# Working Memory and Academic Learning

## Assessment and Intervention

By
Milton J. Dehn

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*To my parents, LeRoy Louis Dehn*
*and Norene C. Dehn, who*
*taught me the value of*
*honesty and hard work.*

# FOREWORD

Working memory (WM) is an important cortical construct that can be described in many ways. It has been identified as the translator between sensory input and long-term memory, the cognitive difference between a baby who is bound by external stimuli and a toddler who becomes dictatorial about his or her likes and dislikes. It is rehearsal, images, inner speech, emotion, attention, and the stuff of how an individual develops preferences.

Deficits in WM produce systemic and lifelong problems. Living a stressful life can diminish WM capacity and depression can radically alter its course, causing significant issues that will affect other aspects of behavior and memory. Deficits in the central executive component of WM create attentional problems that directly affect learning and behavior. Similarly, deficits in the phonological loop and visual sketchpad of WM are involved in most reading disabilities. Therefore, WM interacts with the world and becomes a buffer or conduit depending on the genetic makeup of the individual and his or her experiences in the environment.

The National Institutes of Health and the Centers for Disease Control and Prevention have recently placed great emphasis on the translation of research from the “bench to the bedside.” While many of the federally funded translational research grants that have been recently created focus on medical research, the need for brain-behavior research that translates studies of the brain into practical interventions are also coming to fruition. In some respects, the recent call for accountability in clinical practice and school practice has also prompted translational efforts.

Many researchers in neuroscience and neuropsychology are now extending their efforts from prior theory-to-analysis to theory-to-analysis-to-treatment efficacy. Interventions must be well grounded in theory and studied with multiple validation methods that do not stop short of or omit ecological validity concerns.

In terms of working memory, there is a great deal of federal interest and international discourse on its definition, localization, and functional reach. Studies have sought to define working memory parameters and constituent parts and, although all do not agree on those issues, there is a consensus that deficits in working memory wreak havoc on higher cortical processes such as reading, mathematics, and the organization of intentional behavior. Neuroimaging has sustained the localization of WM functions as generally outlined in theory by Baddeley and Hitch. Now we have images that, for the first time, validate what was hypothesized all along. The future holds much promise for supporting working memory interventions because recent brain imaging techniques have taken a quantum leap in efficiency, practicality, cost, and availability. Perhaps the future will support assessment and intervention with working memory in ways that we cannot attain or even imagine at the present time. Therefore, it is time to be practical and codify theoretical perspectives on working memory and utilize research studies that shed light on interventions that remediate and compensate for working memory deficits. It is time to translate theory into practice because we now know enough to affect positive changes and we are acutely aware of how important WM is to academic and behavioral success.

This Working Memory volume by Dr. Milton Dehn is going to be a timely and welcome addition to the resources available for psychology professionals assisting children in schools, private practice, and clinics. We have known about

the importance of working memory for many years and neuroimaging has confirmed the localization of its main constituent parts, but very little practical information is written about how to identify and enhance working memory in children. In addition, very little is written about the practical aspects of assessing working memory components and relating the information into everyday learning activities in the classroom. There is so much raw information on WM available it is very difficult for the working professional to codify the existing research and theory about WM and then relate it to clinical practice; and here, Dr. Dehn has done the work for us.

In this volume, Dr. Dehn has taken the time to lay out the prodigious history of theory and research on WM. He provides a historical analysis of how working memory came to be defined and also describes the synergy of multiple theorists. The reader is left with an intuitive understanding of how working memory came to be deconstructed in the research literature and a summary of the extensive list of models of WM construction that have come into being. Probably the most important foundational support of this book is Dr. Dehn's presentation of an integrated model of WM. He presents a parsimonious model that easily translates into clinical practice. The model is a bridge between research and intervention and it accurately translates theory into practice.

Also of basic importance for a work of this type, Dr. Dehn stresses developmental aspects of WM that are integral for understanding WM in children and its relationship to other cognitive processes. How WM deficits play out in different disorders first identified in childhood is another area of focus that is important in this book. Clinicians and teachers are directed to specific information about the most common disorders that have WM deficits as a part of the condition. Knowing how WM affects a learning disability, for example,

paves the way to utilizing WM interventions with precision for children with reading disabilities or math disabilities. Dr. Dehn describes various types of cognitive and memory assessment instruments that tap into working memory and describes the contents, strengths, and weaknesses of each instrument. This valuable synopsis allows the clinical reader to easily find and adapt instruments already commonly used in assessment in schools, clinics, and inpatient facilities. Dr. Dehn does not leave it there, however, but he goes on to explain in very explicit terms how WM affects classroom performance and how the clinician or teacher should intervene in everyday learning activities.

It is very rare that an author can demonstrate a thorough understanding of the history and theory of a cognitive construct as complex as WM. It is even more rare to witness an author taking the benefit of history and theory and translating it into assessment, differential diagnosis, and interventions that can be easily administered by educational personnel in the classroom. We live in an age when laboratory research that seeks to infiltrate real life is encouraged and supported by the federal government—when theory and neuroimaging are combined to produce workable models of intervention for those who suffer from disorders that affect thinking and learning. Most of the time, it is up to us clinicians to assemble all of the historical and theoretical studies, digest the information at length, relate the information to fields of study outside of our own, maintain objectivity, build assessment batteries that will address differential diagnosis, develop interventions that directly relate to our efforts, and consult with other professionals who will actually carry out our recommendations. Realistically speaking, this is very difficult and time consuming for the average clinician to do, although we do it. In the case of working memory, however, Dr. Milt Dehn has completed it for us and with rigorous

adherence to the scientist-practitioner model of inquiry. This is a book that demonstrates state-of-the-art brain-behavior relationships. This is a book we can rely on. This is a book that will help us help children. Many thanks to Dr. Dehn!

Elaine Fletcher-Janzen, Ed.D., NCSP

# PREFACE

Working memory is one of the most important concepts to emerge from cognitive psychology in the past 35 years. What is known about working memory has significant implications for cognitive functioning and, in particular, for academic learning. For instance, knowledge of working memory functions can facilitate identification of learning disabilities. Yet many psychologists and educators do not fully appreciate the multidimensional nature of working memory and the critical roles it plays in cognitive functioning and learning. Also, they are not fully aware of the measurement options and evidence-based interventions for working memory deficiencies. Consequently, it is not surprising that psychologists seldom test memory in a direct or comprehensive manner when children and adolescents are referred for learning difficulties, despite the likelihood that a working memory deficit is underlying the child's learning problems. From my perspective, learners of all ages will benefit if educators, psychologists, and related professionals acquire a better understanding of working memory and its relationship with learning, as well as develop more expertise in working memory assessment and intervention. Thus, the primary purpose of this book is to provide professional development on this extremely important topic. This book is also intended for use as a course textbook and a professional reference book.

We have all experienced the limitations of a normal working memory. How many times have we forgotten a piece of information because the focus of our attention shifted to something else? For example, on countless occasions, we have not been able to remember what we

were going to say or what someone else just said. Surely, we have all felt the frustration that occurs when we cannot retrieve information that we were processing just a moment ago. Now try to imagine what it would be like if you were a student with subaverage working memory capacity or a significant intraindividual weakness in working memory. Compound that with not knowing that you have such a deficiency, and for that matter, no one else knowing about it either. Then, imagine having the learning problem resulting from your working memory deficiency attributed to some irrelevant variable, such as motivation. Finally, imagine missing opportunities to learn strategies that could help you compensate for the working memory shortcoming. If you have dedicated your life to helping and teaching children and adolescents, you should now have some compelling reasons for reading this book. What you can learn from this book will increase your ability to help those with working memory problems.

Here's a preview of the chapters:

1. Introduction and Overview introduces the construct of working memory, along with some of the key topics and major themes. The response-to-intervention model is compared with the approach advocated in this book.

2. Theories and Models of Working Memory traces the history of the working memory construct and reviews several major theories. The preeminent model, Baddeley's four-part model, is discussed in depth. Neuropsychological evidence for the construct is summarized. The chapter concludes with an examination of the controversy surrounding the distribution of working memory resources.

3. An Integrated Model of Working Memory proposes an integrated model of working memory designed to facilitate

working memory assessment. For the remainder of the book, the model is used to classify subtests according to the memory component they are thought to measure. The model's structure also forms the basis for analyzing working memory test results.

4. Working Memory Development and Related Cognitive Processes begins with an overview of working memory development, including the emersion of strategies and recoding during the early elementary years. The chapter concludes with descriptions of highly related cognitive processes and disorders that frequently include working memory deficits.

5. Working Memory and Academic Learning is a core chapter with an in-depth review of the literature on the relations between specific memory components and the specific academic skills of reading, mathematics, and written language.

6. Working Memory Assessment Strategies provides a structure for working memory assessment. Step-by-step methods that cover initial hypothesis generation to analysis and interpretation are described in detail. The heart of the recommended methodology is a cross-battery, selective testing approach. The informal methods section contains a comprehensive list of classroom behaviors that are indicative of working memory deficits.

7. Using Cognitive Scales to Assess Working Memory includes a table that identifies the short-term memory and working memory components measured by each of several major cognitive scales. For each scale, the memory subtests are described and interpretative suggestions are provided.

8. *Assessing Working Memory* with Memory Scales has a similar structure to that of Chapter 7, only this time broad memory scales are reviewed, followed by detailed

introductions to three scales that are designed specifically for working memory assessment.

9. Working Memory Interventions is a core chapter that begins with general strategy training procedures. The chapter then proceeds to cite the empirical support for several working memory, several long-term memory, and a few related cognitive interventions. For most of the interventions, enough details are provided for basic implementation. Effective teaching practices that address working memory limitations are also included.

10. Case Studies, Reporting Results, and Recommendations discusses some assessment cases that illustrate typical profiles found in children and adolescents with disabilities. The chapter also contains recommendations for the oral explanation of test results, how to interpret cross-battery results in written reports, future research, and future test development.

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# 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