Memory, Language Comprehension, and Mental Retardation

EDWARD C. MERRILL, REGAN LOOKADOO, and STACY RILEA

DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF ALABAMA,
TUSCALOOSA, ALABAMA

I. INTRODUCTION

There is a long history of research conducted on memory systems and processes of persons with mental retardation. In fact, the relation between memory ability and general intellectual ability was part of many of the earliest intelligence tests (see Estes, 1982). In terms of basic memory systems, researchers have evaluated the performance of persons with mental retardation relative to persons without mental retardation in short-term, immediate, or working memory (e.g., Cohen & Sandberg, 1980; Ellis, 1970), long-term memory (e.g., Prehm & Mayfield, 1970; Sperber, Greenfield, & House, 1973), semantic memory (e.g., Glidden, 1986; Sperber & McCauley, 1984), episodic memory (Stan & Mosley, 1988), tacit memory (Atwell, Conners, & Merrill, 2003), and the possible interactions of some of the various memory systems (e.g., Cody & Borkowski, 1977; Winters, 1986). In terms of memory processes, considerable research attention has been devoted to the study of meta-memory and the use of task-specific memory strategies by persons with and without mental retardation (e.g., Borkowski & Cavanaugh, 1979; Brown & Campione, 1977; Justice, 1986), automatic versus effortful memory retrieval processes (e.g., Ellis, Palmer, & Reeves, 1988; Ellis, Woodley-Zanthow, & Dulaney, 1989), memory scanning (e.g., Merrill, 1990; Phillips & Nettelbeck, 1986), semantic priming (e.g., Sperber, Davies, Merrill, & McCauley, 1982; Sperber, Ragain, & McCauley, 1976), and semantic inhibition (e.g., Cha & Merrill, 1994; Merrill & Taube, 1996).

Memory has always played an important role in the study of language comprehension in cognitive psychology (see Lorch & van den Brock, 1997). In fact, discourse comprehension is often viewed as the cognitive equivalent of constructing a coherent memory representation of the text or discourse during its processing and early models of discourse comprehension relied

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heavily on many of the same mechanisms and processes developed for the processing of semantic knowledge (see Lorch, 1998). Hence, cognitive research on language comprehension has typically involved investigating the type of information that is included in the memory representation of units of discourse (single sentences or multiple sentence passages) and the systems and processes that facilitate the construction of the memory representation. This is the view of language comprehension that has directed our review.

Language comprehension is a complex cognitive activity and obviously involves the use of multiple memory systems and multiple memory processes. The intent of this review is to examine the role of the mechanisms and processes associated with memory for verbal information on language comprehension differences between persons with and without mental retardation. In our analysis, language comprehension involves no less than three separate memory systems: working memory, semantic memory, and tacit, or procedural, memory. Working memory provides space for the temporary storage of important components of the discourse during comprehension and resources for the retrieval and incorporation of relevant information from semantic memory into the memory representation of the discourse. Semantic memory reflects our knowledge about the world and provides the fundamental context for language comprehension activities. Among the most important functions of semantic memory is to promote coherence during comprehension by filling in details, such as causal relations or implied instruments, that are seldom made explicit during written or oral discourse. Tacit, or procedural, memory usually refers to a storage system of relatively complex knowledge of how to do things (very broadly defined), and is typically not accessible to conscious inspection. Many features of language (e.g., word order rules of grammar) occur with a consistency that may be accessible to a form of learning, called implicit learning, that takes place below the level of conscious awareness (see Reber, 1976, 1989). The knowledge gained through implicit learning is stored in tacit memory. Hence, differences in the use of tacit memories may also be related to language comprehension differences.

Obviously, other memory systems are likely to be involved in various aspects of language comprehension (e.g., episodic memory would assist in distinguishing between sources of language activities), however, the three systems on which we focus in this review have the most direct relation to general language comprehension. Although acknowledging the deficiencies inherent in reviews that treat mechanisms and processes of memory as functionally independent from other mechanisms and processes of memory, we review each system separately in the sections that follow. Within each section, we attempt to describe the basic components of the memory system under consideration, discuss each system's role in language comprehension as

revealed by research conducted on skilled language users, evaluate research conducted with persons with mental retardation, and assess how differences between persons with and without mental retardation in language comprehension may be related to the operation of each memory system.

Virtually all of the studies that include persons with mental retardation that we discuss in this review include at least one comparison group. We generally favored studies that matched on the basis of some estimate of Mental Age rather than Chronological Age. In some ways, this choice reflects the assumptions that guide our own research. More specifically, we tend to include chronological age comparison groups when studying what we consider to be basic cognitive processes and abilities and mental age comparison groups when studying what we consider to be cognitive skills (the products of basic processes and abilities). Our rationale is relatively straightforward. Because mental retardation is defined in terms of performance relative to others of the same chronological age, it has made sense to us to catalog pockets of similarity and differences in basic cognitive abilities between persons with and without mental retardation who are similar on chronological age (see for example, Burack, Evans, Klaiman, & Iarocci, 2001 for an alternative perspective on matching). One of the important general results of research using chronological age matches is the observation that there are many similarities in basic abilities between persons with and without mental retardation of the same chronological age (see for example, Atwell et al., 2003; Merrill & Jackson, 1992b; Merrill, McCown, & Kelley, 2001). Hence, we have learned that mental retardation is not characterized by a deficit in all cognitive abilities nor even all situations when ability differences have been observed. In contrast, when evaluating cognitive skills such as language comprehension we tend to favor a comparison of individuals who are matched on mental age. Albeit a relatively gross measure, we have accepted mental age as a construct indicating current ability/performance levels in general cognitive functioning. Therefore, our basic question when investigating cognitive skills focuses on whether or not persons with mental retardation are able to utilize current ability/performance in general cognitive functioning to achieve similar levels of skilled performance as persons without mental retardation of the same mental age. One of the important general results of research using the mental age match is the observation that there are many differences in skilled performance between persons with and without mental retardation of the same mental age (see for example, Courbois, 1996; Merrill & Marr, 1987; Merrill et al., 1987; Spitz & Borys, 1977).

Our review also focuses primarily on research conducted on adolescents with mild mental retardation. The notable exceptions will be studies in which a wide range of ability levels are considered that includes mild

retardation as well as more severe levels of mental retardation. This decision was made because we are more confident that the models of memory and language comprehension that we use to guide our research are applicable to adolescents with mild mental retardation than to younger individuals with mental retardation or adolescents with more severe mental retardation. In addition, the procedures designed to measure memory performance and language skill tend to be more reliable for adolescents with mild mental retardation than for persons in the other classifications. As a result, the research that we discuss typically involves persons with mental retardation whose measured IQs fall between 50 and 70 and estimated mental ages fall between 6 and 9 years. Hence, our conclusions are not necessarily appropriate for other persons with mental retardation.

With the exception of a brief discussion of the relation between vocabulary acquisition and phonological processing, we have also focused on language comprehension activities involved in sentence and discourse processing. This choice was made for two reasons. First, it is in the context of understanding larger units of discourse that memory has its greatest direct impact on language comprehension activities. Second, it is in the processing of larger units of discourse that language serves its primary functions of providing the means for communication, reasoning, and problem solving.

II. WORKING MEMORY

Working memory is now the preferred term to identify the cognitive system responsible for the temporary storage and simultaneous manipulation of information. This system is fundamental to the performance of a variety of complex cognitive tasks. One role of working memory in language comprehension is a storage function to provide access to referents necessary for comprehension. Understanding a full sentence requires that we be able to remember words from initial phrases when we reach the end of the sentence. Understanding larger units of discourse of requires access to referents from several sentences back. In addition, working memory provides and coordinates cognitive resources necessary for the integration of information across sentences, the retrieval of relevant information from semantic memory, and the use of strategies and goals to facilitate language comprehension activities.

The most influential model of working memory currently available identifies working memory as a multi-component system consisting of a central executive and two subordinate slave systems: an articulatory–phonological loop and a visuo-spatial sketchpad (Baddeley, 1986; Baddeley & Hitch, 1974). The two slave systems operate as basic short-term storage

mechanisms, whereas the central executive acts to coordinate resources necessary for the processing and manipulation of information. Several theorists have described the prime function of the central executive as the coordination of resources throughout the cognitive system, with the memory storage function of working memory being one of a number of basic operations that may make demands on the central executive (e.g., Baddeley, 1986; Schneider & Detweiler, 1987). In fact, the central executive is typically assumed to be responsible for a wide range of functions that traditionally have been assigned to attentional processing, such as the retrieval of information from various long-term memory systems and regulating the flow of information among the components of working memory and between the components of long-term memory and working memory (see e.g., Baddeley, 1986; Engle, Tuholski, Laughlin, & Conway, 1999).

In the next two sections, we review the role of working memory in language comprehension activities of individuals with and without mental retardation focusing on the articulatory-loop and the central executive. In the first section we discuss working memory functions related to language comprehension of individuals without mental retardation. As discussed below, the storage function associated with the articulatory–phonological loop appears to play a limited role in discourse comprehension (with the exception of learning to read), but a more prominent role in vocabulary acquisition. However, the central executive, typically measured in terms of working memory capacity (Daneman & Carpenter, 1980), appears to be involved in many aspects of language comprehension. In the second section we review studies that assess the working memory of individuals with mental retardation and compare working memory performance of individuals with and without mental retardation.

A. Working Memory and Language Comprehension: Individuals Without Mental Retardation

Two of the three components of working memory would logically be expected to correlate highly with general language comprehension: the articulatory–phonological loop and the central executive. We do not rule out a possible relation between language comprehension and the visuo-spatial sketchpad in the form of, for example, the processing of visual context to facilitate online comprehension. Unfortunately, much of the research on the visuo-spatial sketchpad has focused on demonstrating a dissociation between its operation and cognitive activities assumed to be related to the articulatory–phonological loop. Hence, data on this issue, especially data that may be relevant to language comprehension by persons with mental retardation, are not available.

Despite the logical relation between the operation of the articulatory–phonological loop and language comprehension, many studies have reported a relatively weak relation between them in the general population. For example, Waters, Caplan, and Hildebrandt (1987) reported that articulatory suppression (forcing participants to engage in a secondary articulation task and limit the role of the phonological loop in sentence comprehension) interfered with the processing of two proposition sentences but not the processing of one proposition sentence. The authors concluded that the phonological representation stored in working memory served as a backup when particularly demanding sentences would overload on-line comprehension processes but was not necessary when on-line comprehension was relatively easy. Martin and Feher (1990) evaluated the role of the articulatory–phonological loop in the language comprehension of patients with short-term memory impairments. They presented sentences with and without printed forms that remained available for as long as the participants wished. They assumed that having a printed form available would limit the working memory requirements of the task because the sentence was physically available. There was no difference in correct interpretation associated with printed versus unprinted versions of the sentences except for Token Test sentences containing many content words (e.g., "Touch the large blue square and the small red triangle") that were considerably more difficult for their patients to process. For even syntactically complex sentences, having a printed version available did not increase correct interpretation of the sentences, indicating a relatively limited role for the phonological loop in sentence comprehension. Butterworth and colleagues (Butterworth, Campbell, & Howard, 1986; Campbell & Butterworth, 1985) have gone so far as to suggest that the phonological loop may not be a critical component of auditory language comprehension on the basis of results from a college student who exhibited severe phonological memory impairment, but unimpaired language comprehension skills.

A number of researchers have noted that the role of the articulatory–phonological loop in language comprehension may be greater for children than it is for adults. For example, Gathercole and Baddeley (1993) have suggested that one important role of phonological memory is to support comprehension off-line, and that it is logical to expect that young children will be required to do more off-line processing when learning to master complex sentence constructions. Hence, it may not be appropriate to assume that the failure to find a clear relation between phonological working memory and comprehension in skilled language users would necessarily generalize to children, and for our discussion, persons with mental retardation. Unfortunately, we were not able to find systematic research on

the role of phonological working memory on language comprehension of children independent of learning to read. Therefore, there is no clear and convincing support for this possibility. More recently, Baddeley, Gathercole, and Papagano (1998) have argued that the use of the phonological loop for retaining sequences of familiar words during comprehension may actually be secondary to its use in the storing of unfamiliar sound patterns during the construction of more permanent memories of new words.

Although it may be that the articulatory–phonological loop is not directly related to the language comprehension abilities of skilled language users, it does appear to play an important role in two other facets of language use: learning to read and vocabulary acquisition. The role of the articulatory–phonological loop in learning to read in the general population has been well established (see Gathercole & Baddeley, 1993). This particular literature and the role of working memory in learning to read by persons with and without mental retardation is reviewed elsewhere in this volume (see Conners) and will not be addressed directly in this review.

Gathercole and Baddeley (1993) present data that indicate a relatively strong relation between phonological memory skills and vocabulary acquisition for children between the ages of 4 and 8 years old. Using nonword repetition as their measure of phonological memory, they found positive correlations between phonological memory and measures of receptive vocabulary that ranged between 0.50 and 0.60 for children at ages 5, 6, and 7. The correlation was only half as large when children were 8 years old. Cross-lagged correlations indicated that the direction of causality actually changed across the age range tested, with phonological memory driving the relationship for the 4- and 5-year-old children and vocabulary skills driving the relationship for the older children. They suggested that the manner in which good phonological memory facilitates the acquisition of new vocabulary is by producing more discriminable and persistent phonological traces that are more likely to be semantically linked with the appropriate referent than would less discriminable and weaker memory traces. This would be most evident with young children.

Despite the lower correlations of phonological memory and vocabulary acquisition exhibited by children over the age of 6 years, research has also indicated that phonological memory may play an important role in the acquisition of new words by adults as well as children. Papagno, Valentine, and Baddeley (1991) presented adults with familiar and unfamiliar words while they were or were not concurrently performing an articulatory suppression task. The suppression task caused greater impairment in memory for the unfamiliar words than for the familiar words. They concluded that phonological memory skills played an important role in the learning of unfamiliar words for which there is no semantic code that can facilitate

memory. Papagno and Vallar (1992) reported that phonological similarity impaired memory for word–novel word pairs more than it impaired memory for word–familiar word pairs, and hence, reached a similar conclusion.

The contribution of the phonological–articulatory loop to basic language comprehension skill may be mostly an indirect one; however, it is clear that the central executive has a direct and more general influence on language comprehension (see Carpenter, Miyake, & Just, 1995; Daneman & Merickle, 1996). The central executive controls available resources and can influence how they are distributed to the storage and processing functions of working memory. In fact, in practice it is often equated with working memory capacity. To assess this feature of working memory, Daneman and Carpenter (1980) developed a measure of working memory span that required individuals to use both the storage and processing components of working memory: they had individuals read or listen to a series of unrelated sentences and, after the entire set was presented, recall the last word of each sentence. Working memory capacity was defined as the number of sentences that individuals could process and still recall the last word of each sentence. In an assessment of good and poor readers, Daneman and Carpenter found that working memory span varied reliably across individuals (two to five final words for college students), and observed that working memory span correlated more highly with global measures of language comprehension than did traditional measures of static memory span. The relation between working memory capacity and language comprehension was assumed to reflect the added processing requirements associated with language comprehension activities for the poor language comprehenders. More specifically, the general claim was that language comprehension activities required more of the available resources of the central executive for the poor comprehenders and left fewer resources for storing and retrieving the last word of the sentences.

Over the last 20 years, this approach to assessing working memory capacity has been used by many groups of researchers who have replicated the basic result that working memory span is highly correlated with general language comprehension (e.g., Daneman & Tardif, 1987; Dixon, LeFevre, & Twilley, 1988; Masson & Miller, 1983; Turner & Engle, 1989). A meta-analysis conducted by Daneman and Merickle (1996) also indicated that measures that reflect the combined processing and storage functions of working memory are better predictors of general language comprehension ability than are those that reflect only the storage component. Further, they report that working memory span predicted language comprehension skill even when the measure of working memory span did not involve language processing (as long as some form of symbolic processing was involved).

Working memory capacity can influence language comprehension in a variety of different language processing situations (see Just and Carpenter, 1992). For example, Daneman and Carpenter (1980) report that a strong relation exists between working memory capacity, as measured by reading span, and the distance over which readers can integrate information across text constituents. Low working memory capacity has also been shown to be related to a reduction in the speed and accuracy with which sentences can be processed, with increasing difficulty being manifested as sentences become more complex in structure (King & Just, 1991). In addition, Just and Carpenter (1992) report that higher working memory capacity increases the likelihood that individuals will use nonsyntactic information to avoid being led down the garden path by syntactic ambiguity. There is also evidence that individuals with a higher working memory capacity were more likely to represent more than one interpretation of a syntactic ambiguity during on-line processing until disambiguating information was presented at some later time (MacDonald, Just, & Carpenter, 1992).

The general influence of working memory capacity on language comprehension can be summarized as follows. When increasing demands are placed on working memory capacity during language comprehension activities, language comprehension performance is likely to suffer. Individuals with lower working memory capacity or who must use more of their available capacity for language processing activities will exhibit a greater decline in comprehension performance than will individuals with higher working memory capacity as processing demands associated with language increases.

B. Working Memory and Language Comprehension: Individuals with Mental Retardation

Assessments of the working memory system of persons with mental retardation have generally shown that a basic similarity exists between the structure of working memory for persons with and without mental retardation. For example, researchers have demonstrated the expected dissociation between measures of verbal memory (reflecting the operation of the articulatory–phonological loop) and measures of visuo-spatial memory (reflecting the operation of the visuo-spatial sketch pad) (e.g., Jarrold, Baddeley, & Hewes, 1999; Wang & Bellugi, 1993). What has also been observed in many of these studies is that individuals with Down syndrome exhibit relative deficiencies in verbal memory and strengths in visuo-spatial memory, whereas individuals with Williams syndrome exhibit the opposite pattern (Grant et al., 1997; Wang & Bellugi, 1994). We will return to the relation between these results and language performance below.

Recently, Numminen et al. (2000) conducted a systematic evaluation of working memory structure of persons with mental retardation. They presented individuals with IQs between 35 and 70 with a battery of tests representing measures of phonological processing, visuo-spatial processing, central executive functions, intelligence, language skills, general academic skills, and everyday memory. Factor-analytic procedures isolated two separate components of working memory: one corresponding to the articulatory–phonological loop, and one corresponding to a combined visuo-spatial sketch pad and central executive that they considered a general component of working memory. On the surface, this may seem contrary to the model described by Baddeley. However, as noted by the authors, recent research has shown that the sensitivity of particular tasks in assessing components of working memory may vary with intellectual level (Engle et al., 1999) and with developmental level (Gathercole & Pickering, 2000). Thus, rather than assuming that working memory is structurally different for these different groups, they concluded that it is more reasonable to expect that the structures are similar but that individuals probably responded to the basic tasks differently.

Comparing working memory performance to participants' performance on the various skills tests, Numminen et al. reported that measures of general intelligence (Raven's and Similarities of the WAIS-R) were related to the general component of working memory, but not related to the articulatory–phonological loop. All academic measures (reading, writing, vocabulary, sentence comprehension, mathematics, and everyday memory) were also related to the general component of working memory. Reading, writing, and sentence comprehension were related to the phonological loop; however, other aspects of language skills were not (vocabulary and story recall). This pattern of performance is fundamentally the same as is typically observed for individuals without mental retardation: measures that reflect general intelligence are associated with the central executive while measures that reflect more specific competencies are associated with the slave systems. In this study, Numminen et al. were able to isolate one slave system and found that it was specific to some language skills. The failure to observe significant relationships between the functioning of the phonological loop and vocabulary or story recall was not particularly surprising. First, as mentioned previously, the correlations between current vocabulary level and phonological memory are not particularly strong as developmental level increases and the participants of Numminen et al. appear to have represented a wide range of ability levels. Second, story recall does not appear to rely heavily on phonological working memory.

Research specific to evaluating aspects of the articulatory–phonological loop with persons with mental retardation has been conducted to compare

processing and memory differences among different etiologies. In many respects, this research has taken the opposite approach from working memory research in the general literature. That is, rather than evaluating working memory and then trying to predict language performance, researchers have observed differences in language skills among different etiologies of mental retardation and have tried to predict differences in working memory performance. The typical evaluation consists of comparing performance on a digit span or word span task with performance on some version of the Corsi blocks task (Milner, 1971). In the Corsi blocks task, the experimenter points to a block or several blocks in sequence and the participant is required to point to the same blocks in order. The digit and word span tasks are presented aurally and reflect the operation of the articulatory–phonological loop, whereas the Corsi blocks task is presented visually and reflects the operation of the visuo-spatial sketchpad. Individuals with Down syndrome exhibit difficulties with language processing that are greater than would be predicted by measures of general intellectual functioning and also exhibit shorter digit and word spans relative to Corsi block spans than control participants matched on general intellectual functioning (e.g., Jarrold & Baddeley, 1997; Marcell & Cohen, 1992; Vicari, Carlesimo, & Caltagirone, 1995). Individuals with Williams syndrome exhibit stronger language processing skills than would be predicted based on measures of general intellectual functioning and exhibit digit and word spans that are often equivalent to persons without mental retardation matched on chronological age, but exhibit shorter Corsi block spans (e.g., Grant et al., 1997). Hence, a general relation between phonological working memory and language performance by persons with mental retardation has been demonstrated.

The operation of the phonological loop is related to vocabulary acquisition in typically developing children (ages 4 and 5) and the rate at which unfamiliar words are learned by adults (Gathercole & Baddeley, 1993). Unfortunately, relatively few studies assessing the relation between phonological processing and vocabulary have been conducted on persons with mental retardation. Investigations across etiologies have generally established that persons with Williams syndrome and persons with Down syndrome exhibit very different behavior profiles with respect to language development. These differences in language performance also include differences in vocabulary performance: individuals with Williams syndrome exhibit better performance on most measures of vocabulary than do individuals with Down syndrome (e.g., Jarrold et al., 1999; Klein, & Mervis, 1999; Mervis, & Robinson, 2000; Wang & Bellugi, 1994). Hence, we observe that groups of individuals who exhibit relatively greater impairments on measures of phonological memory processes also exhibit relatively greater

impairments on measures of vocabulary development. This pattern of performance corresponds with the prediction that phonological processing is positively correlated with vocabulary acquisition across etiologies. However, the results of research that has investigated the relation between vocabulary knowledge and phonological processing within etiologies has been less consistent. In single-participant analysis of a 23-year-old woman with Down syndrome, Vallar and Papagno (1993) describe an individual who exhibited relatively preserved functioning of phonological memory processes and also exhibited an excellent vocabulary and strong foreign language learning skills. These results suggest that preserved phonological processing corresponds with preserved vocabulary development and learning. In contrast, Jarrold & Baddeley (1997) did not find significant correlations between auditory digit span and vocabulary comprehension for groups of children with Down syndrome, indicating a potentially weaker link between phonological working memory and vocabulary acquisition for persons with Down syndrome than reported by Gathercole and Baddeley (1993) for typically developing children.

There are at least a couple of reasons why the relation between vocabulary acquisition and phonological working memory may appear weaker for individuals with Down syndrome than for typically developing children (see Numminen et al., 2000). First, a great deal of special attention is paid to the vocabulary development of children with Down syndrome (Girolametto, Weitzman, & Clements-Baartman, 1998; Kumin, 2001; Kumin, Councill, & Goodman, 1998). It is reasonable to expect that relations that hold during normal development may be attenuated when extraordinary means of instruction are employed. Second, it may be that word and digit span measures are influenced by factors other than phonological processing for persons with mental retardation more than they are for persons without mental retardation. Recently, Connors, Carr, and Willis (1998) evaluated differences in word span for individuals with undifferentiated mental retardation and individuals without mental retardation who were matched for either chronological or mental age. Significant differences in word span were substantially reduced when measures of central executive processing were taken into account.

Laws (1998) recently reported a study comparing phonological memory and language skills for persons with Down syndrome using nonword repetition as her measure of phonological memory. Participants were required to listen to and repeat nonwords read to them by the experimenter that varied from one to five syllables in length. Laws compared the relation between nonword repetition and vocabulary comprehension with the relation between auditory digit span and vocabulary comprehension. Partial correlations were conducted among the measures to remove the

effects of age and nonverbal cognitive ability. The correlation between nonword repetition and vocabulary comprehension was substantially larger than the correlation between auditory digit span and vocabulary comprehension (0.44 vs 0.18, respectively). Hence, the relation between phonological memory and vocabulary may depend, in part, on the measure of phonological memory that is used (cf., Comblain, 1999).

A more direct relation between the operation of the central executive and language comprehension has been reported in the literature on persons without mental retardation (Daneman & Carpenter, 1980; Daneman & Merickle, 1996; Gathercole & Baddeley, 1993; Just & Carpenter, 1992). This relation has been observed comparing both individual differences in working memory capacity (Daneman & Carpenter, 1980) and group differences in working memory capacity (Kemper, 1986) to measures of language comprehension. Such differences may be manifested in a variety of ways, but generally reflect the observation that differences in language comprehension increase between groups differing in memory capacity when increasing demands are placed on working memory.

One theoretical perspective that is consistent with the notion that differences in working memory capacity lead to differences in language comprehension skills between persons with and without mental retardation has been developed by Kail (1992). Kail has suggested that one primary difference between persons with and without mental retardation involves the speed of information processing. Further, after a careful review of 45 studies in which persons with mental retardation performed more slowly on speeded tasks than did persons without mental retardation, he concluded that some global mechanism, such as limited processing resources, was responsible for group differences on speeded tasks. Because the allocation of processing resources is a function of the central executive, differences in general processing speed may be considered to reflect differences in working memory capacity.

Merrill and Marr (1987) assessed the relation between increased processing demands and the speed of language processing for adolescents with mild mental retardation and children matched on mental age by presenting sentences and passages at varying rates of speed. Using a compressed speech technique, it was possible to present materials at rates ranging from 100 to 300 words per minute. In one experiment, participants were played individual sentences followed by word probes that were either included or not included in the sentence. Increasing the rate of presentation did not create group differences in the ability to determine whether or not individual words were part of the presented sentences. However, in a second experiment, four-sentence passages were presented at varying rates and comprehension rather than simple storage was assessed. Differences in comprehension were produced by increasing the presentation rate of

sentences: persons with mental retardation exhibited relatively poorer language comprehension when the passages were presented at faster speeds. Language comprehension differences between persons with and without mental retardation emerged when working memory resources were extended even though simple phonological storage differences did not emerge under the same conditions.

The ability to suppress contextually irrelevant and inappropriate meanings of words presented in sentences is generally assumed to be related to working memory capacity as well. Many current models of sentence processing suggest that sentences are encoded and understood in a series of steps (Kintsch & Mross, 1985; Till, Mross, & Kintsch, 1988). Initially, word recognition involves the activation of both context-appropriate and context-inappropriate aspects of a word's meaning. It is only over time (less than a second) that comprehension activities focus on context-appropriate meanings, with context-inappropriate meanings being suppressed or allowed to fade as words in the sentence are semantically integrated. In a series of studies, my colleagues and I evaluated the relative abilities of persons with and without mental retardation to restrict meanings of words to context-appropriate features during language comprehension.

Merrill and Bilsky (1990) compared the sentence representations constructed during language processing by persons with and without mental retardation. The participants with mental retardation were adolescents with mild mental retardation and the participants without mental retardation were matched on either mental age or chronological age. During the experiment they were presented with a series of sentences, after which their memory for the sentences was tested using a cued recall paradigm. The cues were either the noun of the original sentence, the verb of the original sentence, or the noun plus verb of the original sentence. The logic underlying the cue manipulation was that the two-word cue would be relatively better to the extent that participants had created a semantically integrated representation of the sentence during processing that focused on context-appropriate meanings of the words (the two-word cue and the sentence representation would only include context-appropriate word meanings, whereas the one-word cues would contain both context-appropriate and context-inappropriate word meanings). If they did not construct integrated representations, then the two-word cue would not be any better than the combined performance to the two one-word cues, because the one-word cues would be providing the same information as the two-word cue (i.e., both would include context-appropriate and context-inappropriate information). The results indicated that the chronological age-matched participants without mental retardation exhibited the greatest two-word cue advantage, whereas the participants with mental retardation

exhibited the smallest two-word cue advantage. It was concluded that the participants with mental retardation exhibited a difficultly in language processing that reflected a deficiency in semantically integrating words in a sentence during auditory sentence processing.

Merrill and Jackson (1992a,b) conducted two follow-up investigations that indicate that the semantic processing difficulties exhibited by persons with mental retardation in the Merrill and Bilsky experiment may be due to working memory capacity differences. Merrill and Jackson (1992b) conducted a similar study to Merrill and Bilsky (1990) except that in one condition a pictorial representation of the sentence was included with the auditory presentation of the sentence. Although presenting a picture with the sentence probably does many different things, one likely change in processing is that the working memory capacity requirements associated with sentence processing are considerably less when a picture is presented with the sentence than when a picture is not presented with the sentence. The results indicated that participants with mental retardation exhibited a similar two-word cue advantage as chronological age-matched participants without mental retardation when the working memory capacity requirements of semantic integration were lessened by the picture manipulation.

Merrill and Jackson (1992a) manipulated working memory capacity by presenting sentences in which the individual words were more semantically related (e.g., The hunter shot the rabbit) or less semantically related (e.g., The photographer chased the rabbit). The logic was that a sentence consisting of semantically related words would require fewer working memory resources to construct a semantically integrated representation than would a sentence consisting of semantically unrelated words. Consistent with expectations, individuals with and without mental retardation matched on chronological age performed in a similar manner when processing sentences constructed from semantically related words. However, the participants with mental retardation did not perform as well as the participants without mental retardation when the sentences were constructed from semantically unrelated words. The results of this series of experiments supports the suggestion that differences in sentence processing between persons with and without mental retardation may be closely related to general working memory capacity.

C. Summary

Two components of working memory are directly or indirectly related to general language comprehension: the articulatory–phonological loop and the central executive (typically assessed by reference to working memory capacity). The phonological loop has primary responsibility for vocabulary acquisition and the learning of novel words. The best available

evidence indicates that this relation holds for persons with mental retardation as well as persons without mental retardation. The best available evidence also indicates that differences in phonological processing are not directly related to differences in auditory language comprehension between persons with and persons without mental retardation. On the other hand, working memory capacity, which is highly correlated with measures of general intelligence, also appears to be highly correlated with measures of language comprehension. Unfortunately, we cannot tell from the research we have reviewed whether working memory capacity is a better predictor of language comprehension than are our measures of general intelligence or if we are simply measuring the same thing in more than one manner.

We offer one caveat to these specific conclusions. Research on persons who exhibit normal to above normal working memory capacity has not produced evidence of a direct relation between the activities of the articulatory–phonological loop and language comprehension. It may be that differences in phonological processing can be ameliorated if individuals possess at least a normal working memory capacity. The fact that persons with mental retardation are generally characterized by below average working memory capacity may limit their ability to overcome other deficiencies, such as those that may be associated with the phonological loop. It is quite possible that persons with mental retardation will exhibit correlations between memory mechanisms and comprehension that are not exhibited by persons without mental retardation in some instances. Hence, it would be inappropriate to conclude that the operation of the articulatory–phonological loop is not related to language comprehension for persons with mental retardation on the basis of results obtained in research on persons without mental retardation. Numminen et al. (2000) provide a good starting point for evaluating working memory structure and operations associated with mental retardation without worrying about how they compare to persons without mental retardation. This type of research should continue. It would also be interesting to evaluate the role of the articulatory–phonological loop when working memory capacity is experimentally equated (e.g., test at individually determined half and full working memory capacity being utilized for other tasks) across individuals. Correlations that are not observed when working memory capacity is allowed to vary may emerge when it is experimentally equated.

III. SEMANTIC MEMORY

As mentioned earlier, language comprehension has typically been equated with the construction of a coherent semantic representation of

discourse (see Lorch & van den Brock, 1997). Lorch (1998) has noted that early models of text comprehension (e.g., Kintsch & van Dijk, 1978) relied heavily on the mechanisms described by models developed for understanding the representation and processing of semantic knowledge (e.g., Anderson & Bower, 1973; Collins & Loftus, 1975; Kintsch, 1974). This emphasis is also evident in current theoretical approaches (e.g., Gerrig & McKoon, 1998; Kintsch, 1988; McKoon, Gerrig, & Greene, 1996). One important change in emphasis associated with the more recent models involves a consideration of the role of how individuals use their background knowledge during language comprehension activities (Lorch, 1998). Hence, for many current theorists, language comprehensions activities are assumed to engage a highly automated memory retrieval process (e.g., Myers & O'Brien, 1998). Current debate centers on the degree to which memory retrieval during language processing is restricted to only those aspects of discourse and background knowledge that are relevant to the interpretation of the text (e.g., Albrecht & O'Brien, 1993; Fletcher & Bloom, 1988; Glenberg & Langston, 1992; O'Brien, Rizzella, Albrecht, & Halleran, 1998) and the degree to which language comprehension requires an evaluative, constructivist component as well as a resonance based, automatic memory retrieval component (e.g., Noordman & Vonk, 1992; Singer, Graesser, & Trabasso, 1994). Regardless of the outcome of these debates, it is clear that semantic memory is generally considered integral to language comprehension.

Semantic memory, as we use it here, refers to a context-free repository of knowledge about concepts, words, and nonword symbols. Semantic memory is generally assumed to be highly organized (Anderson, 1983, 1993; Collins & Loftus, 1975; McClelland, Rumelhart, & Hinton, 1988). Many semantic memory models view semantic memory as a network of interrelated conceptual nodes linked together by labeled pathways that specify particular relations between the nodes (Anderson, 1983, 1993; Collins & Loftus, 1975; Collins & Quillian, 1972). For example, the concept "canary" may be linked to the concept "bird" by a "member of" pathway and to the concept of "yellow" by a "property of" pathway. In these models, several assumptions are made about the basic processes that operate on semantic memory that may impact language comprehension. First, memory retrieval, or accessing the meaning of a concept, involves the automatic activation of the node above its resting state when the word or symbol representing the node is encountered. Second, when an individual node is activated, activation spreads from that node to other conceptual nodes with which it is linked in the network. Further, this activation spreads from these newly activated nodes to others with which they are linked, resulting in the full elaboration of meaning for any given word or symbol that is encountered.

Third, much of what we know are things that we never directly learned, but can easily infer from evaluating interconnections of activated conceptual nodes. For example, most of us did not directly learn that a canary has wings. Rather, we learned that a bird has wings and that a canary is a bird. From these two pieces of information, we "know" that a canary has wings.

In addition to knowledge about basic concepts, people also have knowledge about general objects and events that are often constructed from multiple concepts. These units of knowledge have often been referred to as schemas (e.g., Rumelhart & Ortony, 1977) or scripts (Schank & Abelson, 1977). The script or schema is assumed to reflect typical information about common events rather than a specific episode. Hence, we would have a schema for going to a restaurant but not for going to a restaurant with Carol last Wednesday night. Scripts are assumed to be flexible and can vary in their degree of abstractness. Script knowledge allows us to infer actions that are not explicitly stated in a conversation or text. For example, if you hear that I went to a restaurant with Carol last Wednesday night, ate some enchiladas, and left a big tip, it is likely that you would infer a variety of other actions occurred, as well. It is likely that I sat down, ordered from a menu, enjoyed my food, was pleased with the service, paid my check, and left the restaurant. None of these activities was stated in the description, but they are part of our understanding of the event I described. Scripted knowledge is assumed to facilitate general comprehension of information with which individuals are reasonably familiar.

In the next two sections, we consider the role of semantic memory in discourse comprehension. In the first of these sections, we review the basic findings from research on persons without mental retardation. The intent of this review is to demonstrate the basic influence of semantic memory on discourse processing. Most of the studies that we discuss in this section are relatively older. However, the basic findings have not changed over the years, only the theoretical constructs used to explain them. In the second section, we first review studies that evaluate the basic similarities and differences of semantic memory for persons with and without mental retardation. This is followed by a review of research that compares similarities and differences in how semantic memory influences discourse comprehension processes for persons with and without mental retardation.

A. Semantic Memory and Language Comprehension: Persons without Mental Retardation

It is reasonable to assume that language comprehension is related to semantic knowledge in fundamental ways. In a series of studies, Anderson

and colleagues (e.g., Anderson, 1977; Anderson et al., 1976; Anderson & Ortony, 1975) have revealed a number of important ways that semantic knowledge facilitates language comprehension. For example, semantic knowledge provides the basic framework for assimilating text information. In a sense, the semantic framework has slots that can be filled with new information consistent with the framework and facilitates the learning and remembering of the new information. In addition, semantic knowledge directs attention during the comprehension process. Attention is directed to aspects of the verbal material that are deemed important and relevant by the semantic framework. Finally, semantic knowledge facilitates inferential elaboration and reconstruction. Comprehension typically involves making reasonable guesses about information that is not directly given as we listen and read. Semantic knowledge provides the basis for the memory search, editing, and summary processes that make our guesses more likely to be correct than incorrect. Following are several examples of the influence of top–down processing on language comprehension.

Anderson and Ortony (1975) reported that it is common for persons to instantiate specific exemplars consistent with sentence context and general world knowledge when they encounter superordinate labels during discourse processing. For example, they found that when participants were presented sentences such as "The container held the cola" they were likely to remember the container as a "bottle" and when presented sentences such as "The container held the apples" they were likely to remember the container as a "basket." The degree to which these instantiations are made spontaneously is influenced by many factors, including the amount of context available to support the instantiation and the degree to which the specific term is a typical or atypical member of the general category (Rosch, 1975). Nevertheless, it is clear that the ability to perform this operation requires a reasonably well-developed semantic knowledge base, and the specificity of comprehension depends on the ability to perform this operation.

Owens, Bower, and Black (1979) illustrated the importance of activated semantic knowledge providing a semantic framework in basic comprehension activities. They had college students read paragraphs such as the following:

> "Nancy went to see the doctor. She arrived at the office and checked in with the receptionist. She went to see the nurse, who went through the usual procedures. Then Nancy stepped on the scale and the nurse recorded her weight. The doctor entered the room and examined the results. He smiled at Nancy and said, "Well, it seems my expectations have been confirmed." When the examination was finished, Nancy left the office." (p. 186)

Two groups of participants read the story, with the only difference between the two groups being that the one group read a brief thematic statement before they read the story that included the following information:

> "Nancy woke up feeling sick again and she wondered if she really were pregnant. How would she tell the professor she had been seeing? And the money was another problem." (p. 185)

Twenty-four hours later, the participants were asked to recall the story. Participants who had read the thematic statement before they read the passage were able to recall many more facts that were stated in the passage than those who were not provided the theme ahead of time. In addition, they recalled many more facts that were inferred from the passage, but were not directly stated in the passage. The theme, which resulted in an activated base of knowledge for comprehending the passage, allowed for a much richer interpretation of the passage and a more durable memory of what was read (and inferred).

Anderson and Pichert (1978) illustrated how comprehension is influenced by contextual and situational biases. Participants in their study were asked to read a story about the home of a fairly wealthy family from the standpoint of someone considering either the purchase or the burglary of the house. Included in the description of the house were features such as a leaky roof, musty basement, fireplace, coin collection, silverware, and television set. Consistent with expectations, memory about specific features described in the passage was influenced by the participants suggested role: the "burglars" remembered more information about the valuable contents of the house and the "prospective-buyers" remembered more information about the condition of the home. In this case, a selectively activated knowledge base associated with the reader's purpose encouraged a selective encoding and comprehension of information in the passage.

Bower, Black, and Turner (1979) demonstrated that familiarity in the form of activated knowledge may also have a cost if verbatim comprehension and recall is the goal. They presented participants with brief passages such as the following:

> "Bill had a toothache. It seemed forever before he finally arrived at his dentist's office. Bill looked around at the various dental posters on the wall. Finally the dental hygienist examined and X-rayed his teeth. He wondered what the dentist was doing. The dentist said that Bill had a lot of cavities. As soon as he'd made another appointment, he left the dentist's office." (p. 190)

In testing, Bower et al. presented old sentences (The dentist said Bill had a lot of cavities), new related sentences (Bill checked in with the dentist's receptionist), and new unrelated sentences (The receptionist took out the

coffee pot and filled it with water). Participants often mistakenly reported that new related sentences were actually a part of the original passage.

Despite the fact that accessing prior knowledge may contribute to less accurate verbatim memories during language comprehension, it is generally accepted that language materials that are consistent with activated prior knowledge are easier to comprehend and remember (e.g., Bransford, 1979; Bransford & Stein, 1984). However, distinctive and unusual events may be exceptions to this generalization (see e.g., Bellezza, 1983; Bellezza, & Bower, 1981; Graesser, 1981). It appears that novel and unexpected objects that find their way into events are typically much better remembered than irrelevant events. Atypical events may, in fact, receive more processing than typical events (Bellezza, 1983; Bellezza, & Bower, 1981) and be better remembered as a result.

More recently, the concept of "mental model" has been applied to the understanding of text comprehension by adults without mental retardation (see Johnson-Laird, 1983). According to Johnson-Laird, mental models are structural analogues of the environment and can encompass many different concepts and schemas and the relations between them. An important feature of mental models is that they are dynamic and are continually updated as comprehension proceeds. Morrow, Greenspan, and Bower (1987) had participants learn the locations of various objects in several rooms of a building. The building was used as the setting for a narrative that was subsequently presented to the participants. During the narrative, a test sentence was presented, such as "Wilber walked from the library into the reception room." Following the test sentence, the participants were presented with probes that consisted of two of the objects whose locations they had previously memorized. Their task was to determine whether or not the two objects were in the same room. They found that decision times were shorter if the objects were located in the current room of the individual depicted in the narrative, suggesting that the participants were constructing and updating dynamic representations of the narrative during comprehension activities (see also Glenberg, Meyer, & Lindem, 1987). Additional research has found that similar updating occurs for temporal information (e.g., Bestgen & Vonk, 1995), features of the primary characters (e.g., Myers, O'Brien, Albrecht, & Mason, 1994), and goals and intentions of the characters (e.g., Dopkins, 1996; Long, Golding, & Graesser, 1992).

B. Semantic Memory and Language Comprehension: Persons with Mental Retardation

Many aspects of semantic memory appear to operate in a similar manner for persons with and without mental retardation of the same chronological

age (Cody & Borkowski, 1977; Glidden, 1986; Sperber & McCauley, 1984; Sperber et al., 1976; Winters & Cundari, 1979). In the majority of these studies, semantic memory has been evaluated in terms of the relatively spontaneous activation of related concepts when a picture or word representing a particular concept is presented. For example, Sperber and his colleagues used semantic priming procedures to evaluate the organization of semantic memory of adolescents with and without mental retardation of equal chronological age. For both groups of participants, they observed that the processing of a target picture was faster when it was preceded by a semantically related prime relative than when it was preceded by a semantically unrelated prime. In addition, the magnitude of facilitation observed for the two groups was virtually identical. Sperber et al. (1976) and Sperber and McCauley (1984) suggested that these data indicate that the basic organization and operation of semantic memory was similar for persons with and without mental retardation.

Winters and Cundari (1979) used a release from proactive interference procedure and found that the spontaneous influence of semantic knowledge on short-term memory was similar for persons with and without mental retardation of the same chronological age. In this procedure, participants are presented with a short list of words from a single semantic category to commit to short-term memory. As additional lists of words from the same category are subsequently presented, we generally see an increase in intrusions from previous lists. When a list from a new category is presented, interference from previous lists is eliminated (Wickens, 1970). Persons with and without mental retardation exhibit a similar pattern of performance on these tasks, suggesting that semantic memory exerts a similar influence on the basic encoding processes of both groups of individuals.

Researchers have also demonstrated that the "typicality effects" (Rosch, 1973, 1975) characteristic of adult semantic organization are also characteristic of persons with mental retardation. More specifically, category membership is not an "all or none" feature. For adults without mental retardation, some members are better examples of a category than are others and are given preferential treatment when category information is employed in language comprehension and decision-making. For example, a "robin" is a more typical bird than is an "ostrich." When asked the question "Do birds fly?", most individuals respond "yes" because most birds are like the typical robin that does fly rather than like the atypical ostrich that does not fly. Children and persons with mental retardation exhibit typicality effects that operate in a manner similar to adults without mental retardation. However, there is some evidence indicating that the category exemplars that are considered typical versus atypical may vary with age and intelligence (see Bjorklund & Thompson, 1983; Glidden & Mar, 1978).

One potentially important difference in the processing of basic semantic information by chronological age-matched persons with and without mental retardation was reported by Sperber, Davies, Merrill, and McCauley (1982). They classified categories as "perceptual" or "nonperceptual" on the basis of raters' judgments of the similarity or distinctiveness of the exemplars of the category. For example, categories such as "four-legged mammals" and "land vehicles" were judged to be perceptual categories because many of the exemplars share similar perceptual features whereas categories such as "furniture" and "clothing" were judged to be "nonperceptual" because exemplars share relatively few perceptual features. Participants in their study included adolescents with mental retardation and second-, fifth-, and eleventh-grade participants without mental retardation. In the procedure, participants were presented with a prime (the name of the category or a neutral word) followed by a picture and had to identify the picture. All participants benefited from the category prime when identifying pictures from perceptual categories; however, only the eleventh grade participants benefited from the category prime when identifying pictures from nonperceptual categories. Apparently, all conceptual information is not created equally. We now consider the distinction between perceptual and nonperceptual categories to reflect something analogous to the distinction made by Keil and others (see Keil, 1989; Keil, Smith, Simons, & Levin, 1998) between concept formation based on similarity and concept formation based on rules. Similarity-based concepts appear to operate the same for persons with and without mental retardation, whereas rule-based concepts, which are not typically acquired until children reach a more advanced developmental level, operate differently. Hence, demonstrating equivalence in the use of semantic knowledge in language comprehension for one set of concepts may not necessarily generalize to all other concepts.

There are a few studies that have evaluated the use of semantic information during sentence comprehension activities by persons with and without mental retardation. For example, Bilsky, Walker, and Sakales (1983) evaluated the likelihood that adolescents with mental retardation would instantiate specific instances of general concepts during sentence processing. Participants were presented with experimental sentences of the type "The bug stung her arm" or control sentences of the type "The bug crawled up her arm." The former was intended to constrain comprehension by inferring that a specific exemplar was involved (e.g., the bug was a bee) and the latter was not. Using a cued recall measure, they presented either the specific term or the general term to cue the recall of these sentences. They found that the specific cues (e.g., bee) were more effective as a cue for the experimental sentence than for the control sentence, and the specific term was just as

effective in cueing the experimental sentence as the general term. More importantly, they reported that the adolescents with mental retardation benefited from the use of the specific cue just as much as did a group of children without mental retardation with whom they were matched on mental age. Apparently, both groups were able to infer the specific instance during sentence comprehension activities and did so to the same degree. Hence, it appears that semantic memory processes influenced comprehension equally for persons with and without mental retardation in this study.

An extensive search of the literature produced limited results concerning more systematic evaluation of the influence of semantic knowledge on language comprehension processes of persons with mental retardation. However, there is some research that is relevant to the issue. For example, Kim and Lombardino (1991) found that script-based training was more effective than nonscript based training in teaching young children with mental retardation to understand a variety of sentences constructions. The students were four children with mental retardation with measured mental ages ranging between 23 and 30 months and chronological ages between 61 and 78 months. For the script based treatment conditions, the sentence constructions were embedded in the context of popcorn-, pudding-, or milkshake-making. For the nonscript based treatment conditions, the sentence constructions were trained in the context of "playing with some toys." The researchers found that the training of sentence constructions was more effective in the script conditions for three of the four children.

Bilsky, Blachman, Chi, and Chan-Mui (1986) compared the performance of adolescents with mental retardation and mental age-matched children without mental retardation on the ability to generate inferences from story passages. The participants were presented with ambiguous story passages that permitted story-based inferences or computational inferences. Prior to the presentation of the passages, the participants were given instructions that encouraged the processing of the passage as a story, a math problem, or neutral instructions. For all participants, story inferences were processed more accurately under story and neutral set instructions than under math set instructions (Experiment 1). In a second experiment, the desired processing context was further encouraged by embedding target items in story passages or math problems. In this experiment, the accuracy of computational inferences generated by the participants was increased under math set conditions. These results are generally consistent with the notion that different comprehension strategies are employed in contexts that encourage the interpretation of texts as either math problems or stories. Hence, it appears that activation of the appropriate

knowledge base is an important contributor to the comprehension processes of both persons with and without mental retardation.

C. Summary

The results of the studies we have described reveal a fundamental similarity in the ways in which semantic knowledge influences language comprehension for persons with and without mental retardation of the same chronological age. However, we suggest considerable caution in accepting this general conclusion for several reasons. First, activation of the appropriate knowledge base does not appear to be done spontaneously by persons with mental retardation as regularly or effectively as it is done by persons without mental retardation of the same mental age. It is good that semantic knowledge provides a similar basis for comprehension for persons with and without mental retardation, but it is only effective when semantic knowledge is accessed. Similar deficiencies in other aspects of the conscious use of semantic information by persons with and without mental retardation of the same mental age have been noted over the years (Cody & Borkowski, 1977; Davies, Sperber, & McCauley, 1981; Glidden & Mar, 1978; Sperber et al., 1976). Second, each of these studies provides data about relatively rudimentary aspects of semantic knowledge on language comprehension. It is likely that there are differences in the details of semantic knowledge that are available to persons with and without mental retardation, and these details may lead to important differences in aspects of comprehension not assessed in the studies described here. Third, the use of semantic knowledge in comprehension requires that knowledge be applied in a flexible manner. For example, in our discussion of a restaurant script earlier, we indicated that a reasonable inference would be that Carol and I sat down at a table and ordered food from a menu. There are restaurants at which an individual is more likely to sit or even stand at a counter and order from a menu over the top of the food counter. A script or story schema must be flexible enough to handle these changes. It is reasonable to question whether scripts used by persons with mental retardation are as flexibly employed as those by persons without mental retardation. Fourth, the activation and use of semantic knowledge during comprehension may commonly involve working memory. To the extent that this is true, we would expect differences in comprehension performance between persons with and without mental retardation even when all differences in semantic memory are controlled. Fifth, the ability of persons with mental retardation to construct and efficiently use mental models to maintain coherence during discourse processing has yet to be evaluated. This avenue of research should prove fruitful. Clearly, there is a lot of

research yet to be conducted on semantic memory processes of persons with mental retardation.

IV. TACIT MEMORY

Tacit, or procedural, memory refers to a system of memories that are used to perform skills, but are not directly accessible for conscious inspection; that is, procedural knowledge will allow us to perform many activities efficiently and accurately, but not allow us to explain exactly how we have performed them (Anderson, 1982). Many researchers have suggested that language comprehension and production include important contributions from a tacit memory system (e.g., Chang, Dell, Bock, & Griffin, 2000; Dell, Reed, Adams, & Meyer, 2000; Mathews, 1997; Nagy & Genter, 1990). This conclusion is based on two general observations. First, people typically are able to make judgments about the grammaticality of sentences but are often unaware of the reasons underlying their judgments. Second, at least some of the ability to judge grammaticality is learned. Because some sentence constructions are grammatical in some languages and not other languages, it is reasonable to claim that some aspects of grammar are learned rather than innate (see Lachter, 1994). To the extent that these assumptions are true, then language comprehension can be viewed as a learned skill.

Another line of research that implicates the tacit memory system in language activities has recently been reported by Saffran and her colleagues (Aslin, Saffran, & Newport, 1998; Saffran, Aslin, & Newport, 1996; Saffran, Newport, & Aslin, 1996; Saffran, Newport, Aslin, Tunick, & Barruecco, 1997). For example, Saffran et al. (1996) presented 8-month-old infants with artificial languages consisting of "words" that were made up of three nonsense syllables. These words were presented continuously in random order for a period of 2 min. The infants were then tested for their ability to discriminate these words from part words and nonwords made from the same nonsense syllables. During testing, the infants attended to part words and nonwords for a longer period of time then they attended to the words, indicating an ability to distinguish the words from the nonwords and part words with only limited exposure. Because no other information was available to the infants, Saffran et al. concluded that the infants' learning and discrimination performance was based on statistical information associated with transitional probabilities between successive syllabi (see also Aslin et al., 1998). We consider this tacit learning and memory because it is unlikely that the infants were consciously aware of these transitional probabilities. Hence, some aspects of language processing appear to be accessible to a tacit memory system at a very young age.

It is also the case that efficient use of the tacit memory system is generally considered indispensable in the performance of virtually all skilled behavior (Anderson, 1983; Keil, 1989; Sun, Merrill, & Peterson, 2001; VanLehn, 1991). As skill develops, the performance of the skill becomes more and more automatic, requiring less attention to be performed and interfering less with other ongoing cognitive activities (Anderson, 1982). When a skill reaches this stage, the procedures used to carry out the skill are assumed to reflect the operation of a tacit, not accessible to consciousness, memory system. An early and interesting demonstration of the automatization of skill was reported by Spelke, Hirst, and Neisser (1976). Their participants performed a reading comprehension task while taking dictation. At first, combining the two tasks was extremely difficult. However, after several weeks of practice the participants' reading comprehension returned to pre-experimental levels while performing near perfect dictation. Interestingly, they could not remember any of the words they were transcribing, suggesting that conscious memory was not responsible for performance on the dictation task. To the extent that language comprehension reflects a skilled behavior, it is likely that tacit memory plays an important role in general language comprehension as well. Therefore, it is necessary to evaluate differences in the acquisition of tacit memories and the use of the tacit memory system by persons with and without mental retardation and to consider the contribution of these differences to language comprehension. Because the relations between tacit memory and language comprehension have not been studied directly, we will focus on the development of tacit memories in the next section.

A. Tacit Memory Research on Persons without Mental Retardation

Tacit memory of persons without mental retardation is generally studied in the context of skill acquisition (Anderson, 1982, 1983; Keil, 1989; VanLehn, 1995). One way that tacit memories are acquired is through "proceduralization." For Anderson (1982), the initial stages of skill acquisition are characterized by the acquisition of basic declarative (i.e., explicit) knowledge about the task to be performed. More specifically, people often learn specific rules and steps that enable them to perform the task first, and the task can only be performed with careful attention directed toward each step (the classic example is learning to drive a car). Through extensive practice, performance of the task becomes proceduralized, which is accomplished by converting explicit, declarative knowledge in the form of instructions into production rules. Production rules allow people to perform the task without attending to declarative knowledge about how to perform

the task, and in many cases without awareness of any of the details of task performance. Other researchers have described a similar progression from declarative to procedural, or tacit, memory in the areas of general skill acquisition (Fitts & Posner, 1967), concept formation (Keil, 1989), and verbal information reasoning (Sun, 1994).

Several lines of research have developed in recent years that indicate that people may also learn to perform complex skills without learning extensive declarative knowledge first (e.g., Lewicke, Hill, & Czyzewska, 1992; Mathews et al., 1989; Reber, 1989; Reber & Lewis, 1977). This process has been called "implicit learning." For example, in the domain of artificial grammar learning Reber and colleagues have conducted an extensive series of studies on the possibility that relatively complex rules can be acquired without learning declarative knowledge in the domain (Reber & Lewis, 1977; Reber, 1967, 1976, 1989). Participants were asked to commit a series of letter strings to memory, where the letter strings were formed on the basis of a set of probabilistic rules or were formed randomly. They were not told of the rules or informed that rules were used to construct the letter strings. After experience with "rule-based" letter strings, participants were able to commit new rule-based strings to memory more rapidly than they were able to do without prior experience of the strings. In addition, they were able to classify new strings as grammatical or not grammatical at levels significantly above chance. However, they were not able to explicitly state the rules of grammar that allowed them to classify the new letter strings. Although somewhat controversial because it is difficult to demonstrate with certainty that conscious learning does not play a role in laboratory investigations of these tasks, many researchers believe that implicit learning plays an important role in the learning of language, communication, and social skills (e.g., Lachter, 1994; Mathews, 1997).

B. Tacit Memory Research on Persons with Mental Retardation

Studies of proceduralization have not been conducted on persons with mental retardation. However, Merrill, Goodwyn, and Gooding (1996) have examined the role of extensive practice in the development of automatic processing in a relatively simple visual search task by persons with and without mental retardation. Participants with and without mental retardation (matched on chronological age) were given extensive practice searching through sets of two, three, and four pictures for instances of a designated target category (e.g., clothing). Over a period of 4 days, participants received approximately 1200 search trials. Automatic processing was indexed by a reduction in search rates that indicated that search

times were not influenced by the number of items in the search set. This measure was used because automatic processing is assumed to allow parallel processing, whereas conscious processing is assumed to operate in serial fashion (see Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). When search times are unaffected by set size, the indication is that the items in the set are being searched in parallel. In the experiment, the participants without mental retardation exhibited evidence of automatic processing after about 2 days of practice, whereas the participants with mental retardation did not exhibit evidence of automatic processing until they completed 4 days of practice. Assuming that we can generalize the results of this experiment to the proceduralization of more complex activities, we would conclude that persons with mental retardation require much more extensive practice to develop a functional tacit memory of a complex procedure relative to persons without mental retardation of the same chronological age. No corresponding study comparing persons with and without mental retardation on mental age has been conducted.

Atwell et al. (2003) recently reported the results of an experiment designed to evaluate implicit learning by persons with and without mental retardation. Participants in this experiment were also adolescents with and without mental retardation matched on chronological age. The procedure of the experiment was a modified artificial grammar learning task. In this case, participants were exposed to strings of colored geometric figures that were formed on the basis of a set of rules. Following exposure, the participants were shown a series of previously seen strings or new strings that were formed in accordance with the same set of rules or were formed randomly. They had to determine if the strings were previously presented or not. Atwell et al. reasoned that if participants had learned features of the rules that were used to form the original strings, they would be more likely to confuse new strings formed on the basis of the same rules as old strings than they would new strings that were formed randomly. Both groups of participants exhibited more confusions with the rule-based strings than they did with random strings. In addition, the degree to which the groups exhibited differential interference as a function of type of string was essentially identical. One difference between groups was observed, however. To exhibit the same level of implicit learning as the participants without mental retardation, the participants with mental retardation required about twice as many presentations of the original series of geometric forms.

C. Summary

Based on the admittedly limited research conducted to date, we can tentatively conclude that persons with and without mental retardation exhibit

the ability to acquire tacit memories, and that they appear to do so in fundamentally the same ways. However, it is also clear that persons with mental retardation require more experience/practice with the acquisition materials before they exhibit the same degree of tacit knowledge as persons without mental retardation of the same chronological age. Research has not been conducted that examines how persons with and without mental retardation use tacit knowledge during language comprehension. In addition, research has not been conducted that investigates the relative limits of the abilities of persons with and without mental retardation to acquire tacit knowledge and use it in relatively complex skills. To date, research has only demonstrated that persons with mental retardation can acquire tacit memories for relatively simply materials through implicit learning. It may be that the fundamental difference between persons with and without mental retardation in tacit memory reflects a difference in the degree of complexity of information that can be proceduralized with practice or learned implicitly.

V. CONCLUSION

In this chapter, we have outlined several ways that memory is related to the language comprehension activities of persons with mental retardation. We focused on three memory systems: working memory, semantic memory, and tacit memory. Semantic memory probably plays the biggest role in language comprehension activities. It is in the semantic system that word meanings are stored and organized in a manner that supports language comprehension. However, it is working memory that has been given the majority of credit for explaining individual differences in language comprehension. The role of working memory is to provide resources for and coordinate the retrieval and incorporation of relevant information from semantic memory into developing memory representations that reflect on-line comprehension. Tacit memory may play a relatively indirect, but necessary role in language comprehension. Implicit learning, or the process that is involved in the creation of tacit memories, appears to be involved in the learning of lower-level regularities of language. In particular, research has demonstrated that even children as young as 8-months-old can detect regularities associated with word boundaries. This is a fundamental skill for the development of language abilities.

As is typical of research comparing the performance of persons with and without mental retardation, we found that most studies revealed a basic similarity in the structure and operation of the various memory systems. Language materials are processed and used in fundamentally the same ways by persons with and without mental retardation. However, the level of

language comprehension achieved by persons with mental retardation is considerably less than that achieved by persons without mental retardation. In many instances, comprehension falls below expectations based on measures of general mental age.

Working memory plays a prominent role in on-line language comprehension activities and appears to be closely tied to differences in language comprehension between persons with and without mental retardation. Working memory is also the component of memory assumed to be most closely associated with language comprehension difficulties of persons without mental retardation. More specifically, it is working memory capacity that underlies individual differences in language comprehension. However, in light of the research conducted on persons with Down syndrome and Williams syndrome that we have reviewed, this conclusion may be too general. One important outcome of etiology specific research such as this is the observation that differences in the operation of the articulatory–phonological loop may be responsible for some differences in language comprehension, at least for persons with mental retardation. A reassessment of the role of phonological processing in language comprehension processes of persons with mental retardation resulting from different causes may benefit from procedures that do not allow working memory capacity to vary.

We are cautiously optimistic about the similarities in the use of semantic memory during language comprehension by persons with and without mental retardation. Semantic memory appears to serve very similar functions and operate in much the same way during language comprehension activities for persons with and without mental retardation. Our note of caution reflects the fact that persons with mental retardation do not appear to access semantic memory to facilitate language comprehension activities as readily as persons without mental retardation access semantic memory. This may be due to several factors, with working memory capacity involved here as well. Working memory is used in the retrieval of information from semantic memory. If working memory capacity is insufficient to process language on-line and access semantic memory at the same time, language comprehension is likely to suffer. Another possibility is that persons without mental retardation have a greater expectation that language activities should result in comprehension than do persons with mental retardation. Hence, they actively access semantic memory to facilitate comprehension when they do not understand whereas as persons with mental retardation do not.

Based on our general search of the literature, we have concluded that research considering semantic memory and semantic memory processes and the role of semantic memory in the language comprehension activities of persons with mental retardation has slowed considerably in recent years. Perhaps this has been the result of discovering fundamental similarities,

rather than important differences in the structure and organization of semantic memory for persons with, relative to persons without, mental retardation. However, there are many aspects of how semantic memory is used in general cognitive skills, including language comprehension, by persons with mental retardation that require some research attention. Specific areas that will benefit from further investigation include the following. We would like to see research that evaluates differences between persons with and without mental retardation in the amount of contextual support necessary to spontaneously activate and retrieve relevant background knowledge from semantic memory during language comprehension. We would like to see additional research on whether persons with mental retardation are able to use semantic knowledge in as flexible a manner as necessary for language comprehension activities. In conjunction with the previous suggestion, we believe that research on language comprehension processes by persons with mental retardation would benefit from a consideration of the concept of mental models. To the extent that comprehension of discourse involves a continual updating of information presented in the narrative, mental models provide the features for considering how the updating mechanism operates.

We are intrigued by the possibility that tacit memory may play an important role in language comprehension activities and may be related to differences in the language comprehension of persons with and without mental retardation. It appears that persons with mental retardation do not benefit as much from extensive practice/experience with stimuli as do persons without mental retardation of the same chronological age. Saffran and colleagues (Saffran et al., 1996) have demonstrated that typically developing children as young as 8-months-old benefit from exposure to regularities that occur in language-like materials. Corresponding research on infants at risk for mental retardation and infants diagnosed with syndromes associated with mental retardation would be very informative. If persons with mental retardation are not as sensitive to covariations in the environment as are persons without mental retardation, then we would expect that natural language learning would be much more difficult for the persons with mental retardation. Therefore, research concerning the acquisition and use of tacit memory by persons with mental retardation may prove to be a fruitful area of investigation.

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