a category cue (e.g., "It's something you eat.", "It's a vehicle." etc.). Or, the picture was identified as an object in the same category as the item but

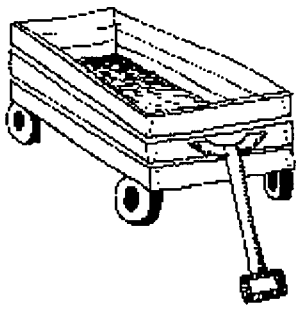
Figure 1

Examples of Set 1, 2, and 3 Pictures for "wagon"

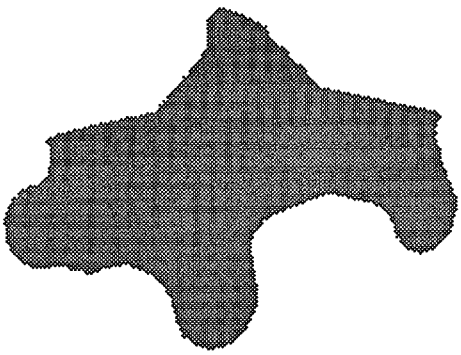
Set 1



Set 2



Set 3



the incorrect basic level item was chosen (e.g., they knew that it was an animal but identified a 'cow' incorrectly as a 'dog').

Eight children who did not participate in the present study were also asked to identify the Set 3 pictures. Results indicated that approximately 40% of the pictures were identifiable for the children. For pictures that were identified incorrectly or not at all, semantic or category cues were useful approximately 30% of the time in allowing the children to identify the pictured item. These data indicate that the manipulations of the Set 3 were partially successful in reducing the recognizability of the pictured objects.

Design and Presentation

Overview of Experiment

In the experimental task, children participated in a computerized, picture-matching task using the Set 1, 2, and 3 pictures.[1] The experimental task was administered in a single, uninterrupted session for all the children. Participants briefly viewed a single Set 1 picture (target), followed by a short interval, after which they were presented with an array of three pictures (choices) and were asked to find the match (correct response) to the one they saw before. The choice array consisted of a linear presentation of three pictures, one of which was the correct response item and two of which were foils selected from different categories than the target. There were 32 trials in each of three conditions for a total of 96 trials, so each child participated in these 96 trials in addition to either three or six practice trials. The conditions varied in the relationship of the correct response picture to the target. In the identity condition, the target and the correct response were identical items (e.g., the exact same picture of a shoe); in the category condition, the target and its match were different members of the same basic level

[1] The children also participated in a second task which will not be discussed here. It was presented after the task described in this paper for all subjects and as such had no effect on performance on the first task.

class (e.g., a men's dress shoe and a women's pump); and, in the shape condition the correct response was a 'shadow' of the target (e.g., a shoe and a visually simplified version of the same shoe). Presentation order of the 96 trials was fixed for all subjects. Appendix C provides details for the final version of the task, with target, choice array, and trial type specified for each of the 96 trials.

Experimental Design

The task was designed to ensure a balanced distribution of the 32 items and the four categories across the 96 trials: (1) by role (i.e., as target, correct response, and foil); (2) by position in the choice array (i.e., left, middle, or right); and (3) by combinations within array.

Each of the Set 1 pictures was presented as the target three times, once in each condition (i.e., once with a match from picture Set 1, once with a match from picture Set 2, and once with a match from picture Set 3). This yielded 96 trials divided evenly between the four categories of animals, foods, vehicles, and clothing items. Moreover, for each category there were eight identity trials, eight category trials, and eight shape trials.

To aid in randomization and balancing, the targets for each of the 96 (32 x 3) trials were listed in alphabetical order within category (e.g., cow1, cow2, cow3, duck1, duck2, duck3, etc.), with categories ordered as follows: animals, vehicles, food, and clothing. Positions (Right, Middle, and Left) for the correct responses in the choice array were then assigned using a Latin Square rotation scheme across targets (e.g., cow1R, cow2M, cow3L, duck1M, duck2L, duck3R, etc.). The outcome of this was that in each category and across all trials, the correct responses appeared as equally as possible in each position in the choice array.

Foil pictures for the identity and category conditions came from the Set 1 drawings and differed both from the correct response item and from each other in category. Pairing again

made use of alphabetization and Latin Square rotation schemes similar to the one described above, yielding items in which members of every category appeared with members of every other category with approximately equal frequency. Foil pictures for the shape condition came from the Set 3 pictures but in all other respects the design of items in this condition was as described for the identity and category conditions.

Once the 96 choice arrays had been designed they were randomized with the following constraints:

- no more than two consecutive trials of the same condition
- no more than two consecutive trials with the target in the same category
- no more than two consecutive trials in which the correct response occupied the same position in the choice array

A two-way mixed model design was used with Group (3) treated between children and Condition (3) treated within child. RT was the dependent variable and independent variables were condition and group. The use of AM and LM control groups allowed for a comparison of task performance by age (younger/older), language level (lower/higher), and language status (typical/atypical).

Experimental Procedures

Setting and Apparatus

Each participant was seated at a table facing a computer monitor and a response box, approximately 50 cm from the viewing screen. The experimenter was seated directly beside the participant with the response box and the monitor clearly visible.

In order to determine handedness, before beginning the task each participant was asked to draw either a circle (for the younger children) or his or her name (for older children).

Participants were then instructed to use their dominant hand to perform the task and to keep their non-dominant hand in their lap. A template was fixed to the table in front of the child to show hand position between each trial.

The experimental task was administered on a Hewlett Packard Pavilion Notebook computer running E-Studio Beta Version 5.0 software (Psychology Software Tools, Inc., 2000). The display was a17-inch flat-face Samsung SyncMaster 753DF color monitor. The children's responses were inputted using a custom-designed button box with three differently colored buttons (red, blue, and yellow) positioned in a linear array, approximately 7 cm from one another.

Selection of Timing Parameters

The children viewed a computer screen with a single target picture which was presented for 500 msec. The choice array was presented after a 750 msec interval and remained visible until the child pressed a button to indicate a response. RT was measured from the time of presentation of the choice array until the child pressed the button to indicate his or her selection of the correct response. The experimenter initiated the next trial when the child appeared to be attending to the computer screen.

The timing parameters used were selected based on a limited number of relevant studies in the literature. Riddle and Johnston (1992) conducted a study with 3- to 5-year-old children using a similar task paradigm as the primary task in a dual task study. In their study, the target stimulus was presented for 2000 msec with a 1000 msec delay prior to presentation of the decision slide (choices). Accuracy levels of 87% and above for all children in the study indicate that these timing values are sufficient for even very young children to perform this type of task.

In another study, DiLollo, Hanson, and McIntyre (1983) examined visual processing in 8- to 14-year-old children with dyslexia and a group of age-matched, normal control participants. The children were presented with a computerized task in which visual information (an alphabetic letter) was presented for 1 msec. After an interval of 1 sec, a probe was presented on the screen. The task was to press a button to indicate whether the probe and the test stimulus were the same or different. Results indicated that even very brief presentations allow children to process visual information about alphabetic letters.

In another relevant study, Yuille and Ternes (1975) looked at visual and verbal coding by adults. In one of the experiments in this study, participants performed a recall task in which three words were presented consecutively for 5/16 of a second each (approximately 312.5 msec). The stimulus items were one- and two-syllable concrete nouns, with high frequency ratings. Recall was errorless for all participants when they were tested with immediate recall. This suggests that even a very short presentation time allows sufficient time for adults to process information about written words.

Doty and Savakis (1997) conducted a study in which adult participants performed a continuous visual recognition task with words or pictures. The stimuli were displayed for either 2 sec or 200 msec, at intervals of 5 sec. The participants were required to press a button to indicate whether the stimulus was new, not previously presented in the list, or old, previously presented in the same. While there were differences in accuracy of response between the two timing conditions and the two stimulus conditions (words versus images), the finding that is methodologically relevant to the present study is that even with very short stimulus presentations, participants were able to process information about both words and pictures.

While these studies reflect widely disparate subject populations, tasks, and purposes, they do provide general guidelines from which to determine timing parameters for the present study.

Across these studies, presentation durations as short as 1 msec and as long as 2 seconds were used. For the purposes of the present study, though, it was necessary to take into account the young ages of the participants. The goal in selecting timing parameters was to ensure that the task was simple enough for children between the ages of four and seven years old, but challenging enough to allow for variance in task performance. Also, it was hoped that the timing parameters selected would not predispose children to either visual or verbal coding strategies. Very short presentation values, for example, might result in reduced accuracy rates for young children. Longer presentation rates, on the other hand, might predispose the children to verbal coding if enough time were allowed for verbal rehearsal.

A total of 12 children, ages four to seven, participated as pilot subjects. Four different timing parameters were selected for piloting in which the length of target presentation and interval were varied as follows: 750 msec/1000 msec, 500 msec/750 msec, 500 msec/500 msec, and 750 msec/500 msec. These values were thought to be long enough to ensure that the children would see the target easily, but not so long as to encourage verbal rehearsal. No significant differences were found for the children's task performance at these different timing values.

The experimenter and two adult judges also performed the task and ruled out 750 msec/1000 msec as too long (possibly allowing time for verbal rehearsal) and 500 msec/500 msec as too short for the youngest children in the study. Out of the remaining two possibilities, the 500 msec/750 msec was selected rather than the 750 msec/500 msec as it was thought that the shorter target display time would add a challenging component to a relatively simple task. Admittedly, the lack of directly related studies on which to base the timing parameters used in this study meant that the selection of values relied, in large part, on intuitive judgments of their

appropriateness. Thus, timing parameters will remain an area open to further refinement for those who go on to utilize this paradigm in future research.

Experimental Task

Prior to beginning the experimental task, all children were instructed as follows (information in parentheses indicates gestures accompanying verbal instructions):

> We're going to play a game on my computer. It's a matching game. You're going to see a picture at the top of the screen up here (point). I want you to remember that picture. Then it's going to disappear. You will see three more pictures, one here (point), one here (point), and one here (point) and I want you to pick the one that matches the one you saw before. If you think the first picture is the best match, you push the first button (subject is directed, in a hand-over-hand fashion to push the left-most button). If you think the middle picture is the best match you push the middle button (subject is directed in hand-over-hand fashion to push the middle button). And if you think the last picture is the best match, which button would you push? (if the children did not indicate the right-most button at this point, they were prompted to do so).

Following the directions each child was presented with three practice trials. The length of stimulus presentation in the practice trials was increased to a 1200 msec target presentation and a 1000 msec interval before the presentation of the choices. Increasing the length of presentation and interval is a training procedure that has been used in RT studies of children's visual processing abilities (D. Giaschi, personal communication, February, 2001). If the child responded correctly on two out of three practice trials then the experimental trials began immediately. If the child responded incorrectly on two or three of the practice trials he or she

was instructed again then presented with the same three practice trials before beginning the experimental task, after which the experimental trials began immediately regardless of the accuracy of the child's responses on the second set of practice trials. Three of the children in the SLI group and two children in the LM group required extra training. All the children in the AM group began the experimental task after one practice set. It was hoped that the longer timing values for the practice trials would not predispose children to verbal rehearsal and thus verbal coding. During the practice trials, most of the children appeared to be focused on learning the task, and none were observed to spontaneously label the target picture.

All experimental data were collected by the experimenter or by a research assistant who was a graduate student in speech-language pathology. All assessments for the two groups of typically developing children were administered by the experimenter and the research assistant. Some of the SLI children, however, had recently participated in speech and language assessments in their schools. For these children test scores supplied by their school speech-language pathologists were used if the assessments had been done within four months of the child's date of participation in the present study, as reassessment on identical measures could have resulted in inflated scores.

Each child was told that the experimenter was interested in learning about how children remember things, then asked whether he or she would like to look at some pictures and play a game. Upon consenting to participation, each child was taken to a quiet room in his or her school or daycare center for testing. One child with SLI was seen at a Health Unit Speech Clinic at the request of her parents. All the children were seen individually over two to four sessions of approximately one half hour each. The length and timing of the sessions depended on various factors including the attention and motivation level of the child and the scheduling needs of the

teacher, daycare staff, or family. The experimental task took the children between 5 and 15 minutes and was always administered in a single, uninterrupted session.

Preparation of Data

The dependent variable in this study, RT, was measured from the time between presentation of the choice array and the time at which the child pressed a button to select the correct response. Prior to calculating mean RT's, trials on which the children responded incorrectly were removed. Table 4 details mean group values and percentages of data removed due to errors and outliers. From the total possible number of trials for the 39 participants approximately 8% were removed due to errors. The AM group showed the lowest number of errors , followed in turn by the SLI group and the LM group. Included in the accuracy measure were 'skipped trials', trials in which the child missed the presentation of the target. In these cases, the experimenter pressed an incorrect button to conclude that trial and then initiated the next trial.[2] As can be seen in Table 5, the LM group had the lowest accuracy rate, followed in turn by the SLI group and the AM group. The high accuracy rates for all groups across the three conditions suggest that all children adequately understood the task and that the task placed a relatively low burden on memory.

Outliers were then removed from the data using a classic box and whisker plot procedure (StatSoft Inc., 1995). First, mean RT was calculated for each child on accurate trials, for each condition, then mean group RTs on the three conditions were calculated. The RT values corresponding to the 25th and 75th percentile values for each group for each condition were calculated and outliers were identified for each group on each condition according to the following two formulae:

[2] Skipping missed trials served to reduce task administration time and thus helped to maintain the children's attention to the task.

RT values > 75th %ile + 1.5 (75th %ile RT value – 25th %ile RT value)

RT values < 25th %ile RT value – 1.5 (75th %ile RT value – 25th %ile RT value).

As detailed in Table 4, the SLI group had the fewest data points removed as outliers and the LM children the most outlier values removed. Mean RTs for each child in each condition were then calculated on the remaining RT values and then group means were calculated based on these data. For all groups combined, approximately 14 % of the data was removed due to errors and outliers.

Table 4

Reaction Time Data Removed from Data Analysis for Language Impaired Children and Two Matched Control Groups

	Errors			Outliers			Range in Accuracy (/96)		
Group	No.	Total # of trials	%	No.	Total # of trials	%	Min n	Max n	% Data Removed
SLI	92	1248	7.4	68	1248	5.4	66	91	12.8
AM	56	1248	4.5	80	1248	6.4	66	95	10.9
LM	142	1248	11.4	84	1248	6.7	61	95	18.1
All	290	3744	7.7	232	3744	6.2	-	-	13.9

SLI Group Children with specific language impairment

AM Group Typically developing children matched by chronological age with SLI group

LM Group Typically developing children matched by vocabulary production level with SLI group

Table 5

Accuracy Data for Language Impaired Children and Two Matched Control Groups

	Condition								
	Mean Number and % Correct out of 32 trials						*SD*		
Group	Identity		Category		Shape		Identity	Category	Shape
	No.	%	No.	%	No.	%			
SLI	30.6	95.6	29.9	93.4	28.4	88.8	1.6	1.3	3.7
AM	30.5	95.3	30.2	94.3	31.0	96.9	1.7	2.0	1.0
LM	27.9	87.2	28.8	90.0	28.4	88.8	2.7	2.4	2.5
All Groups	29.7	92.8	29.6	92.5	29.3	91.6	2.4	2.0	2.9

SLI Group Children with specific language impairment

AM Group Typically developing children matched by age with SLI group

LM Group Typically developing children matched by vocabulary with SLI group

CHAPTER THREE: RESULTS

Overview

The research questions to be explored in the present study were: (1) Do children with SLI rely less on verbal coding strategies than their typically developing age matched peers? (2) Is the coding strategy preference of SLI children similar to that of younger, typically developing children matched by language level? (3) Are there developmental differences in coding strategy between younger and older typically developing children? It was hypothesized that children with SLI would be less likely to use verbal coding strategies than their typically developing age peers. If so, the children with SLI could be expected to show a pattern of performance indicating longer RT's on conditions where the correct choice item and the target were categorically related relative to conditions on which the target and correct response were similar in visual characteristics. If children with typical language development are coding verbally, on the other hand, they should not show this pattern of RT. Verbal coders would be expected to show a smaller RT difference between the category condition relative to the identity or shape conditions. Two sets of analyses were conducted to explore these questions and possible explanations for the performance patterns of the children.

Results of Analyses

Main Effect for Group

The primary analyses looked at whether SLI children were more likely than their normal language peers to use visual coding strategies. A two-way mixed model ANOVA was conducted with Group (3) treated between children and Condition (3) treated within child. The dependent variable was RT, as measured from the time the response array was displayed to the time the child pressed the button corresponding to the selected item. Table 6 summarizes the mean RTs

and standard deviations for each group in each condition. As expected, there was a significant main effect for Group, $F(2, 36) = 11.29$; $p < .01$. The AM group showed the shortest RTs on all conditions, followed by the SLI group, with the LM group responding the most slowly. This pattern was as expected based on prior cognitive studies in which language delayed children have been found to perform better than control groups matched by language level, but more poorly than control groups matched by age (e.g., Fazio, 1994; Kamhi, 1981; Terrel, 1984). Post hoc tests (Fisher LSD, $p < .05$), indicated the RT differences between the SLI children and the AM children were significant. There were also significant differences between the RT's of the AM group and the LM group (Fisher LSD, $p < .05$). The difference in RT between the SLI and LM children was not found to be significant.

Main Effect for Condition

A significant main effect was also found for condition across all groups, $F(2, 72) = 140.79$; $p < .01$. As can be seen in Table 6, mean RT was fastest in the identity condition, followed by the category condition, with the slowest mean RT's overall on the shape condition. Post hoc tests (Fisher LSD, $p < .05$) were conducted and indicated that the difference in RTs between the identity and category condition was significant. The difference in RTs between the identity and shape condition was also significant (Fisher LSD, $p < .05$). This pattern suggests that the category condition and the shape condition were more difficult for all the children than the identity condition. However, RTs on the category and shape conditions were not significantly different. The similarity of RTs on the category and shape conditions suggests that whatever coding strategies were being used had the same consequences for these two conditions.

Group by Condition Interaction

The main hypothesis for this study, i.e., that the SLI group would be less likely to use verbal memory coding strategies, was directly tested by the interaction term of the ANOVA. As predicted, there was a significant interaction between Group and Condition, $F(4, 72) = 6.09; p < .01$. Table 6 summarizes means and standard deviations for each group in each condition, and the entire pattern of responses is pictured in Figure 2. As can be seen, each group showed longer RTs in the category condition than in the identity condition. However, the SLI group showed the greatest differential between these conditions. This is highlighted in Figure 2 in the slope of the line between the identity and category conditions. The AM group show the smallest RT difference between these conditions (304 msec), followed by the LM group (432 msec). The SLI group showed the largest difference between the two conditions (515 msec) and, hence, the steepest slope. The reliability of these group differences was tested using planned comparisons. The SLI group differed significantly from the AM group, $F(1, 3) = 7.74, p < .05$, but not from the LM group, in the degree of disparity between the identity and category conditions. There were also no significant differences between the two normally developing groups in this pattern. Assuming that the category condition favors verbal coding, this pattern of findings suggests that the SLI children were less likely to use verbal coding strategies to remember information than the typically developing AM children.

In order to determine whether the findings for the interaction between group and condition were related to the group differences in non-verbal intelligence scores, the analysis was also done using CMMS age deviation score as a covariate. The relative performance patterns of the groups remained essentially unchanged from the original ANOVA. Also, the analysis was conducted after eliminating the data from those children in each group whose non-verbal

Table 6

Mean Reaction Time and Standard Deviations for Three Groups of Children Differing by Age and Language Level

	Condition (msec)							
	Identity		Category		Shape		All Conditions	
Group	*M* RT	*SD*	*M* RT	*SD*	*M* RT	*SD*	*M* RT	*SD*
SLI	1415	211	1930	335	2011	305	1785	323
AM	1261	105	1565	216	1526	210	1451	165
LM	1645	330	2077	415	2209	463	1977	420
All	1441	278	1857	390	1915	442	1738	370

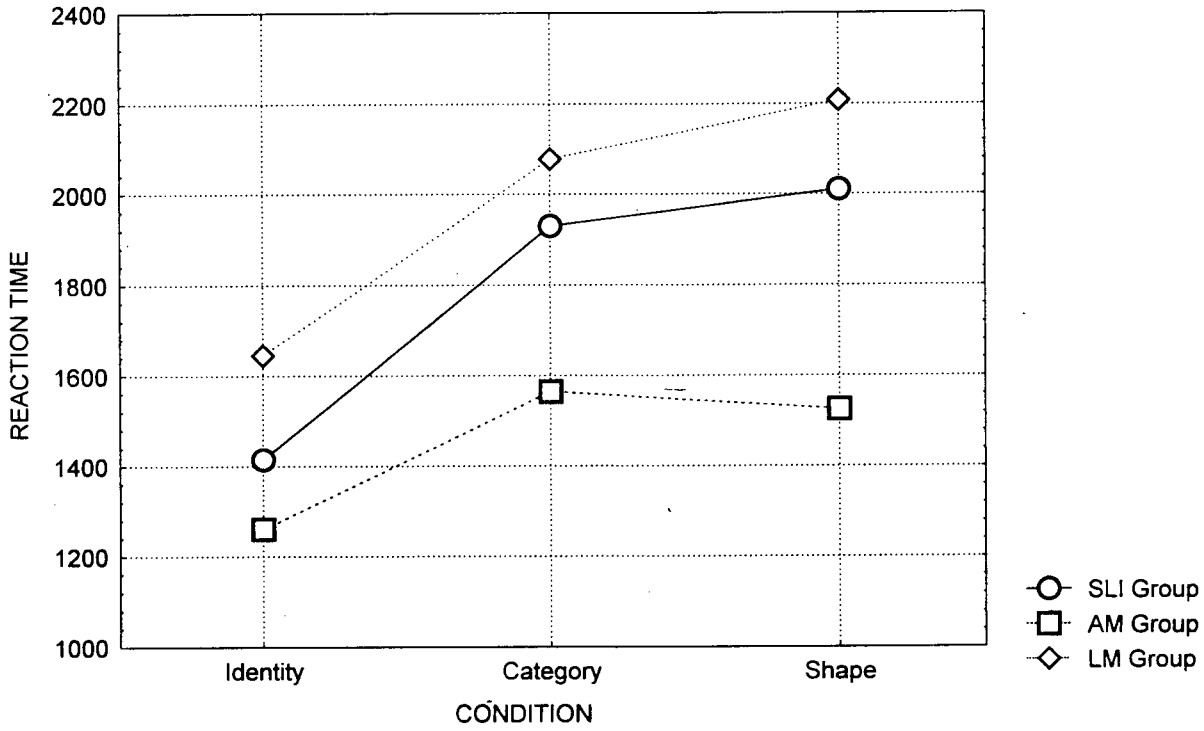
SLI Group Children with specific language impairment

AM Group Typically developing children matched by chronological age with SLI group

LM Group Typically developing children matched by productive vocabulary with SLI group

Figure 2

Interaction of Group and Condition



intelligence age deviation scores were in the above average range. This did not significantly change the results and the group patterns of performance remained essentially the same.

It was hoped that the children's performance on the shape condition would provide evidence supporting the hypothesis that SLI children were relying more on visual coding strategies than the AM children. The expectation was that children who showed smaller RT differences between the identity and category conditions and, hence, appeared to prefer verbal coding strategies, would show relatively longer RTs in the shape condition and, thus, a larger RT difference between the identity and shape conditions. However, contrary to these predictions, RTs for all groups were similar on these two conditions.

Additional Analyses

Overview

To aid in the interpretation of the RT findings, additional analyses were conducted on accuracy of the children's responses by group and by condition. Between-group differences in RTs were also examined by position of the target in the choice array. Correlations between RT on the experimental task and the children's test scores on the vocabulary measures were examined. Finally, results of an analysis of between group differences in RT and pattern of RT, excluding those children in the AM and LM group whose age ranges overlapped, will also be presented.

Accuracy

A two-way mixed model ANOVA was conducted with Group (3) treated between groups and Condition (3) treated within child. Accuracy was the dependent variable and was measured as the number of responses answered correctly by each child. Table 5 summarizes accuracy data

for each group in each condition. Accuracy was found to vary significantly between the groups, $F(2, 36) = 5.2, p < .025$. As can be seen, there were small but significant differences in accuracy between the groups. The AM group had the highest accuracy rate, followed in turn by the SLI group and the LM group. Post hoc tests (Fisher LSD, $p < .05$) indicated that the difference in accuracy was only significant between the AM and the LM groups. There was also a significant Group by Accuracy interaction, $F(4, 72) = 3.09; p < .025$. Post hoc tests (Fisher LSD, $p < .05$) indicated that the AM and LM children performed at essentially the same level of accuracy in each of the three conditions. The SLI group, however, made more errors on the shape items than on the identity or category items. While these effects are significant, the overall range in mean accuracy was small, with values between 28 and 31, out of a maximum of 32 trials per condition.

Position

An analysis was also conducted to determine whether there were differences in RT by position in the choice array. A three way ANOVA was conducted using Group (3) treated between children, Position (3) treated within child, and Condition (3) treated within child. A main effect was found for Position, $F(2, 72) = 27.48; p < .01$. Fastest RTs for all children were found when the target was in the middle position of the choice array. No interactions were found between group and position or between condition and position.

Correlations between RT and Vocabulary

Correlational analyses were conducted for RT on the three conditions and raw scores on RV and EOWPVT, the vocabulary measures used for inclusion into and matching between groups. Table 7 details these correlation coefficients for the three groups. Negative correlations

would point to an inverse relationship between vocabulary knowledge and speed of responding on the experimental task. As can be seen, there were negative correlations for all of the groups. For the SLI children there were two negative correlations, for the AM children four of these correlations were significant, and all six correlations were significant for the LM children.

Analysis of RT Data for AM Children over 60 Months of Age and LM Children Under 60 Months

To aid in the evaluation of alternate explanations for the findings, an analysis of the RT data was conducted exluding those children in the LM group whose ages were above 60 months (5 children) and those in the AM group whose ages were below 60 months (1 child). This served to provide control groups whose ages were discrete. Main effects were found for group, $F(2, 30) = 32.56$; $p < .01$ and condition, $F(2, 60) = 125.27$; $p <. 01$. Post hoc analyis (Tukey HSD, $p < .01$) indicated that the SLI group mean RT was significantly different from the mean RTs of both the AM and LM children, and that the mean RTs of the AM and LM children were also significantly different from each other. A correlational analysis based on this more limited set of control group children was also done. This indicated that, for those children in the LM group under 60 months of age, there were no significant correlations between RT and the two vocabulary measures used.

Table 7

Correlations between Reaction Time in each of Three Conditions and Vocabulary Measures for Language Impaired Children and Two Matched Control Groups

Measure	1	2	3	4	5
		SLI Group (n=10)			
Identity RT	-	.89	.69	-.22	-.76
Category RT		-	.86	.07	-.55
Shape RT			-	-.07	-.29
EOW				-	.20
RV					-
		AM Group (n=13)			
Identity RT	-	.85	.88	-.59	-.55
Category RT		-	.78	-.58	-.59
Shape RT			-	-.46	-.39
EOW				-	.63
RV					-
		LM Group (n=12)			
Identity RT	-	.83	.94	-.57	-.53
Category RT		-	.84	-.55	-.54
Shape RT			-	-.61	-.59
EOW				-	.84
RV					-

SLI Group	Children with specific language impairment
AM Group	Typically developing children matched by age with SLI group
LM Group	Typically developing children matched by productive vocabulary with SLI group
EOW	Expressive One-Word Picture Vocabulary Test – 2000 Edition, Raw Score
RV	Relational Vocabulary Subtest of the Test of Language Development – Primary, 3rd Edition, Raw Subscale Score

CHAPTER FOUR: DISCUSSION

Overview

This study compared the performance of language-impaired children with that of their chronological age- and language level-matched peers on a short-term memory task. The focus of this study was to explore the use of visual and verbal coding processes in these three groups of children. Two aspects of performance were examined: (1) mean RTs for each condition and overall; and (2) the pattern of RTs across conditions. In the following discussion, the findings will first be summarized. Then between group differences in cognitive level, age, processing speed, and language level will be considered with respect to interpreting the data. The findings are useful in providing preliminary responses to the three research questions discussed in Chapter One, which will be discussed in turn. Ultimately, these findings will considered in the perspective of past and current research in this area, then implications of these findings for future research and clinical practice will be discussed.

Visual and Verbal Coding Strategies

Summary of Group Differences

Within child and between group comparisons in RT showed both significant differences and trends for SLI children relative to their typically developing peers. As expected, there was a main effect for group that indicated that the AM group obtained a shorter mean RT over all conditions than either the LM or the SLI group. While the LM children were slower than the SLI children, this difference was not significant. Mean RT on the experimental task might serve as a gross measure of processing speed. If this is the case, then the shortest mean RTs of the AM children would suggest that these children showed faster speed of processing than either the LM

or SLI children. There was also a main effect for condition. All groups were faster on the identity condition than on the category or shape condition. The main variable of interest, though, was in the pattern of RTs across the three conditions, independent of overall RT, which should allow an examination of possible qualitative differences in task performance. The discussion of these differences in pattern will focus first on the RTs in the category condition relative to the identity condition. Results for the shape condition will be considered later.

The AM children showed the smallest RT difference between the category and identity conditions, followed in turn by the LM group and the SLI group. The category versus identity condition difference, however, was only significantly different between the AM group and the SLI group. It was assumed that the category condition required the child to match pictures based only on category membership. Thus, the pattern of performance was thought to reflect the difficulty each group had in matching pictures that shared only category membership relative to the difficulty of matching pictures that were identical in both their visual and category characteristics.

As argued in Chapter One, one explanation for differences in speed of matching identical versus categorically-related items lies in a consideration of differences in dominant coding strategy. The data may be compatible with the interpretation that there were group differences in use of coding strategy according to the language status of the children. Specifically, children with atypical language development may be viewed as relying less often on verbal coding strategies than same age typically developing children. However, as the three groups in this study differed on variables other than language status, in order to accept this interpretation of the findings it will be necessary to rule out the possibility that other factors resulted in the observed group differences in task performance. Therefore, the results will first be examined with respect

to cognitive level, age, and processing speed differences between the groups prior to discussing the link between language development and memory coding strategies in children. In addition, the overall pattern of RTs across all three conditions was contrary to predictions and this must be considered in evaluating the support that the data provide for a coding strategy explanation of task performance.

Cognitive Level

While non-verbal intelligence scores for all groups were in the average range, between group differences were found on this measure. The AM group achieved a significantly higher mean CMMS age deviation score than the SLI group. The LM group scored lower than the AM group and higher than the SLI group, although the differences between the LM group scores and those of the other groups were not found to be significant. It had been intended that the groups would not differ significantly in non-verbal intelligence but since there were differences the possibility that cognitive level related to task performance was explored. The original two-way ANOVA was redone using CMMS age deviation score as a covariate. Results indicated that group differences in non-verbal intelligence were not significantly related to task performance and the relative performance patterns of the groups remained essentially unchanged from the original ANOVA.

Age

AM children were significantly faster to respond on all conditions than the LM children. This finding can be explained, at least in part, with reference to children's increases in speed of processing with age (Kail, 1986). It should be noted, however, that age-related changes in

processing speed would be expected to affect RT equally across conditions assuming the three conditions were of equal complexity. If complexity is controlled for, and if age were the only variable impacting on task performance, then typically developing children of different ages should show similar patterns of RT's across the conditions, different by a constant value equal to the contribution of processing speed to task performance. In fact, the AM and LM children do show similar patterns of RTs. Although the difference in RT between identity and category conditions was longer for the LM children than the AM children, this difference was not significant.

At face value, the similarity in response patterns of the LM and AM groups would seem to indicate that there were no differences other than processing speed between them. This conclusion may be premature. The absence of significant differences in pattern of RT between the LM and AM children might be due to the fact that, in spite of a 17-month difference between the mean ages of the two groups, the age ranges of the children in these groups overlapped considerably. Children in the AM group ranged in age from 61 months (5;1) to 90 months (7;6), while the range for the LM group was 50 months (4;2) to 75 months (6;3). The overlap of the ages of the children in these two groups may have minimized the performance differences between them. Had the two groups been composed of children of distinctly different ages, the differences between them in pattern of RT may have achieved significance.

This possibility was explored in a reanalysis of the RT data in which only children in the AM and LM groups whose ages did not overlap were included. By doing this, differences in pattern of RTs between the AM and LM children were increased, and did, in fact, achieve significance. This suggests that there may have been differences beyond mere processing that were not apparent based on the original analysis of the data. It is possible that the conditions

varied in their complexity, and thus between group differences in processing speed could interact with complexity to contribute to the longer RTs on more complex conditions for children with slower processing speed. This would be particularly true if the processing demands associated with complexity exceeded the child's capacity. Issues related to complexity will be considered further in a later section.

Processing Speed

Differences were also found between the AM and SLI groups in their overall mean RT on the experimental task. Again, the AM children responded the fastest, followed by the SLI children and this difference in mean RT was significant. This finding implies differences in processing speed between these two groups that cannot be attributed to differences in age. A number of prior studies have likewise found that children with SLI are slower than age peers with typical language development on a wide range of tasks, including motor, nonlinguistic cognitive, and linguistic activities (Miller et al., 2001) and picture naming (Lahey & Edwards, 1996). However, in the present study, given that the experimental conditions varied in complexity as the earlier analysis seemed to indicate, any processing speed differences between the SLI and AM groups should differentially affect RT across conditions. Such was the case. Processing speed will be considered further in a later section, along with a more detailed consideration of the nature of any potential complexity differences between the conditions.

Language

Vocabulary

Although the higher vocabulary level AM children were faster on all conditions than the

lower vocabulary level LM group, this was not a surprising result because vocabulary level was confounded with age. The more interesting findings concern the LM and SLI group comparison. Even though productive vocabulary was used as a matching variable to generate the LM group, vocabulary knowledge wasn't expected to have an impact on task performance because the word selection parameters used in developing stimuli were designed to ensure that all children would be familiar with the appropriate category labels. Nevertheless, while the pattern of RTs across conditions was not identical for the LM and SLI groups, it was also not significantly different. Given the early age-of-acquisition values for the experimental stimuli, this group similarity most probably reflects the influence of general language competencies rather than lexical knowledge per se. I turn next to consider that variable.

Language Status

Children whose language develops in different ways may also differ in the processes which underlie working memory. An examination of task performance, then, in relation to the children's language status might contribute to our understanding of the deficits that underlie the atypical language development of children with SLI.

Language status differentiates the children in the SLI group from the two control groups: the SLI group consisted of children with language impairment, while the AM and LM groups were both composed of children with normal language development. The hypothesis of this study is that children who differ in language status also differ in their use of visual and verbal coding strategies underlying task performance. More specifically, it was hypothesized that children with atypical language development rely less on verbal coding strategies than age peers with typical language development.

The finding of interest here concerns the group patterns of RT across conditions. The SLI group showed a larger difference in RT between identity and category conditions than the children in either the AM group or LM group, although only the comparison with the AM group achieved significance. These differences are pictured in Figure 2 and can be seen in the slope of the lines between mean RTs for the identity and category conditions. The value of the difference between RT on the identity condition and RT on the category condition can be viewed as reflecting the degree to which each group used verbal coding strategies to perform the task. From this perspective, the results would suggest that the SLI group relied less often on verbal coding strategies than the AM group but were similar in coding strategy to the LM group. However, this latter point may need reformulation.

To fully understand the relationship between the coding strategies of the LM and SLI groups, we need to recall the correlational data presented at the end of chapter three. These data raise the possibility that the similarity in pattern of RT of the two groups might actually conceal differences in their use of underlying coding strategies. For the LM group all six of the correlations between vocabulary test scores and speed of response on the experimental task proved to be significant; that is, children with greater absolute vocabulary knowledge had shorter RTs. For the SLI group, though, only two of these correlations were significant. This suggests that for the LM group absolute vocabulary level and RT are closely linked whereas for the SLI group lexical competence is not as closely tied to task performance. This might mean that, while the task performance of the SLI and LM groups was not significantly different on the surface they may have, in fact, been doing the task differently. It is possible, for example, that the LM children may have been relying more on "inner language" to perform the task than the SLI children, hence the strong link between task performance and language scores.

This raises the question of why there might be differences in processes underlying task performance in these groups. Here again, the specific composition of the LM group seems to be pertinent. As noted earlier, the range in age for the LM group was from 4;0 to 6;2 with a mean age of 4;11. Research suggests that there is a developmental shift in the use of visual and verbal coding strategies hypothesized to occur when normally developing children are about 5 years old. Conrad (1971), for example, found differences, before and after 5 years old, in children's recall of items with similar sounding or different sounding names. For the children in Conrad's study who were younger than 5 years there was no difference in task performance between these conditions, but after age 5 there was a systematic progressive advantage when the pictures had unlike sounding names. Conrad explains this finding with a coding explanation, suggesting that the absence of an effect for name similarity on recall means subjects are using visual coding, while the presence of an effect means that the children are coding verbally. Thus interpreted, Conrad's data would indicate that children are increasingly likely to use verbal memory codes after age 5. Similarly, Bruner (1964) found that preliterate children were less likely than older children to recode pictorial stimuli in verbal form and more likely to retain them in visual form. These explanations point to the possibility of heterogeneity in the LM group, suggesting that some of the older LM children may have been relying more on verbal strategies while for the some of the younger children in this group visual coding may have still been the dominant strategy.

This interpretation is supported by a second correlational analysis in which the LM children over 60 months were excluded. All significant correlations between vocabulary and RT for the children in this group disappeared. It is possible, then, that in the age range sampled in this experiment, SLI children and their younger, LM peers are actually similar in their use of

coding strategies. Comparisons of SLI and LM groups at older ages will be needed to determine whether this remains true.

Summary

Thus far, the patterns of performance in the identity and category conditions seem to indicate that the SLI children were less likely to use verbal coding strategies than their age peers. And, further, that the SLI children resembled the younger LM children in this regard. To add further support to this interpretation, I turn next to consider the main effect for condition.

Other Task Effects

Main Effect for Condition

Overview. One unexpected finding in the present study was the difference in RT between identity and category trials for the AM group. If it is assumed that the AM children were primarily using verbal coding strategies and that the use of a verbal code is effective in both the identity and the category conditions, then these children should perform similarly on these two conditions. This was not the case, though, as the AM group, like the other groups, performed more slowly on the category condition than the identity condition, albeit to a lesser degree. The similarity in pattern of RT raises the question of why the AM children, if they were coding verbally as hypothesized, showed a RT difference between identity and category conditions. An explanation for this finding will now be considered.

Coding flexibility. One explanation that could account for the effect of condition is that coding strategy use might be probabilistic rather than absolute. The idea that use of coding strategy is probabilistic implies that visual or verbal coding might be more likely for some

children, tasks or stimuli, but that individuals can use either strategy. Corsini (1973), for example, found that school-aged children performing a recall task showed best recall when both verbal and nonverbal cues were available. He suggested that this might mean that children have some flexibility of coding and that the materials dictate the coding strategies used. This argument lends support to the interpretation that the coding strategy preference of the children in this study was probabilistic. It seems reasonable to assume that the SLI children are less likely to code verbally while the AM children are more likely to do so. This does not imply that the groups could not, or did not, code using both types of strategies, but rather that they were more or less likely to do so in performing this task.

Summary. In summary, one likely explanation for the RT difference between the identity and category conditions for the AM group lies in the likelihood that coding strategy use, for all children, is probabilistic. That is, although the AM children seemed to rely on verbal coding strategies more than the SLI children, this does not necessarily mean that they never used visual coding strategies. It is possible that over the course of the task the AM children demonstrated coding flexibility. If they sometimes use visual coding strategies this would have increased their mean RTs in the category condition.

Thus far, I have considered the RT patterns for the identity and category conditions and their implications for memory coding. I have argued that the data support the view that children with specific language impairment are less likely to use verbal codes than their age peers, especially if we take into account the specific age of children in the LM group and remember that the use of coding strategies is likely to be a matter of preference in the moment, not absolute availability. I turn now to consider the findings for Condition 3, the 'shape' condition, and will use these findings to introduce an alternate explanation for the entire data set.

Matching by Shape

Overview. In condition 3, the object arrays consisted of grey-tone filled outline shapes without internal details. It was anticipated that the shape trials would reward visual coding, such that visual coders would show a smaller difference in RT between the identity and shape conditions than verbal coders since visual coders would have available at least some of the requisite overall shape information. Those using a verbal code would lack this useful shape information and thus show longer RTs on this condition relative to visual coders. Contrary to predictions, however, performance on the shape condition was similar to that of the category condition for all groups. The similarity in pattern of RT suggests that these two conditions were equal in difficulty for all groups. Why might that be? The answer to this question returns us to the issue of complexity. In the following sections, sources of complexity will be considered and a task analysis will detail specific steps required to complete the experimental task. Ultimately, we will consider the possibility that processing speed and complexity can explain the experimental results without appeal to memory codes.

Complexity. One way to consider the complexity of a task is in terms of the number of mental steps the child must take in order to complete the task. And, the number of steps required for a particular condition might vary depending on the coding strategy preference of the child. Thus, the relative complexity of each condition might be different for children using different coding strategies. For example, if a child is coding verbally when faced with a visual match to the target he or she might need to take the extra step required to translate their internal categorical representation into visual representations of one or more category members in order to select the appropriate match, resulting in longer RTs. Those using a visual code would not need this extra step, and thus should show shorter RTs on the shape condition. For verbal

coders, then, the shape condition might be more complex while for visual coders the more complex condition might be the category condition. However, the shape condition was as difficult as the category condition for all children, suggesting that complexity arising from the nature of the memory codes does not seem to account for the data from the shape condition.

Before abandoning this line of explanation altogether, however, we need to consider the nature of the drawings in both conditions 2 and 3. In spite of efforts to limit the visual similarity of the items in these two conditions, it is possible that they did share visual characteristics because they were examples of the same type of object. A man's dress shoe is very different in shape from a woman's pump, and hence a filled-outline drawing of the man's shoe would in no way resemble the shape of the woman's shoe. However, a metal wagon does not differ much in shape from one with wooden sides and a filled-outline drawing of one will still resemble the shape of the other. A review of the drawings indicates that some 69 % of the category item-shape item pairs share many shape features.

The ultimate effect of these similarities would be to minimize performance differences. The child using visual codes could be equally successful in the category and shape conditions. While none of the objects in these arrays would be perfect matches for the remembered image of the target, there would be substantial shape congruencies between the target and the 'correct choice' object in both of these conditions. Likewise, the verbal coder who needs to generate a new internal image of a category member would find that image equally useful in conditions 2 and 3.

This analysis, if valid, would help to explain the similarities in performance between the category and shape conditions for children using either sort of code. And, if coding strategy is potentially irrelevant to interpreting this aspect of the data, perhaps it is possible to explain the

entire set of findings without appeal to specific types of memory codes. I will now consider the steps required to complete the experimental task, and the possibility that performance differences between the groups arose from other sources of complexity.

Task analysis. The experimental task in the present study was fundamentally a memory task involving short-term memory for pictures. Task completion would seem to include the following stages: perceiving the target picture, forming an internal code and maintaining it in short-term memory, perceiving the pictures in the choice array, comparing the representation in memory with each of the choices, and responding by pressing a button to select the correct response. Each of these steps will be examined in order to determine from which stage or stages the performance differences between the groups could have arisen. In particular, we need to explain the facts that: (1) the AM group is faster overall than the other two groups, (2) that conditions 2 and 3 are both more difficult than condition 1, and (3) that this difficulty is especially apparent in the SLI group.

If differences in perception of either the target or the choice array were leading to the differences in task performance for the SLI group, it would be expected that these children should have consistently slower RTs across conditions and lower rates of accuracy relative to the AM group. Overall, the SLI subjects were indeed slower than the AM group but they were especially slower on the category and shape conditions, suggesting that perceptual difficulties alone cannot account for the results.

Performance differences between the groups could also, in principal, arise due to differences at the responding stage of the task, a stage which required a motor response. As noted earlier, longer RTs have been shown for SLI children on many tasks, a fact which has been variously attributed to the effects of neuromotor maturity (Wolff, Michel, & Ovrut, 1990) or

generalized slowing (Kail, 1986; Lahey & Edwards, 1996; Miller et al., 2001), either of which could conceivably impact on speed of the motor response. But again, such effect would be constant across conditions. In agreement with this conclusion, Gillam et al. (1998) suggest that "perceptual and output processes, in and of themselves, are not sufficient to explain the kinds of difficulties that children with SLI present on basic working memory tasks" (p.923).

Processing speed could, however, have a differential effect on performance in those aspects of the task involving more complexity, for example, in forming memory codes of any sort and using those codes to determine which member of the choice array is most like the remembered target object. Here we might expect that we would see slower responses wherever the condition requires more cognitive complexity, or children have reduced cognitive capacity.

To illustrate this point, consider that one aspect of the necessary decision-making involves a search through the choice array. Given the nature of the task, children may engage in exhaustive scanning, in which the entire array is scanned prior to choosing the match. Or they may perform non-exhaustive scanning in which the match is selected without examining the entire array first. The use of exhaustive versus non-exhaustive scanning strategies would be influenced by the relationship between the target and correct response, by coding strategy, and by the position of the matching object in the array. It is possible, for example, that non-exhaustive scanning strategies would be employed whenever the coded target and a match could be found early in the search process – a situation which could occur for visual coders in the identity condition, or for verbal coders in all conditions.

One way to observe the putative effects of search complexity would be to look for position effects: if participants were scanning non-exhaustively then RTs would be shorter when the correct response item was in the position the children scanned first, but, if children were

scanning exhaustively we would expect no such position effect. Since target presentation was always in the horizontal center of the screen, at a point directly above the position where the middle item in the choice array would displayed, the children's fixation was likely to be in the middle of the screen when the choice array was presented. Hence, given that children begin scanning with the middle item in the array then move to the outer positions, and given as argued above that a majority of the condition 2 and 3 coding strategy pairings do have the potential for non-exhaustive search, a position effect should be found if search paths are a component of the RTs.

Post hoc analysis indicated that, in fact, there was a relationship between position and RT. It was not possible to include coding strategy in this analysis as there was no independent way to assess memory codes. Nevertheless, all the children were fastest to respond when the match was in the middle position of the choice array, although this position effect was only significant for the category and shape conditions. This finding suggests that the length of the required search was one source of complexity in this task.

Differences in task complexity could also, in principle, have arisen from differences in the children's ability to maintain the coded information in memory while waiting for the presentation of the choice array or in the decision processes that were needed as items were scanned. Although this, again, is difficult to assess, such difficulties could be expected to lead to increased error rates for conditions that took longer. No such increase was found.

This brings us finally back to the starting point of the study, that is, to the nature of the memory codes themselves. Whether the children in this study used visual or verbal coding strategies would have impacted on the nature of the code used to mediate between the target and response, thus impacting on how the information was stored, manipulated, and recalled.

Performance differences in terms of differences in use of coding strategies would impact on this stage of the task and may provide an explanation of the findings for the participants in this study. As described in an earlier section, when confronted with a category match to the target children using verbal coding strategies could make a comparison between their internal code and the verbal label for the items in the choice array. However, when confronted with this same categorical match to target task, children using visual coding strategies to internally represent the target picture would need to recode their internal representation verbally in order to select the correct match, as no visual match would be available. This would seem to be true even acknowledging that some of the 'category' objects physically resembled the original target. The lack of identity would, at the very least, prolong the search, and well could prompt recoding. This extra step of recoding could account for the longer RTs of the SLI children on the category condition relative to the identity condition.

Verbal coding in the shape condition. This explanation works less well when we consider condition 3, the shape condition. Recall that these items were designed to reward visual coding. The choice array pictures were not line drawings, but rather were shaded-in and visually altered versions of the line drawings used in the other conditions. The intent of performing these manipulations was to make the picture unidentifiable as the object it represented and hence provide a condition in which the verbal label could not be used to select the match, thus rewarding visual coding but not verbal coding. However, this condition was not faster for the SLI children, as expected, and it was the same as the category condition for all the children. This fact raises two quite different interpretive possibilities.

First, it could be that the findings in condition 3 are the result of faulty item design. Even after the manipulations, some of the shape stimuli were recognizable out of context

approximately 40 to 50% of the time, suggesting that participants may have been able to effectively use a verbal code to identify the match when confronted with shape stimuli in the choice array. This would effectively minimize the distinction between conditions 2 and 3. In each case, there would be no identity match, but there would be the possibility of using the verbal label to search out an object that was 'similar' to the target, although here the basis for similarity would be shape rather than category.

Secondly, it could be that the shape condition has its own complexity, regardless of coding preferences. Perhaps, for example, neither visual or verbal coding schemes provided a good fit to these pictures, that is, there may have been equivalent distance between the target and the codes. And, having said this, we must acknowledge that even for condition 2, where the coding strategy explanation seems to fit, the performance patterns may only reflect the difficulty of deciding – on any basis at all – that one object is 'like' a second, non-identical object.

Summary. At this point there are no objective data that allows us to choose between these possibilities. It is possible that verbal coding was rewarded in both the category and shape conditions leading to the similarity in RTs between them. Or, the category and shape conditions were both more complex in some other way than the identity condition, resulting in longer RTs for all children on these two conditions. One interesting point to note is that many of the children were observed to name the stimuli while selecting the correct response (e.g., "that's a plane"), and this pattern was also noted on shape trials. This seemed to serve the function of 'checking' to make sure they were selecting the right match. This might indicate that the shape condition, indeed, favored verbal coding thus accounting for the similarity in pattern of RT between the shape and category conditions and suggesting the differences in coding strategy are pertinent.

Coding Strategy Use in Children with SLI

and Typical Language Development

Overview

Thus far I have considered the data from this study in terms of the several factors that may have resulted in the observed between group differences in pattern of RTs. These findings will now be summarized with respect to their implications for the three research questions of the present study. Findings will also be discussed from the perspective of related theories and research in the field of memory and language, particularly those studies relevant to visual and verbal processes and language impairment.

Research Question 1: Do children with SLI rely less on verbal coding strategies than their typically developing age matched peers?

Findings from this study can be interpreted as indicating that the answer to this question is yes. Children with language impairment were slower to respond than their typically developing age peers when required to match categorically, a condition thought to favor verbal coding. Certainly, these groups differences cannot be fully explained with reference to cognitive level, age, processing speed, or given the correlational data, perhaps not even by general language level. We are left with two possibilities. Either there are differences in children's reliance on verbal coding strategies, or, if we take into account the relative complexity of conditions 2 and 3 vis-a-vis condition 1, mere differences in processing speed may be adequate to account for the observed group differences. The close similarities in performance between the SLI and LM groups, as well as the comments of the children, do suggest that verbal coding

facility was pertinent to task success. However, design ambiguities in condition 3 make it ultimately impossible to chose between the coding strategy and general complexity explanations.

Research Question 2: Is the coding strategy preference of SLI children similar to that of LM children?

The similar pattern of RTs for the SLI and LM children suggests that similar coding strategy preferences might be underlying task performance between these two groups. And the correlational analysis that excluded the older children suggests that the patterns of RT for these children were even more similar than the original analysis indicated and that any differences between the groups may have been contributed by these older LM children.

It is possible that matching the groups on a different language variable would have lead to different results. For example, had the SLI and LM groups been matched by mean length of utterance or syntactic complexity, that likely would have increased the difference in mean age and there may have been greater performance differences between the groups. It is also possible that, at older ages, children with normal language processing abilities would perform differently than SLI children at equivalent vocabulary levels. This will need to be explored further in future research.

Research Question 3: Are there developmental differences in use of coding strategy between younger and older typically developing children?

The findings from the original analysis of the data do not provide direct evidence of developmental differences in coding strategy use. While there were differences in pattern of RTs for the identity versus category conditions between the LM and AM children, this difference was

not significant. If coding strategy use is tied to developmental factors then the differences between these two groups may have been minimized by the overlapping age ranges of the children in the groups. The reanalysis of the data from these two groups excluding those whose ages overlap suggests the possibility that there were differences between the groups that could be accounted for either with reference to a coding strategy explanation or a processing speed explanation. Future research to examine developmental trends in typically developing children will need to examine groups of children whose age ranges form more distinct groups of children and do not span the age at which a developmental shift in coding strategy use is hypothesized to occur. In addition, differences in processing speed will need to be accounted for in order to confidently interpret task performance in terms of underlying coding strategy.

The Basis for the Coding Preferences

Overview

If we interpret the findings from this study to be valid and to indicate that SLI children use verbal memory codes less often than their age peers, we are left with the task of explaining this preference. Why might SLI children find nonverbal codes more attractive? Evidence from several related areas of research points to a difficulty for children with SLI in remembering linguistic information. There are several accounts of this difficulty, one treating verbal working memory deficits in children as capacity limitations (Ellis Weismer, 1996, 1999) and the other treating them as fundamentally phonological (Gathercole & Baddeley, 1990; Gillam et al., 1998). The processing speed account that has been suggested as a way to interpret the findings might also provide a valid way to understand the performance differences between the groups, and is not incompatible with either the capacity limitations or the phonological working memory

literature. A final alternative is also possible, and suggests that the primary difficulty in children with SLI is in memory for items that are of sequential nature (Gillam et al., 1995; Kushnir & Blake, 1996; Tallal, 1976; Tallal & Stark, 1980). These will now be considered.

Capacity Limitations

Ellis Weismer (1996, 1999) has looked at deficits for children with SLI in processing multiple pieces of linguistic information, but does not specify the precise nature of the information. As presented in chapter one, Ellis Weismer suggests that children with SLI have significant limitations in processing resources. This 'capacity limitation' can be seen whenever complex mental tasks must be coordinated or when broader, more encompassing, schemes have not yet been established. Looked at only from the vantage of the experimental task itself, capacity does not seem to have been the limiting factor. The high levels of accuracy obtained by the children suggests that the task placed a minimal burden on memory and likely does not tap into the processing aspects which Ellis Weismer discusses in her studies of verbal working memory. This makes sense if we note that the task in the present study was a memory task in which a relatively low burden was placed on memory. Yet, even in the absence of a challenging processing component to the task, children with SLI still seemed to perform differently than their age peers in using verbal codes to remember.

Despite the lack of direct evidence for capacity constraints in the current study, capacity limitations may still have played a role. Children's strategic preferences arise as much from past experience as from the current task. Children with SLI might rely less on verbal coding strategies than typically developing age peers because they have learned that the use of verbal strategies generally requires more resources than the use of visual strategies. Alternatively, the

transformation from a visual stimulus to a verbal code may place relatively more demands on these children than for their AM peers. In either case, the SLI children may have performed differently than their peers, not because of the inherent cognitive challenges of the experimental task, but because they had concluded on the basis of past experience that the cost of verbal memory codes is frequently too high.

Phonological Working Memory Deficits

Phonological working memory accounts of the memory deficits in SLI suggest an alternative basis for their less frequent use of verbal coding. Gillam et al. (1998) view phonological codes as internal mental codes that form "an essential link in the causal chain leading from auditory stimulus presentation to overt spoken response" (p. 923). Gathercole and Baddeley (1989) suggest that when individuals use phonological coding acoustic and temporal aspects of sound are recoded into a phonological form and it is this verbal information that undergoes activation and reactivation processes.

A number of studies have shown that children with SLI have memory difficulties specific to auditorily presented sequences of speech sounds (Gathercole & Baddeley, 1990). Perhaps these phonological difficulties could explain their coding preferences in the present study. Baddeley & Gathercole (1990) suggested that children with SLI are limited in their ability to form adequate phonological codes and that the recoding of visual stimuli to a phonological code may require extra mental processes. Similarly, Gillam et al. (1998) hypothesize that children with SLI may have difficulty retaining previously formed phonological codes during multiple mental operations or that they avoid creating phonological representations unless such codes are necessitated by task requirements.

At first pass, the findings from the present study would seem to indicate that these processes are not an issue here, since there were no acoustic stimuli; however, Gathercole and Wilson (1993) extend their findings and suggest that similar phonological coding processes are generated internally when pictures are presented as when speech is heard. Thus argued, it does seem possible that difficulties with phonological representation could have slowed the performance of the SLI children, particularly for the categorical items. The similar performance of the SLI and LM children on vocabulary and RTs lends support for Gathercole and Baddeley's hypothesis that vocabulary and phonological working memory go hand-in-hand.

Summary

To summarize, then, the outcomes of this study point to the possibility that there may be coding strategy differences for SLI children relative to typically developing peers. It is also possible that the findings can be explained, at least in part, with reference to differences between the groups in processing speed. The processing speed account is not incompatible with either a capacity or phonological working memory account for the difficulties of SLI children in working memory. However, the findings do not allow us to choose between the capacity and the phonological coding explanations for these differences. Either, or both, could be valid. It seems, though, that sequential memory deficits did not play a role in the present study because the task did not have an obvious sequential component. Any sequential memory deficits in SLI must, then, coexist with other processing deficits.

Implications of Findings

Implications for Understanding Memory Deficits in SLI

Visual and verbal coding strategy differences underlying task performance in this study provide one way to explain the data presented here. Processing speed differences between the groups might also be a valid way to interpret some of the obtained group differences. The findings from this study also converge with much research in the area of memory which has widely confirmed that, for children with language delay, "verbal codes are poorly created, retained, or used" (Gillam et al., 1998, p. 923). It also supports the research that points to both developmental differences in processing speed and differences in processing speed between children with language impairment and typically developing age peers. These conclusions have at least three implications for our understanding of SLI.

First, coding strategy explanations might provide another way to look at some of the well-documented memory deficits in children with SLI. It is clear that if children with SLI do, in fact, rely less on verbal than visual coding strategies, this may only be one area of need in a constellation of deficit areas. Examining coding strategy use in children with SLI might, for instance, allow us to see a new consequence of poor phonological representation or capacity limitations in SLI. Also, while deficits in phonological coding may exist in children with SLI, it is possible that there might be another pattern of deficits found for verbal coding more generally (Gathercole & Baddeley, 1990). Or capacity limitations might coexist with deficits specific to verbal memory processes. Furthermore, the data suggest that processing speed differences between children of different ages and different developmental levels will interact with any other group differences in determining task performance.

Secondly, findings from the present study point to memory deficits for children with SLI that are not limited to sequential information. While deficits in sequential memory for children with SLI have also been well documented, the task in the present study did not seem to have a sequential component. Hence, the fact that there were performance differences between SLI children and their typically developing peers suggests that difficulties with sequential memory do not fully explain the mechanisms underlying the memory difficulties in children with SLI.

Finally, lower frequency of verbal coding will also likely have implications for higher level cognitive functioning in children with SLI. Verbal labels provide a richness of propositional and interpretive information. Visual codes, on the other hand, represent a great deal of depictive information but lack an interpretive aspect. Conceptual development, reasoning, and problem solving will likely be negatively impacted if a child is unable to effectively use verbal codes to make such interpretations about his or her world.

Clinical Implications

A better understanding of coding strategy use by children with SLI might also help in developing and motivating remediation programs for these children. In the first place, a reliance on visual coding strategies in children with SLI provides support for the widely held belief that SLI children are relatively strong in the visual modality. An implication of this belief is the common pedagogical and clinical practice of providing visual supports to learning for these children. This practice will need to be reconciled with findings on coding strategy use and phonological working memory deficits in children with SLI that suggest auditory presentation and a verbal response might best support memory processes, because these seem to predispose the child toward the formation of a phonological code. Perhaps, then, providing language

impaired children with visual cues to support learning, either in the clinic or in the classroom, may not be the best method of teaching these children. If coding strategy use is probabilistic then treatment could focus on teaching children strategies that will encourage their ability to form and use verbal codes. One clinical example of this type of therapy is in the treatment of word finding problems, both for adults and children, which can involve teaching the individual to state various attributes of a word to strengthen the connections between the word and its attributes thus prompting its retrieval (e.g., Where do you find it? What do you do with it? etc.). Furthermore, if processing speed is a factor for SLI children then presenting information at slower presentation rates, particularly more complex information, may allow for more optimal performance.

Limitations

Overview

This study provides preliminary evidence in support of differences in coding strategy use for children with SLI and typically developing peers. However, as this study was of a preliminary nature, there are several variables that need to be considered in evaluating the findings.

Task Variables

The task in this study was based on the primary task developed for a dual-task study used to explore attentional mechanisms in preschool-aged children (Riddle & Johnston, 1992). The purpose of the task in the present study was different than its purpose in the study for which it was developed. As a result, several aspects of the task design were modified for use in the

present study. And, the fact that there were few directly related studies meant that these modifications were made based on a limited selection of past research and piloting data. It is likely that modifications of the task parameters such as rate and stability of target presentation, size of the interstimulus interval might affect the results obtained. In addition, it will be important to carefully select and prepare the stimulus pictures for the task, as degree of visual similarity between the pictures might also influence task performance.

An additional consideration when evaluating the performance of the children in the study is that attention to task varied considerably between participants due to individual differences in response to the simple and repetitive nature of the task. Some children had no difficulty attending to the task and were able to complete it in a very short time. However, for others, maintaining on-task behavior was more of a challenge and thus task completion took much longer. Furthermore, since the target stimuli were presented only briefly, attention likely played a key role in task performance. Those who had more difficulty focusing their attention may have been more likely to miss the target. In particular, one child in the LM group with suspected Attention Deficit Disorder showed the lowest accuracy rate out of all the subjects (78%), due in large part to a high number of 'missed' trials. While completing the task she was observed to have difficulty sitting still, staying on task, and ignoring extraneous noise in the testing situation. One way to counter this problem in future studies using this paradigm might be to use self-paced rather than experimenter-paced trials.

Subject Variables

As the present study made use of a computerized, picture-matching task, one possible source of the observed differences is children's level of familiarity with video games or

computer-based games. Children with strong computer skills may have had an advantage in learning or performing the task due to increased ability to attend to the briefly presented stimuli and well-developed hand-eye coordination. Two boys in the LM group who stated that they regularly played video games and computer games obtained the shortest mean RTs across conditions in the group. For future studies utilizing computer-based tasks, it would be beneficial to obtain a measure of video game or computer experience in order to be able to factor out the influences of such experience.

An additional factor that may have impacted on the reliability of the results from this study was the reliance on parental report for some of the information. Parents were provided with the list of criteria for participation in the study in the introductory letter that accompanied their consent forms. It is possible that parents may not have been aware of or may not have disclosed details regarding developmental history and medical information, such as early signs of neurological involvement, that might have served to exclude some of the children from the study.

Variables Impacting on the Generalizability of the Findings

Our ability to generalize the findings of this study is limited by the ability of standardized tests of language and non-verbal intelligence to identify distinct groups of children. In addition, using these tests as measures for inclusion into the SLI group mean that those included were only those whose scores on a standardized test of language development were in the below average range. However, many children who have received speech therapy directed at remediating gaps identified by these standardized tests may score in the average range on such tests, but continue to fail to perform as expected academically due apparently to language-based learning difficulties. Including only those children with a language delay measurable on standardized

tests may limit the generalizability of the results of this study to those whose language delay has not recovered by the early primary years. It will be important to develop measures that will allow us to include those children with 'recovered' language impairment.

Measurement Variables

One challenge when conducting a study with children in a daycare or school environment is the inherent inconsistency in environment across participants. It was not possible to control many environmental factors such as the height of the chair or table, lighting, or noise level, or to prevent interruptions due to people entering the testing environment. Also, children were assessed in a wide variety of environments, a factor which may have influenced both their results on the assessments used for inclusion into, and matching between, the groups, and their task performance.

Future Directions

This study explored a novel application of one task to understanding coding processes underlying memory. This study achieved preliminary success in eliminating some of the conceptual and methodological factors that impact on the ability to draw clear conclusions from findings of previous research in this area. However, this task is in the early stages of development for the present application and the version presented here is but one permutation of many variables of task design. Altering any of these factors may have a significant effect on task performance and thus the results obtained. Stimuli design and processing characteristics are a critical dimension to understanding the influence and role of visual and verbal coding. The task now is to experimentally delineate how each of the task parameters contributed to the outcome,

both to further clarify the results and to lead to a more adequate empirical and theoretical understanding of children's use of visual and verbal coding strategies.

It would also be useful to examine coding processes in different populations of children such as subgroups of SLI, those with non-specific language delays, and 'recovered' SLI children. This will allow us to determine whether deficits in verbal coding are specific to a certain subgroup of children with SLI or are apparent in children with language delays of varying types and etiologies. Lahey and Edwards (1996), for instance, have shown that children with delays only in language production perform differently on naming tasks than those with both language production and language comprehension delays. While the SLI group in this study consisted of children with both mixed and production-only language delays, due to the small *N* in the present study it was not possible to make these observations about patterns of performance by subtype of SLI. In future research, though, it would be beneficial to distinguish subgroups of children with language impairments as the patterns of performance, and thus the underlying coding strategies, might be different.

Conclusion

In summary, this study contributes to a growing body of experimental evidence pointing to deficits in verbal memory processes in children with SLI. The findings from this study suggest that children with SLI may be less likely to use verbal coding strategies than their typically developing peers, and may even use verbal coding less often than their language peers. The findings also suggest that differences in processing speed impact on children's ability to perform tasks of varying complexity. Clearly, the way in which we process information in our daily lives affects our interpretation of experiences, our use of problem solving strategies, and the

way we perceive and deal with the world (Jahanderie, 1986). Children with SLI must confront life without strong verbal coding skills to support language development, and, more importantly, to serve as an effective tool for thinking, problem solving, and learning. The contribution of coding strategies in memory for children with language impairments and the impact of processing speed differences remain areas in need of conceptual clarification and further empirical study.

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APPENDIX A

Child	Group	EOW		CMMS	TOLD							
					RV		GU		GC		SI	
		Raw	SS	ADS	Raw	SS	Raw	SS	Raw	SS	Raw	SS
1	SLI	60	83	87	9	6	21	10	10	6	10	6
2	SLI	57	83	92	8	6	19	9	9	6	14	8
3	SLI	56	75	94	7	6	19	10	19	10	10	7
4	SLI	64	99	110	6	6	18	10	16	11	5	6
5	SLI	43	86	94	5	5	8	5	3	5	1	1
6	SLI	44	73	104	7	6	16	8	14	9	9	7
7	SLI	55	90	104	-	6	-	8	-	2	-	1
8	SLI	49	84	95	7	7	17	10	5	6	8	7
9	SLI	49	93	87	4	6	13	9	1	5	1	4
10	SLI	56	89	98	6	6	19	11	15	10	5	6
11	SLI	40	77	95	-	2	-	5	-	8	-	3
12	SLI	46	85	109	-	5	-	4	-	4	-	6
13	SLI	56	89	91	2	3	13	7	4	6	3	4
14	AM	85	107	119	18	11	24	12	25	13	22	11
15	AM	68	95	104	16	11	20	10	24	13	15	9
16	AM	61	91	113	12	10	19	10	15	9	20	11
17	AM	70	109	111	16	13	20	12	16	11	22	13
18	AM	82	115	123	13	10	19	10	12	8	17	8
19	AM	74	100	114	18	12	24	14	20	10	16	9
20	AM	79	113	98	11	10	21	13	22	13	21	13
21	AM	64	101	118	12	11	20	12	17	11	18	11
22	AM	61	109	110	4	6	10	8	16	12	10	10
23	AM	80	111	118	16	12	19	10	19	11	9	7
24	AM	69	106	111	13	11	23	15	15	10	24	14
25	AM	63	103	99	4	5	14	9	7	8	6	8
26	AM	64	97	104	6	6	21	13	11	9	22	13
27	LM	60	100	104	8	9	19	12	9	9	7	8

28	LM	60	98	114	9	10	19	12	4	7	11	10
29	LM	57	102	100	8	10	15	10	14	12	7	9
30	LM	66	101	118	12	11	20	12	14	10	6	7
31	LM	45	101	99	6	10	11	10	10	12	7	11
32	LM	44	98	105	-	-	15	12	6	8	10	12
33	LM	50	98	98	5	7	12	9	12	11	9	10
34	LM	48	94	115	9	11	12	9	14	12	8	9
35	LM	45	99	99	4	8	15	12	10	12	9	12
36	LM	50	100	93	7	10	9	8	8	11	9	8
37	LM	44	102	99	3	7	13	11	5	10	6	10
38	LM	49	104	105	6	9	10	10	8	12	8	11
39	LM	56	97	106	9	10	19	12	9	9	10	9

-	Subtest scores unavailable
SLI Group	Children with specific language impairment
AM Group	Age-matched children
LM Group	Language-matched children
EOW	Expressive One Word Picture Vocabulary Test, 2000 Edition
CMMS	Columbia Mental Maturity Scale, Revised
TOLD	Test of Language Development, Primary, 3rd Edition
RV	Relational Vocabulary subtest of TOLD
GC	Grammatic Completion subtest of TOLD
GU	Grammatic Understanding subtest of TOLD
SI	Sentence Imitation subtest of TOLD

APPENDIX B

Trial Number	Position 1	Position 2	Position 3	Trial Type
1	cow	sock	**corn**	Shape
2	**tractor**	banana	rabbit	Identity
3	sock	**cow**	banana	Category
4	hat	**boat**	frog	Shape
5	**pear**	watch	squirrel	Category
6	squirrel	**banana**	truck	Identity
7	duck	sandwich	**sock**	Shape
8	**wagon**	frog	sock	Identity
9	**apple**	pig	glove	Category
10	pants	apple	**airplane**	Category
11	shoe	**truck**	pig	Identity
12	truck	**lion**	cake	Category
13	corn	dress	**tractor**	Shape
14	glove	**train**	carrot	Shape
15	shoe	**carrot**	tractor	Identity
16	**corn**	boat	hat	Identity
17	**glove**	boat	squirrel	Shape
18	duck	sandwich	**bus**	Category
19	**boat**	carrot	pig	Category
20	bus	frog	**apple**	Identity
21	**carrot**	boot	lion	Shape
22	cow	**dress**	sandwich	Shape
23	cow	**shoe**	corn	Identity
24	**truck**	duck	pear	Shape
25	pig	wagon	**watch**	Identity
26	bus	**duck**	sandwich	Shape
27	apple	boat	**cow**	Shape
28	carrot	**sock**	boat	Category
29	**pig**	pants	bus	Category
30	**boot**	pig	airplane	Identity
31	pants	rabbit	**banana**	Category
32	**sandwich**	glove	truck	Shape
33	cake	**watch**	lion	Category
34	**cake**	train	hat	Identity
35	rabbit	wagon	**carrot**	Category
36	dress	**frog**	corn	Identity
37	**shoe**	bus	bread	Shape
38	boot	cow	**cake**	Identity
39	carrot	duck	**glove**	Category
40	banana	**pants**	tractor	Shape
41	**duck**	bread	shoe	Category
42	sheep	bread	**bicycle**	Shape
43	**train**	squirrel	boot	Category
44	train	**sandwich**	sheep	Identity

Trial Number	Position 1	Position 2	Position 3	Trial Type
45	sock	**apple**	boat	Shape
46	**sock**	truck	rabbit	Identity
47	pig	dress	**sandwich**	Category
48	dress	corn	**boat**	Identity
49	**hat**	banana	tractor	Identity
50	carrot	**pig**	hat	Shape
51	**pants**	bicycle	frog	Category
52	pants	**wagon**	apple	Category
53	apple	sheep	**boot**	Shape
54	shoe	**bread**	tractor	Category
55	tractor	dress	**rabbit**	Category
56	**bus**	lion	sock	Shape
57	frog	airplane	**pear**	Identity
58	lion	bread	**train**	Identity
59	**banana**	airplane	watch	Shape
60	cake	**bicycle**	shoe	Category
61	**sheep**	watch	train	Identity
62	squirrel	**airplane**	glove	Identity
63	wagon	**cake**	sheep	Shape
64	**watch**	airplane	pear	Category
65	airplane	hat	**lion**	Shape
66	**squirrel**	sock	corn	Category
67	truck	rabbit	**dress**	Identity
68	apple	sheep	**pants**	Identity
69	**rabbit**	shoe	banana	Shape
70	**lion**	carrot	glove	Identity
71	train	**boot**	cake	Category
72	truck	boot	**squirrel**	Identity
73	**bicycle**	watch	rabbit	Identity
74	lion	bicycle	**bread**	Shape
75	pear	tractor	**frog**	Category
76	bicycle	**corn**	duck	Category
77	frog	bicycle	**hat**	Shape
78	apple	boat	**pig**	Identity
79	lion	**hat**	bread	Category
80	wagon	**glove**	corn	Identity
81	cake	cow	**wagon**	Shape
82	hat	**tractor**	sheep	Category
83	**airplane**	banana	cow	Shape
84	belt	wagon	**duck**	Identity
85	pear	**bus**	boot	Identity
86	**dress**	pear	bus	Category
87	cake	**squirrel**	bicycle	Shape
88	**cow**	bicycle	boot	Identity
89	sandwich	**sheep**	glove	Category
90	**bread**	duck	dress	Identity

Trial Number	Position 1	Position 2	Position 3	Trial Type
91	squirrel	train	**shoe**	Category
92	bus	**pear**	pants	Shape
93	wagon	bread	**sheep**	Shape
94	airplane	**rabbit**	pear	Category
95	sandwich	watch	**truck**	Category
96	**frog**	pants	train	Shape

BOLD font indicates the identity of the target/correct response for that trial

APPENDIX C

	Educator's Word Frequency Guide[1]				Kolson[2]	Morrison, Chappell, & Ellis[3]	
	SFI overall[a]	U overall[b]	F overall[c]	U, Gr1 corpus[d]	Spoken Freq.	Objective AoA (75%) (Months) [a]	Subjective AoA (Months) [b]
animals							
cow	55.6	36	693	154	142	23.4	16.2
duck	53.0	19	532	390	68	22.1	25.2
frog	56.0	40	1094	876	19	23.4	38.4
lion	55.0	31	858	225	9	23.4	38.4
pig	54.3	27	747	310	's 133	23.4	23.4
rabbit	56.0	40	1104	460	*bunny* 64	23.4	27
sheep	57.9	61	1305	192	37	44.5	25.2
squirrel	51.7	14	346	105	39	25.1	46.8
vehicles							
airplane	54.8	30	593	87	76	23.4	42
bike	55.2	33	675	173	18	23.4	36
boat	59.9	97	2024	379	341	23.4	30.6
bus	59.1	81	1542	349	38	23.4	27
tractor	47.5	5	110	1	61	23.4	45.6
train	59.4	87	1671	222	553	25.1	36
truck/^lorry	58.1	64	1241	308	466	^44.5	^40.8
wagon	56.8	48	1111	49	329	-	-
food							
apple	56.0	39	767	53	291	22.1	28.8
*banana	47.1	5	117	1	9	23.4	25.2
bread	58.4	69	1367	142	95	38.5	34.2
cake	54.3	26	649	259	134	23.4	28.8

carrot	46.1	4	89	11	21	25.1	42
corn	58.8	75	1438	42	84	-	-
pear	43.7	2	49	-	9/'s 116	44.5	45.6
sandwich	51.8	15	288	23	74	38.5	34.2
clothing							
belt	55.2	32	601	38	31	50.5	55.2
boot	47.5	5	144	6	9/'s 19	23.4	32.4
dress	57.6	57	1092	70	382	38.5	23.4
glove	46.9	4	125	6	's 18	44.5	45.6
hat	57.7	59	1387	369	407	23.4	23.4
pants/ ^trousers	51.9	15	340	54	86	^25.1	^34.2
shoe	53.4	22	400	45	186	22.1	12
sock	43.7	2	79	13	15	23.4	23.4

1 Zeno, Ivens, Millard, & Duvvari (1995). Educator's Word Frequency Guide.

a) SFI – Standard Frequency Index based on the total Corpus (a logarithmic transformation of U, therefore retaining all the advantages of U and providing a more compressed range of values than U, making it easier to use. Range of values in EWFG – 3.5 to 88.3, corresponding to a low frequency per million words of approx. 0.0002 and a high of 67,5000

b) U – an index of frequency expressed as N per million, weighted by D, based on the total corpus; frequency of the type per million tokens weighted by D (D is an index of dispersion across content areas based on the total corpus; a measure of relative entropy or disorder to reflect how widely a word is used in different subject areas – values from 0 (only one subject area) to 1.00 (used in all subject areas).)

c) F – raw frequency per million words in whole corpus

d) U value for Grade 1 corpus

2. Kolson (1961). A measure of spoken word frequency of kindergarten children in multiple settings. The figure in this column indicates number of productions of that word, across settings out of a total 98,961 words produced.

3. Morrison, Chappell, & Ellis (1997)
   a) Objective age of acquisition in months, based on values from 20 children each in a six month band of ages
   b) Rated age of acquisition in months (by 20 undergraduate students)