CHAPTER 1

Introduction and Overview

Nearly every aspect of human life depends on memory. Individuals who cannot encode, store, or retrieve information must rely on others for their survival. Even mild memory impairments can make daily activities challenging. Because learning depends on memory, deficiencies in any aspect of memory can prevent children and adolescents from acquiring the skills and knowledge necessary for success in life. As the research accumulates, it is becoming quite evident that memory problems are frequently the cause of learning problems. Even individuals with normal memory capacity must utilize their memory resources efficiently if they are to learn effectively. Successful teachers have recognized the limitations of human memory and have discovered how to facilitate the construction of strong memory representations in their students. Therefore, those engaged in supporting learning can be more effective when they have expertise in memory.

The recognition of memory's crucial role in life and learning can be traced back to the days of the ancient Greeks. With the advent of public education in the nineteenth century, American educators began to identify different types of memories and instructional methods designed to support memory. The young science of psychology was also quick to focus on memory models and measurement (James, 1890). For example, the classic digit span test goes back to the 1880s. However, it wasn't until the mid-twentieth century that psychologists were able to identify distinct memory dimensions and functions. More recently, the memory construct known as "working memory" has emerged and refinement of the construct continues to the present day. Currently, research on working memory is at the forefront of neuroscientific investigations. Also, the fields of education and psychology have demonstrated a high interest in learning more about working memory. In the first six months of 2007 alone, more than 150 articles on working memory were published in professional journals.

The scientific literature provides an opportunity to learn more about the functioning of memory and how to treat memory deficits. Acquiring more knowledge about working memory can make a significant contribution to our understanding of how students think, learn, and remember. Armed with such knowledge, we can better identify the probable causes of learning difficulties and suggest evidence-based interventions that address memory deficiencies.

What is Working Memory?

In the study of human cognitive functions over the past 35 years, working memory has been one of the most influential constructs. Traditionally, working memory has been conceptualized as an active memory system that is responsible for the temporary maintenance and simultaneous processing of information (Bayliss, Jarrold, Baddeley, Gunn, & Leigh, 2005). Alternatively, working memory has been defined as the use of temporarily stored information in the performance of more complex cognitive tasks (Hulme & Mackenzie, 1992), or as a mental workspace for manipulating activated long-term memory representations (Stoltzfus, Hasher, & Zacks, 1996). Overall, working memory is viewed as a comprehensive system that unites various short- and long-term memory subsystems and functions (Baddeley, 1986). Diverse working memory theories and models (see Chapter 2) have several structures and processes in common: (1) a division into verbal and visuospatial stores; (2) an encoding function; (3) involvement in effortful retrieval from long-term memory; (4) enactment of strategic processes; and (5) executive and attentional processes. In general, the combination of moment-to-moment awareness, efforts to maintain information in short-term memory, and the effortful retrieval of archived information constitutes working memory. Despite definitions limiting working memory to memory-related functions, many researchers and practitioners use the term broadly. From the perspective offered in this text, we must be cautious when considering the construct of working memory, lest everything that goes on in the mind is classified as working memory. If the construct is allowed to become too inclusive, then its usefulness will decline. Consequently, in this text, the definition of working memory is limited to the management, manipulation, and transformation of information drawn from either short-term or long-term memory (see Chapter 3).

However, it is difficult to delimit working memory and disentangle it from related cognitive processes, such as reasoning. From a broad perspective, working memory is a central cognitive process that is responsible for the active processing of information. It appears to be a fundamental capacity that underlies complex as well as elementary cognitive processes (Lepine, Barrouillet, & Camos, 2005). Working memory supports human cognitive processing by providing an interface between perception, short-term memory, long-term memory, and goal-directed actions. Working memory is particularly necessary for conscious cognitive

processing because it permits internal representation of information to guide decision making and overt behavior. Fundamentally, working memory is one of the main cognitive processes underlying thinking and learning. By utilizing the contents of various memory-storage systems, working memory enables us to learn and to string together thoughts and ideas.

Working memory's relations with various aspects of academic learning (see Chapter 5) mainly arise from its limited capacity. Although there are individual differences, the capacity of working memory is quite restricted, even in individuals with normal working memory resources. For example, the typical individual can only manipulate about four pieces of information at a time (Cowan, 2001). And, unless information is being manipulated, it will only remain in working memory for a short interval, perhaps as little as 2 seconds. Thus, there has always been an emphasis on working memory's limited capacity to retain information while simultaneously processing the same or other information (Swanson, 2000). Because of the central role working memory plays in cognitive functioning and learning, successful learning is largely a function of the individual's working memory capacity. For instance, a child with a severe deficit in verbal working memory is likely to have a reading disability (see Chapter 5). Moreover, given the inherent limitations of working memory, efficient utilization of its resources is important for all individuals, not just those with working memory deficits.

In our daily activities, we are constantly dealing with demands and goals that compete for the limited processing capability of working memory. Luckily, the active participation of the working memory system is not needed for all cognitive operations or behavior. Many cognitive functions and behaviors can be carried out in a fairly automatic fashion with little or no reliance on working memory (Unsworth & Engle, 2007). However, working memory is necessary for the acquisition of skill mastery that leads to automatized processing. It is also necessary when dealing with novel information, problems, or situations; trying to inhibit irrelevant information; maintaining new information; and consciously retrieving information from long-term memory.

Working Memory versus Short-Term Memory

Many cognitive psychologists and memory experts view short-term and working memory as interchangeable or consider one to be a subtype of the other. Other theorists and researchers contend that working memory and short-term memory are distinguishable constructs (see Chapter 2)—a perspective promoted in this text (see Chapter 3). Regardless of which view the reader adopts, it is important for assessment and intervention purposes to recognize the contrasts between short-term memory (STM) and working memory (WM). The chief differences are:

- STM passively holds information; WM actively processes it.
- STM capacity is domain specific (verbal and visual); WM capacity is less domain specific.
- WM has stronger relationships with academic learning and with higher-level cognitive functions.
- STM automatically activates information stored in long-term memory; WM consciously directs retrieval of desired information from long-term memory.
- STM has no management functions; WM has some executive functions.
- STM can operate independently of long-term memory; WM operations rely heavily on long-term memory structures.
- STM retains information coming from the environment; WM retains products of various cognitive processes.

Short-term memory and working memory are separable, and short-term memory can function without working memory. Nonetheless, short-term memory and its measurement are included in this text, mainly because the predominant theories of working memory incorporate short-term memory as a subsidiary system. Accordingly, the majority of empirical investigations have included short-term memory, with many not discriminating well between short-term and working memory. Likewise, several assessment instruments are structured in ways that confound the measurement of short-term and working memory.

Controversies Surrounding Working Memory

Some psychologists question the working memory construct itself. Unlike short-term memory, it is more difficult to prove that working memory is a unique cognitive entity. For example, working memory has been viewed as essentially the same as focused attention, executive processing, and linguistic processing. Moreover, we have much to learn about some of the subprocesses that comprise the working memory system. For instance, the functioning of phonological short-term memory and verbal working memory is well documented but there remains considerable cloudiness regarding the executive functions of working memory. In addition to these uncertainties, there has been an ongoing dispute over the distribution of working memory resources. Some researchers argue that there is a single pool of resources shared by all short-term and working memory components, whereas others advocate for separate capacities for each component. Furthermore, the debate over the immutability of working memory capacity is far from settled. Some recent research (see Chapter 9) has indicated that capacity can be increased; however, most evidence-based interventions for working memory focus on increasing its efficiency. Regarding the relations

between working memory and academic learning, overwhelming evidence has unequivocally established learning's dependence on working memory (see Chapter 5). With learning, about the only dispute that remains is whether students with learning disabilities have diminished working memory capacity or are simply not using their working memory resources efficiently (see Chapter 5).

Working Memory Measurement

Since the early days of psychology, when more children began attending school for longer periods of time, the existence of individual differences in mental capabilities, including memory, has been apparent. In 1905, Binet and Simon included short-term memory subtests in their seminal intelligence scale. Wechsler did the same with the introduction of his first scale in 1939. Despite the early start, the development of broad-based memory scales did not occur until nearly the end of the Twentieth Century. Within the past 15 years, interest in the measurement of working memory has corresponded with several new options. For example, the most recent revisions of intellectual scales have incorporated "working memory" measures for the first time. Also, batteries designed for the comprehensive assessment of working memory have been introduced. Unfortunately, now that we have the measurement technology for working memory assessment, the usefulness of school-based cognitive testing is being challenged, especially in regards to assessment for learning disabilities.

The apparent decline in school-based cognitive testing is primarily the result of dissatisfaction with the ability-achievement discrepancy approach to identifying learning disabilities. However, some of the "blame" for the impending decline in cognitive testing can be placed on the structure of intellectual scales and an overemphasis on IQ scores. Although measures of general intelligence are strong predictors of academic learning and success in life, an IQ score leaves many questions unanswered. In particular, an IQ score fails to explain *why* some students with normal intelligence have extreme difficulties learning. Furthermore, IQ scores provide little direction regarding the selection of interventions that might benefit individual students.

At the forefront of working memory assessment are multiple-factor instruments that allow investigation of the subprocesses involved in short-term and working memory (see Chapter 8). If we could only obtain estimates of overall working memory functioning or only one component of short-term and working memory, there would be little need for this text. Although knowing that a working memory impairment exists is important information, it is even more helpful to know the underlying processing problem that accounts for the deficit. For example, a working memory deficit might be due to a phonological/verbal memory deficit, a visuospatial memory deficit, or an executive memory deficit. Depending on which memory processes or components are deficient, the learning implications and the best interventions differ

dramatically. The application of the assessment methods recommended in this text, in conjunction with the use of existing test batteries (including intellectual and cognitive scales), will allow psychologists to parse and distinguish the various short-term memory and working memory components that are so indispensable for academic learning.

Despite the recent advances, assessment of working memory presents some challenges (see Chapter 6). The main obstacle is the paucity of test batteries designed for the comprehensive assessment of working memory and related memory functions. Moreover, there is inconsistent measurement across tests (partly because some of the batteries are atheoretical). Given the exact same task, different test authors will claim that it is measuring different constructs. For example, some authors claim that forward digit span is measuring attention, others say it is measuring short-term memory, and still others classify it as a working memory measure. Consequently, it is usually unclear as to which memory components the scales actually measure and how short-term and working memory are differentiated (see Chapter 6). Of the various working memory stores and processes, phonological short-term memory is the only one for which there are relatively pure measures. Even with adequate measurement tools, working memory performance is highly influenced by several factors, including attention, executive processes, processing speed, long-term memory, and the individual's level of expertise in particular domains, such as mathematics skills. Finally, the assessment of working memory is challenging because it is difficult to measure directly. Because working memory subtests typically measure short-term memory span, examiners can only draw inferences about working memory capacity and processes.

Compatibility with Response-to-Intervention

The Response-to-Intervention (RTI) movement now being adopted by many states and school districts emphasizes early, evidence-based interventions for all children who fail to meet grade-level benchmarks in academics. Proponents of RTI believe that a child's failure to respond to an evidence-based intervention is a strong indication of a learning disability. According to RTI advocates, the identification of a "processing deficit" (working memory is a type of processing) is an ineffective method of determining the existence of a learning disability. RTI proponents also consider processing and memory assessment irrelevant because they do not believe there are any effective interventions for processing and memory problems. Both of these claims are disputed in this text and an abundance of evidence is provided that will allow the reader to make an informed decision regarding this debate. First, there is overwhelming evidence that working memory and all types of academic achievement are highly related (see Chapter 5). Furthermore, a high percentage of children with learning disabilities are found to have working memory weaknesses and deficits. There should be little doubt that working memory difficulties are highly predictive of

early school failure. Not only can working memory assessment inform the diagnosis of learning disabilities, but the early screening of working memory could identify children at risk for learning problems. Second, there are evidence-based interventions for memory impairments, and these interventions can produce more effective learning (see Chapter 9).

Assessment and intervention for working-memory problems are compatible with RTI. Even with an extremely effective RTI program, some students with learning challenges will continue to struggle academically. Following the RTI approach, these students will then receive more intense interventions and be considered for special education placement. An assessment, including cognitive testing, may be conducted when a child has failed to respond to regular education interventions. Inclusion of working memory testing can be justified because: (a) it might identify why the student is not responding to intervention (many students with disabilities are ''resistant'' to routine interventions because of a memory or processing impairment); and (b) identification of a working memory weakness or deficit is important information to consider when designing or selecting more intense interventions. (Not all academic interventions include practices that address working memory deficiencies.) To ignore the information a working memory assessment can provide is to make intervention selections with limited knowledge of the child's learning processes. Both RTI and the practices advocated in this text have the best interests of learners in mind. Current psychological measurement tools can provide invaluable information about the working memory strengths and weaknesses of students in need of academic assistance. Learners with working memory deficits might benefit from evidence-based interventions specifically designed to ameliorate memory weaknesses. It is also important that teachers recognize the student's working memory problems and provide appropriate accommodations. In addition, it is essential that the selected academic interventions incorporate methods that allow a student with working memory deficiencies to learn effectively.

Interventions for Working Memory

Most of the working memory interventions reviewed in this text are intended for school settings and can be performed by teachers and related professionals. Consistent with other types of educational interventions, these interventions are often compensatory in nature. The interventions are not intended to increase working memory capacity any more than interventions for students with mental retardation claim to increase intelligence. Rather, the bulk of the interventions are designed to improve performance. Most often, performance can be improved by increasing the efficiency of working memory processing. Increased efficiency allows for more effective utilization of working memory resources. Thus, many of the recommended interventions consist of strategies that enhance working memory processes.

It may surprise some readers to learn that some of the recommended interventions (see Chapter 9) are not specifically designed for working memory impairments. Because of the highly interactive nature of working memory, strengthening peripheral systems can improve working memory performance. For example, interventions that improve phonological processing may produce collateral improvement in phonological short-term memory. This principle also applies to mnemonics and other long-term memory interventions. That is, stronger long-term memory structures or representations reduce the load on working memory, thereby improving working memory performance. In addition, the interventions approach in this text adheres to a top-down model. The top-down philosophy is that improvements in higher-level functions will produce improvements in subsidiary systems. For example, when most of the working memory components are weak, the initial intervention should focus on executive working memory. Finally, this text will review effective teaching practices and instructional models that support the working memory deficiencies of challenged learners.

Learning Objectives

After reading, reviewing, and applying the information and practices discussed in this text, the reader will be able to:

1. Trace the history of the working memory construct, from its origins in the 1950s to contemporary factor structures.
2. Identify the four components of Baddeley's preeminent working memory model, as well as some of the supportive research.
3. Explain the interdependency between working memory and long-term memory, and state why the connection between the two is as important as the short-term memory and working memory relationship.
4. Recognize the limitations of working memory and short-term resources, and how these resources are distributed during different processing activities.
5. State some of the key differences between short-term memory and working memory.
6. Recognize the effects of expertise and automatization on working memory.
7. Differentiate between cognitive weaknesses and cognitive deficits.
8. Identify several cognitive processes that are closely related with working memory.
9. Identify some of the relationships that short-term memory and working memory components have with specific academic skills.

10. Differentiate between subtests that measure short-term memory and those that measure working memory.
11. Recognize several classroom behaviors that are indicative of working memory deficiencies.
12. Apply selective testing and cross-battery procedures to a comprehensive assessment of working memory.
13. Correctly complete the *Working Memory Analysis Worksheet.*
14. In regards to working memory assessment, state the relative advantages and disadvantages of several cognitive ability scales.
15. In regards to working memory assessment, state the relative advantages and disadvantages of several broad memory batteries.
16. Recognize the unique contributions of recently published tests that are designed for the comprehensive assessment of working memory.
17. Describe several strategy-training procedures that should be used when implementing working memory interventions.
18. Identify several evidence-based working memory interventions.
19. Identify several effective teaching practices that address working memory limitations.
20. Describe the unique aspects of interpreting working memory assessment results.