1-1-2001

Investigating the relationship of verbal span and spatial span in a combination task

Miriam E Dunbar

University of Nevada, Las Vegas

Follow this and additional works at: https://digitalscholarship.unlv.edu/rtds

Repository Citation
https://digitalscholarship.unlv.edu/rtds/1357

This Thesis is brought to you for free and open access by Digital Scholarship@UNLV. It has been accepted for inclusion in UNLV Retrospective Theses & Dissertations by an authorized administrator of Digital Scholarship@UNLV. For more information, please contact digitalscholarship@unlv.edu.
INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI®

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
INVESTIGATING THE RELATIONSHIP OF VERBAL SPAN
AND SPATIAL SPAN IN A COMBINATION TASK

by

Miriam E. Dunbar
Bachelor of Science
University of Nevada, Las Vegas
1995

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science in Educational Psychology
Department of Educational Psychology
College of Education

Graduate College
University of Nevada, Las Vegas
August 2002
The Thesis prepared by

Miriam E. Dunbar

Entitled

Investigating the Relationship of Verbal Span and Spatial Span in a Combination Task

is approved in partial fulfillment of the requirements for the degree of

Master of Science in Educational Psychology

Examination Committee Chair

Dean of the Graduate College

Examination Committee Member

Graduate College Faculty Representative
ABSTRACT

Investigating the Relationship of Verbal Span and Spatial Span in a Combination Task

by

Miriam E. Dunbar

Dr. Alice J. Corkill, Examination Committee Chair
Associate Professor of Educational Psychology
University of Nevada, Las Vegas

Measurement of working memory span typically involves tasks designed to introduce stimuli to the unique slave systems. It is widely accepted that these isolated measurements indicate, at a relatively simple level, the span of the given working memory system. This study hypothesizes that separate working memory systems can be combined to enhance span length. To evaluate this hypothesis, the Corsi Block Task, a commonly used measure of spatial working memory, will be altered to include verbal information (colors). One hundred subjects completed the following typically used cognitive tasks to observe the relationship between verbal abilities in working memory and spatial abilities in working memory: 1) the Raven’s Progressive Matrices, a standardized test of intelligence; 2) two forms of the Corsi Block Tapping Task, a test.
that measures the ability to maintain spatial information in working memory; 3) a word span task, a test that measures the ability to maintain verbal information in working memory; 4) and a color span task, a test that may measure the ability to maintain visual information in working memory. A comparison of these working memory span measurements was used to determine the extent to which verbal information may contribute to the enhancement of spatial working memory.
TABLE OF CONTENTS

ABSTRACT ....................................................................................................................... iii
LIST OF TABLES ............................................................................................................... vi
ACKNOWLEDGMENTS ................................................................................................... vii

CHAPTER 1 INTRODUCTION ........................................................................................ 1
Review of Literature ..................................................................................................... 10
Current Study ............................................................................................................... 27
Hypotheses ................................................................................................................... 29

CHAPTER 2 METHODOLOGY ...................................................................................... 30
Participants ................................................................................................................... 30
Materials ....................................................................................................................... 30
Procedure ..................................................................................................................... 35

CHAPTER 3 RESULTS ..................................................................................................... 41
Analysis of Specific Hypotheses ................................................................................. 42
Exit Survey ................................................................................................................... 46

CHAPTER 4 DISCUSSION .............................................................................................. 54
Hypotheses ................................................................................................................... 54
Recommendations for Future Research ................................................................. 61

APPENDICES ..................................................................................................................... 63

REFERENCES ..................................................................................................................... 69

VITA .................................................................................................................................... 74

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
LIST OF TABLES

Table 1  Sex Differences on All Tasks ................................................................. 42
Table 2  Male and Female Comparison of Non-Verbalization Condition with Verbalization Condition on the CCBT ................................................ 43
Table 3  Intercorrelation Matrices for All Tasks for Males .............................. 45
Table 4  Intercorrelation Matrices for All Tasks for Females ...................... 45
Table 5  Strategies Used in Remembering Block Locations on the CBT .......... 48
Table 6  Strategies Used in Remembering Block Locations on the CCBT .... 49
Table 7  Comparison of Task Difficulty on the CCBT and CBT ................. 50
Table 8  Helpfulness of Color Verbalization on the CCBT: Non-Verbalization, Conditions One and Three ................................. 51
Table 9  Helpfulness of Color Verbalization on the CCBT: Verbalization, Conditions Two and Four .................................................. 52
Table 10 Helpfulness of Color Verbalization on the CCBT: Comparison of Responses by Sex ......................................................... 53
ACKNOWLEDGEMENTS

I have new respect for people who have written theses, dissertations, or completed other arduous writing projects. I am appropriately humbled by their accomplishments. As writing this thesis, I am convinced, very nearly killed me! A life-consuming project, such as this thesis, rarely affects just the life of the author. Those around them cannot escape the long hours, uncelebrated birthdays and holidays, ignored e-mails, canceled plans, and resulting loneliness. To my family and friends, I owe a huge debt of gratitude for your support, understanding, and patience during this particularly intense time in my life.

No matter who you are or how noble your task, there are still only 24 hours in a day. Time given to one is time sacrificed from another. I sincerely appreciate and thank the many people who have graciously given me their time. I would like to thank my subjects, some of whom participated not just to fulfill a requirement, but because they understood how important their data were to my project. I am so grateful to them for their willingness to “feel stupid” for me. I hope this final product is worthy of their time.

Almost ten years ago, Dr. Corkill gave me a pamphlet from the Educational Psychology Master’s program. I hope she does not regret her actions! To Alice Jane, thank you for your confidence in me. During this process, you always knew when to step in with advice, and when to let me figure things out for myself. I will always cherish the hours we spent discussing memory theory, analyzing data, or just talking. I look forward to more of the same.
Few people know how close I was to abandoning this thesis before the literature review was even written. Had it not been for Dr. Dempster's direction and feedback on draft after draft, I would have given up. Frank, this thesis would not have been completed without your help. The words, thank you, cannot begin to express my gratitude. I am honored and grateful to have been given your time.

Before the topic for my thesis was even chosen, Dr. Kardash was there with her calm, logical advice. Basically, she said, "What are you waiting for? Get started!" Thank you for motivating me to begin this overwhelming task.

When it looked like I might have difficulty finding 50 male volunteers for my study, Dr. Guadagnoli and his Kinesiology students came to my rescue. This was truly above and beyond. Thank you!

Over a period of six weeks, 101 subjects came through the Educational Psychology office, twice each! To Kathy and Derek, our secretary and office assistant, thank you for greeting each one. And thanks, too, for taking more than my fair share of phone messages.

Collecting the data was not only time consuming, but also cognitively taxing for both the subjects and the researcher. But my friend and colleague, Barbie, willingly pitched in to help. Thank you for listening to me whine and for knowing just when I needed a hug. Now it is your turn!

Finally, to our future Professor McCrudden: You are correct, Matty. The best thesis IS a finished one!
CHAPTER 1

INTRODUCTION

Working memory is one of the components of the complex human memory system. For information to reach long-term storage, which is necessary for learning to occur, it must first be processed through the limited capacity of working memory. Increasing the ease with which working memory can hold and process information may facilitate learning by increasing the amount of information that passes to long-term storage. The structural capacity of the normally developed adult's working memory, that is, the cognitive space in which one can hold information, may not change. However, the amount of information that can be held within the limited capacity of working memory may be increased through various methods that enhance the functional capacity of working memory. These methods include connecting short-term information to long-term memory (strategies), increasing the efficiency of working memory (reducing cognitive load), and presenting information in more than one mode (dual coding). Increasing working memory's functional capacity has been investigated through strategy use, instructional practices, and presentation modes. A brief overview of these capacity increasing methods is followed by a description of the architecture of working memory. Next, I discuss various working memory distinctions from a theoretical perspective, concluding with a review of the literature in areas related to the present study.
Strategies to retain and recall information may increase the functional capacity of working memory (Hitch, Halliday, & Littler, 1989). Strategies are cognitive tools that can be taught and practiced to facilitate recall of information. Mnemonic devices, chunking, and rehearsal are examples of strategies (Ormrod, 1999). Most mnemonic devices, such as method of loci and imagery, require time, practice, and processing. Therefore, they may not be efficient strategies to use for immediate recall of lists of items, such as the information required in working memory span tasks. If working memory span is seven items, plus or minus two (Miller, 1956), one may group information, or create "chunks" of information, which can be remembered as one item. Remembering nine numbers, for example, could be reduced to three items by grouping the numbers into three chunks of three numbers each. Finally, rehearsal is a simple strategy whereby information is quickly repeated, either aloud or subvocally, while being held for immediate recall (Ormrod, 1999).

Instructional techniques can influence the amount of information the brain must process. These techniques are of particular interest in the area of instructional design. One theory related to instructional design is cognitive load theory (Sweller, van Merrienboer, & Paas, 1998). Cognitive load theorists suggest that increasing the efficiency of working memory may improve learning by reducing the work, or cognitive load, required to process incoming information (Sweller, et al., 1998). One way to reduce cognitive load, according to this theory, is to physically adjust the location of the information presented in a text. That is, improving the presentation format of the to-be-learned information increases the ability of working memory to process the information.
This may include, for example, presenting descriptive information directly on, rather than beneath a diagram. It is theorized that more information can be processed in working memory by relieving the requirement of holding information from a diagram while attempting to study corresponding written descriptions located elsewhere. This consolidation reduces the amount of work required to process the information, thus increasing the efficiency of working memory.

Another technique for reducing cognitive load is automation of tasks through deliberate practice. Automation of tasks reduces the amount of conscious thought required to complete the task (Mousavi, Low, & Sweller, 1995). Practicing tasks until they require little cognitive effort to perform frees space in working memory that was previously used to think about and carry out the task. Once cognitive load is reduced in this way, working memory space is available for holding and processing other information. This new free space in working memory, due to a reduction in cognitive load, may then be used to carry out other tasks, thus increasing the functional capacity of working memory.

The various ways information is presented also has an effect on the functional capacity of working memory. Information presented in two different modalities using the functions of two working memory structures is known as dual coding (Clark & Paivio, 1991; Emerson, Miyake, & Rettinger, 1999). According to Clark and Paivio (1991), dual coding involves the verbal and nonverbal memory systems. The verbal system processes linguistic related stimuli, including written and spoken words. The nonverbal system processes nonlinguistic related stimuli, including images, sounds, actions, and behaviors.
Emerson et al. (1999) suggest that dual coding may involve either integration, coordination, or both. When two sources of information are related and the desired outcome is a result of combining these sources, this is integration. When two sources of information are not related and the desired outcome involves simultaneous completion of a task, this is coordination. Integration relieves capacity demands placed on one working memory system by allowing the same information to be encoded through a separate memory system. Coordination increases capacity demands on working memory by requiring two separate memory systems to be simultaneously engaged in the processing of different information. Further discussion of dual coding theory and related studies is presented in the "Combination Tasks" section of the Literature Review.

Strategy use, reducing cognitive load, and dual coding focus on the same goal: enhancing the functional capacity of working memory by increasing the amount of information that working memory can process. The functional aspects of working memory are one consideration in the study of memory capacity. The structure of working memory also contributes to the understanding of memory capacity. A discussion of the theorized structure of working memory follows.

The Architecture of Working Memory

Atkinson and Shiffrin (1968) formulated the popular modal model of memory. This model separates human memory into three systems: 1) sensory registers, 2) short-term store, and 3) long-term store. Each system in this theorized model is responsible for specific tasks of information processing. Visual, auditory, and haptic sensory registers
receive environmental stimuli, which are then transferred to the short-term store for further processing. The short-term store is responsible for producing responses and also communicating information to the long-term store. The long-term store, it is theorized, has unlimited capacity. The modal model's pictorial representation has contributed to the dialogue and further understanding of human memory, as well as served as a catalyst for other models of memory. A discussion of two such models, the information processing model (Baddeley & Hitch, 1974) and the levels of processing model (Craik & Lockhart, 1972), is followed by a discussion of the theorized processing complexity within working memory.

Expanding on the short-term store component of the modal model, Baddeley and Hitch (1974) posited a widely accepted model of the short-term or working memory system, which includes a central executive and at least two slave systems. The central executive is thought to mediate attention and serve as a processor of information between the separate slave systems and long-term memory (Baddeley & Hitch, 1974). Research has yet to focus much on the investigation of the functions of the central executive (Baddeley, 1998; Logie, 1995). Areas that have been investigated indicate control of attention allocated to stimuli, including the amount of attention and perception of chosen stimuli. Other research suggests that a cognitive processor, similar in description to the central executive, is influenced by development. Functions of this theorized cognitive processor include the evaluation of surroundings and judgments of appropriate responsive actions (Span, 2002). In Baddeley and Hitch's (1974) model, the central executive is
believed to play a key role in working memory functions, though the receiving and temporary storage of information falls to the slave systems.

One of the two slave systems theorized by Baddeley and Hitch (1974) is the phonological loop, which is thought to process verbal information. The phonological loop consists of two components: a phonological store and an articulatory control process. Theoretically, the two components work together to hold and rehearse information. Information in the phonological store lasts for only one-and-a-half to two seconds. The articulatory control process aids in the retention of information in the phonological store by providing verbal rehearsal mechanisms.

The second theorized slave system is the visuospatial sketchpad, which is thought to process visual and spatial information. This information can be received either through sensory memory or generated through imaging. Some research suggests that the visuospatial sketchpad is comprised of two separate systems. As Baddeley (1998) indicates, neuropsychological evidence suggests that the visual working memory system has two separate components: one for identifying objects and the other for the perception of the location of objects.

Many researchers cite Baddeley and Hitch's (1974) theory of the structure of human memory: it is the standard by which all working memory models are compared. One criticism of the model is that only two slave systems provide an incomplete explanation of working memory functions. Perhaps to blunt this criticism, Baddeley (1998) has eluded to "a number of subsidiary slave systems" (p. 52), suggesting that the
phonological loop and visuospatial sketchpad are not the only slave systems, but rather, just the two that were chosen for study.

In contrast to the multi-storage structure of human memory posited in the modal model (Atkinson & Shiffrin, 1968), Craik and Lockhart (1972) offer a view of memory as a continuum of levels, increasing in depth of processing. Retaining information depends on the depth to which it is processed. Stimuli that are familiar and meaningful will be processed more quickly and deeply than less familiar or less meaningful information, and will, according to this theory, be remembered better. There are two types of processing described within Craik and Lockhart's (1972) model of memory. Type I processing refers to the shallow interaction with stimuli that are commonly used to keep information active for a short period of time. Type II processing refers to a deeper, analytic interaction with stimuli to which meaning is associated and information is subsequently remembered. In addition to depth of processing, information retention, by this model, is explained by actively maintaining the information within one level of processing. This is accomplished by continually attending to the given stimuli, thus assuring its activation within memory.

The two previously discussed models offer differing theories of the operation of working memory. Baddeley and Hitch's (1974) model addresses the structural aspects of working memory, while Craik and Lockhart's (1972) depth of processing model approaches working memory from a functional perspective. The study of these and other divergent theories has greatly contributed to our present understanding of working
memory. Further research will, no doubt, continue to confirm and challenge present theories.

The Distinction Between Working Memory and Short-Term Memory

The terms working memory and short-term memory are used to describe memory processes. Historically, "short-term memory" was a label for the component responsible for receiving information from sensory memory. More recently, some authors have replaced "short-term memory" with "working memory" (Baddeley, 1998), while others use the terms interchangeably (Ormrod, 1999). Another school of thought uses both terms to separate immediate memory functions based on theorized levels of cognitive complexity, relative to individual effort and task requirements (Cantor, Engle, & Hamilton, 1991; Engle, 2001). "Short-term memory" is a label for the passive memory function that temporarily holds and maintains a limited number of items through simple strategies (Engle, 2001). The label, "working memory," describes a similar, yet separate construct involving not only receiving and temporarily storing information for immediate output, but also additional attention required by tasks demanding further processing (Cantor, et al., 1991; Engle, 2001). Following this theory, tasks requiring the short retention and immediate recall of stimuli, such as digit span or word span, measure short-term memory. Tasks in which attention must be shifted back and forth between the items to be remembered and a processing activity measure working memory (Engle, Tuholski, Laughlin, & Conway, 1999). Working memory includes a transformational or
manipulation function, thus distinguishing it from short-term memory (Hitch & Towse, 1995; Engle et al., 1999).

According to Engle et al. (1999), short-term memory and working memory are closely related but different constructs. Short-term memory describes the function of remembering lists of items for immediate recall, while working memory adds a manipulation component to the memory process (Engle et al., 1999; Miyake, Friedman, Rettinger, Shah, Hegarty, 2001). Short-term memory would apply to simple span tasks; working memory would apply to tasks requiring additional thought, problem solving, and/or manipulation of information.

In a study investigating the difference between short-term memory and working memory, 33 subjects completed 3 tasks designed to measure short-term memory and 3 tasks designed to measure working memory (Engle et al., 1999). The three tasks designed to measure short-term memory were simple word span with dissimilar words, simple word span with similar words, and backward word span with dissimilar words. The three tasks designed to measure working memory were operation span with words, a modified version of the reading span task, and a counting span task. The difference between the tasks, according to the researchers, was that the working memory tasks required an additional processing activity, in this case, making a judgment about a statement or solving a math problem, which the short-term memory tasks lacked. Engle et al. (1999) theorize that both short-term memory and working memory rely on the central executive for controlled attention. The shared central executive functions of memory tasks indicate that short-term memory and working memory can not be
independently measured. However, short-term memory and working memory are
different constructs, according to this theory, because short-term memory measures do
not correlate with intelligence and working memory measures do. Engle (2001) further
concludes that short-term memory and working memory are labels for different levels of
memory functions.

To summarize, Baddeley and Hitch's (1974) model of human memory includes three
main components: the sensory register, working memory, and long-term storage. The
component responsible for holding and manipulating information is working memory.
Working memory processes are carried out by various components assigned to specific
types of stimuli, including spatial, visual, and verbal. Within working memory, the
amount of information that can be held and immediately recalled is one's span. Span
length is determined by performance on tasks designed to measure the isolated or
combined components of working memory.

The following review of literature addresses research on spatial and verbal working
memory, sex differences, and stimulus encoding. A review of research combining
working memory components is followed by the final section, which is a discussion of
the present study.

Spatial Working Memory

Baddeley and Hitch (1974) propose that spatial working memory is a component of
the visuospatial sketchpad within working memory. In turn, visuospatial memory is
made up of both visual and spatial components. This theorized two-system structure
works symbiotically to receive information for maintaining the identity and location of objects either through sensory memory or imaging (Logie, 1995). Maintaining information in visuospatial working memory requires the allocation of attentional resources (Smyth & Scholey, 1994). Maintaining information in visuospatial working memory is interfered with by tasks demanding spatial attention. For example, visually reading words, attending to the location of sounds, and engaging in motor activities reduces visuospatial span length.

In studies of the visuospatial sketchpad, the contributions of visual and spatial factors have been investigated using modality specific interference tasks. Smyth and Scholey (1994) found that spatial span was interfered with by spatial stimuli presented either visually or auditorily. In a study investigating the contribution of spatial monitoring in a phonological memory task, Morris (1989) found that interference of spatial span occurred with spatial tasks presented during encoding, but not during maintenance of spatial stimuli. Another study indicated that extraneous visual stimuli interfered with recall of spatial sequences during both encoding and maintenance, suggesting that some spatial information is encoded and retained visually (Toms, Morris, & Foley, 1994). These results indicate that stimuli demanding spatial attention interferes with the recall of spatial information. Such data provide support for the construct of spatial working memory.

A theoretical factor in the measurement of spatial span is the intensity of the cognitive work required in the completion of the measurement tasks. Logie’s (1995) theory of visuospatial memory suggests that the functions of this system include receiving and
maintaining visual and spatial information. Processing information is a demand placed on the long-term memory system, or to a lesser extent, the central executive. The amount of involvement from the central executive defines the terms "span" and "ability" in spatial measurement tasks, similar to the distinction made by Engle (2001) and his colleagues between the terms "short-term" and "working memory."

Spatial span is measured using tasks that require the immediate recall of object location, position, or sequence (Logie, 1995). Span tasks, such as the Corsi Block Tapping Task use basic processes of working memory (Miyake, et al., 2001). In spatial span tasks, information is temporarily stored and immediately repeated. The difference between spatial span and spatial ability tasks is that ability tasks require not only temporary storage of information for recall, but also additional cognitive work required for "representing, transforming, generating, and recalling symbolic, nonlinguistic information" (Linn & Petersen, 1985, p. 1482). Based on a meta-analysis of spatial ability tasks used in research, Linn and Petersen (1985) separate spatial ability tasks into three categories: spatial perception, mental rotation, and spatial visualization. They suggest that compared to span tasks, the processing requirements of ability tasks places an additional demand on the central executive (Engle, et al., 1999).

In a study using both spatial span and ability tasks, Miyake, et al. (2001) found that they tended to rely on considerable involvement from the central executive. Visuospatial working memory span and ability were correlated with measures of central executive function. Measures of spatial span included the Corsi Block Tapping Task and the dot memory task, which involve temporary storage of the location of blocks and dots for
immediate recall. Measures of spatial ability included letter rotation and a dot matrix
task, which require problem solving and short term retention of the repositioned location
of letters and dot placement. Measures of executive processing included the Tower of
Hanoi and random number generation, which are thought to require activation.
maintenance, and management of a series of goals. As expected, results indicated a
significant correlation between visuospatial ability and executive functioning. However,
visuospatial span and executive functioning demonstrated a correlation nearly identical to
that of visuospatial ability and executive functioning. This similar reliance on executive
processes suggests, according to the researchers, that spatial span and spatial ability are
not separate constructs.

To summarize, Baddeley and Hitch's (1974) visuospatial slave system involves visual
and spatial encoding of information. The functions of visuospatial working memory
include temporary retention of information for immediate recall, as is required for span
measures, and perception, mental rotation, visualization, generation and maintenance of
spatial images, as is required for ability measures. Tasks used to measure spatial span
require the immediate recall of object location, position, or sequence. Tasks used to
measure spatial ability demand more cognitive processing and mental manipulation of
information than is required in simple span tasks (Engle, et al., 1999). Despite the
theoretical differences in processing requirements between ability and span measures,
both types of tasks rely to some degree on visuospatial working memory and the
executive processor for attentional control (Engle, 2001; Miyake, et al., 2001). The
theoretical differences and similarities of spatial span and spatial ability have implications for hypothesized sex differences in spatial measurements.

Research indicates sex differences favoring males on spatial ability tasks (Halpern & LaMay, 2000; Loring-Meier & Halpern 1999; Voyer, Voyer, & Bryden, 1995). Sex differences in spatial working memory may occur to a greater or lesser degree depending on the amount of cognitive work required to complete the task. In a study conducted by Loring-Meier and Halpern (1999), sex differences in spatial memory were related to the amount of cognitive processing required by the visuospatial task and the type of tasks used. Males, for example, responded more quickly and accurately on tasks requiring imaging, rotation, and manipulation of spatial stimuli. The study also noted that males were more likely to use imagery when solving spatial problems. According to the researchers, the differences in response time and problem solving strategies between males and females contributed to the observed sex differences in spatial ability.

Other studies have found sex differences in spatial ability measurements such as tests involving the mental rotation of 3-dimensional drawings of blocks (Goldstein, Haldane, & Mitchel, 1990). Mental rotation tests are scored by the speed, rather than the accuracy, with which they are completed. When accuracy alone is used in scoring mental rotation tasks, no sex differences emerge (Linn & Petersen, 1985). However, subjects tend to demonstrate high accuracy in mental rotation tasks, thus lowering score variability in general. Caplan, MacPherson, and Tobin (1985) accentuate the inconsistencies in spatial ability measures, theorizing that sex differences either do not exist to the extent reported or do not exist at all. Caplan, et. al., (1985) also believe that preferential bias for
publishing data indicating sex differences may motivate researchers to find differences where none exist.

A review of the literature presents conflicting results regarding sex differences in spatial ability. A major criticism of the research is that spatial ability is inconsistently measured across studies and, therefore, they can not be compared (Caplan, et al., 1985). However, the overwhelming majority of published studies indicate differences between males and females in the performance of spatial ability tasks. Absent from the literature is a statement regarding sex differences in spatial span tasks, the theoretically less demanding spatial memory tasks. The similar engagement of executive processes for all spatial tasks, ability or span. (Miyake, et al. 2001) suggests that it is appropriate to investigate possible sex related differences in simple, spatial span.

Verbal Working Memory

Verbal working memory, a function of the phonological loop, involves remembering linguistic information for a short period of time. In Baddeley and Hitch’s (1974) model of working memory, the phonological loop is responsible for two functions: encoding and rehearsing language based stimuli. Evidence for the phonological loop is found in four memory phenomena: 1) word similarity effect, 2) unattended speech effect, 3) articulatory suppression, and 4) word-length effect (Baddeley, 1998). A discussion of these four phenomena follow.

First, remembering a list of similar sounding words is more difficult than remembering a list of dissimilar sounding words (Baddeley, 1998; Logie, 1995). This
difficulty is known as the word similarity effect. Second, speech, theoretically, is directly encoded into the phonological loop (Baddeley, 1998). Speech that is not intentionally attended to, but is heard none-the-less, is called unattended speech. Experiments clearly demonstrate that verbal span lengths are diminished when unattended speech is present (Salame & Baddeley, 1982). Therefore, theorists concluded that unattended speech is processed, at some level or to some degree, by the phonological loop. This attenuation is known as the unattended speech effect. Third, articulatory suppression, when subjects repeatedly say a word during the presentation of verbal stimuli, interferes with the encoding of verbal stimuli by competing for limited capacity in verbal working memory. Articulatory suppression interferes with the encoding of verbal stimuli by competing for limited capacity in verbal working memory (Baddeley, Lewis, & Vallar, 1984). As with unattended speech, articulatory suppression results in diminished verbal span lengths (Baddeley, 1998). Finally, in verbal span tasks, rehearsal is thought to play an integral role in recalling stimuli. In relation to shorter words, longer words can be rehearsed less often, resulting in diminished recall. Therefore, when word lists of longer words are used, verbal span tends to be smaller than when lists of shorter words are used. This is known as the word-length effect (Baddeley, 1998).

The effects of the phenomena described above suggest that working memory includes a component responsible for encoding and rehearsing phonological information. Baddeley and Hitch (1974) labeled this component the articulatory loop, which later became known as the phonological loop. In the following section, the encoding of verbal information is discussed in terms of these four phenomena.
Sensory memory receives stimuli that are then transferred to the appropriate modality specific systems in working memory. In order for information to reach verbal working memory, it must be encoded either visually or auditorily (Baddeley, 1998; Logie, 1995). Span length varies depending on the method with which stimuli are encoded. Verbal span measured with auditory presentation of stimuli tends to be longer than verbal span measured with visual presentation of stimuli (Watkins & Peynircioglu, 1983). In two experiments, subjects were presented with lists of letters and numbers either auditorily or verbally. In serial recall, span for auditorily presented lists was longer than span for visually presented lists.

Articulatory suppression in a task using similar sounding words helps to illustrate one of the information encoding and transfer processes related to presentation modes. Baddeley, et al., (1984) conducted a series of experiments investigating several memory phenomena related to word recall and the phonological loop. In one experiment, subjects were auditorily presented with phonologically similar lists of words while engaging in articulatory suppression. The results suggest that under articulatory suppression conditions, the phonological similarity effect was reduced, but still present. Subsequent experiments confirmed that with auditory presentation of words, some of the confusion in recall caused by the phonologically similar words remained even under articulatory suppression conditions. However, visual presentation of words under articulatory suppression conditions does eliminate the phonological similarity effect.

The results of the Baddeley, et al. (1984) study suggest that the phonological similarity effect occurs whether the list of words is heard or read. Furthermore,
articulatory suppression blocks the transfer of visually presented material to the phonological store. Therefore, during articulatory suppression, span length for visually presented words is the same for both phonetically similar and dissimilar words.

However, auditorily presented words are directly encoded into the phonological store (Baddeley, 1998). This direct encoding allows some of the confusion from the similar words to effect word span length. Articulatory suppression, therefore, does not completely remove the similarity effect from auditorily presented phonologically similar words (Logie, 1995). These results suggest that the presentation modality, in this case, visual or verbal, requires different encoding processes to reach the phonological loop.

In summary, research suggests that differences in encoding processes contribute to the observed differences in span length. Measurements of verbal span with auditorily presented stimuli, according to research, tend to be longer than verbal span measured with visually presented stimuli. Differences in span length may also occur between males and females. As previously discussed, research has found sex differences in spatial working memory. The following is a discussion of sex differences in verbal working memory.

As indicated in a prior section, research indicates that on some measures of verbal ability, females perform better than males. Tasks such as word generation, picture naming, and word recall sometimes indicate a female advantage (Maccoby & Jacklin, 1974). The inconsistent results of sex differences in verbal memory studies does not dissuade researchers from generalizing a female advantage in verbal ability. The inconsistent results, however, could be related to the multiple memory resources used in
completing the assessment tasks. Ability tasks, as argued previously, are different from span tasks in that they involve multiple resources, such as the central executive (Logie, 1995). Measures of verbal span are unique because of the contribution from a single working memory resource. Theoretically, measures of working memory span would be a more accurate reflection of sex differences than those found in ability tasks. The following studies illustrate the difficulties involved in investigating sex differences in verbal ability.

In a meta-analysis of studies investigating sex differences in verbal ability, Hyde and Linn (1988) categorized and calculated the effect size for over 100 studies from a 31 year span. The categories included the type of test, type of cognitive processing, and mean age of the subjects. The effect size was calculated by subtracting the mean score for males from the mean score for females, then dividing by the aggregate standard deviation. A negative value on the mean effect size indicated superior male performance, and a positive value indicated superior female performance. Overall, results indicated a slight female advantage in verbal ability.

The results of Hyde and Linn's (1988) meta-analysis are problematic for two reasons. First, results from only one experimental outcome from each study were included, even if the study included several experiments. Random selection of the included outcomes helped preclude bias, but may have failed to accurately reflect the actual study conclusions. Second, verbal ability measures include a wide variety of tasks. Verbal abilities, according to Hyde and Linn's (1988) meta-analysis, range from word recall tasks to reading comprehension. Not only does this broad collection of tasks include an
equally broad range of administration and scoring techniques, but also a complex combination of different memory resources. Understanding the diverse nature of verbal ability measures and memory resources, therefore, may require individual consideration of their unique characteristics, rather than categorizing and grouping processes or results.

In a study designed to investigate sex differences in spatial ability, Duff and Hampson (2001) compared verbal working memory tasks with the outcome of a spatial task. The spatial task involved matching ten pairs of colored dots or geometric forms concealed by flaps and arranged in a 4x5 grid. This spatial task, according to the researchers, yielded a sex difference in favor of females. They concluded that the spatial task included a large contribution from verbal working memory, and it was the verbal component, not the spatial component, that facilitated the female advantage. Verbal tasks were used to determine the extent of female advantage in verbal working memory. One verbal task, the Digit Ordering task, indicated significant sex differences in favor of females, while another, digit span, resulted in no sex differences.

The conflicting female advantage in the two verbal working memory tasks above illustrates the differences between memory measurements. The Digit Ordering and digit span tasks, both believed to measure verbal working memory, may involve different ratios of working memory resources between the tasks themselves and males and females. For example, Chincotta, Underwood, Ghani, Papadopoulou, and Wresinski (1999) found that recalling digits may involve spatial working memory as well as verbal working memory. Performance on tasks thought to measure verbal abilities may include other memory resources, confounding the intended measurement.
To address the inconsistent outcomes in sex differences research, Halpern and Wright (1996) posit a process-oriented model in which tasks are categorized by the cognitive processes required to complete them. They hypothesized that males would outperform females on working memory tasks involving maintenance and manipulation of stimuli, while females would outperform males on working memory tasks involving retrieval of information from long-term memory. To investigate their hypotheses, they chose five tasks: verbal analogies, mental rotation, arithmetic, and two verbal fluency tasks. The researchers chose these tasks because they required unique processing characteristics. For example, mental rotation tasks require subjects to imagine the position of an object and compare the mentally repositioned object with a visually presented object. The mental rotation and comparison are the unique qualities of mental rotation tasks, and tend to favor males. Verbal analogies, another task favoring males, require subjects to hold information in working memory while generating and comparing relationships between words. Tasks that require searches through long-term memory, such as the arithmetic task and letter and synonym generation fluency tasks, tend to favor females. The same subjects, 78 females and 72 males, completed all five tasks.

Two criteria were used to compare the task outcomes: the number of problems solved correctly and the time it took to solve them. As hypothesized, males performed better on the mental rotation and verbal analogies tasks. Also as predicted, females performed better on the letter and synonym generation fluency tasks. However, males correctly solved more arithmetic problems in the same amount of time as females. The researchers believed that the arithmetic task, thought to require accessing long-term memory, may
actually have involved holding and manipulating information. processes hypothetically favoring males.

By using cognitive processes as the criteria for defining types of tasks. Halpern and Wright (1996) attempted to standardize research of sex differences in memory. That is. they believed that cognitive processes in completing tasks allowed for consistent comparison of task outcome. However. as the researchers noted. males and females may use different processes for completing the same tasks. The use of different processes may help explain inconsistencies across studies. That is. the measurement of sex differences is confounded by factors not intentionally included. which. in turn. may lead to inconsistent outcomes.

In summary. research on sex differences in verbal ability has yielded conflicting results. Inconsistencies arise when researchers generalize study specific results. Differences in the ratio of memory resources used to complete experimental tasks contribute to these inconsistencies. Halpern and Wright’s (1996) cognitive processes theory offers a possible method for consistent comparison of outcomes. but as demonstrated with the arithmetic task. determining the cognitive processes also produces conflicting results. Whether the comparison of males and females is accomplished with tasks or processes. caution should be used in generalizing the results.

Combining Working Memory Systems

The following discussion focuses on research that investigates combinations of working memory systems. The first study assessed a possible combination effect of
verbal and spatial working memory systems in recalling number symbols. The second study theorizes that verbal span can be enhanced by including a motor activity during encoding. The final study investigates the combination of verbal and spatial working memory using a shape location recall task.

Chincotta, et al. (1999) discuss a study in which the unintentional combination of spatial and verbal working memory resulted in an unexpected difference in span between number symbols and number words. The researchers reported that span for number symbols was greater than span for number words. Subjects participated in span tasks in which working memory span was compared using number symbols and number words. In six experiments, number symbols and number words were presented on a computer screen. Conditions in the experiments included manipulating the location, order, and reading direction of the symbols and words during visual presentation. Spatial and visual interference techniques were also employed in some conditions. With the exception of one condition, using a spatial interference task, span for number symbols was greater than span for number words. One explanation offered for the longer span of number symbols compared to number words, according to the researchers, was that serial recall of number symbols had additional support from spatial working memory.

Chincotta et al.‘s (1999) study demonstrated not only the effects of a combination of verbal and spatial working memory, but also the effects of spatial interference. When subjects were required to engage in a spatial interference task, span length for number symbols was almost identical to number words in one experiment, and less than number words in another. These results suggest that the symbol advantage may be due to
involvement from the spatial working memory system aiding verbal working memory in recalling the digits.

Encoding information in more than one mode disperses incoming stimuli to multiple structures and may increase the amount of information that can be processed by working memory. Reisberg, Rappaport, and O'Shaughnessy (1984) theorize that new, temporary storage components can be created by any activity. In a series of six experiments, the researchers taught subjects to encode and remember lists of digits using a finger tapping activity. The fingers were assigned numbers from one to four and seven to ten, beginning with the left hand pinky as number one, and continuing in order to the right hand pinky as number ten. The thumbs and numbers five and six were not used. After becoming proficient at remembering which finger matched each number, subjects tapped the corresponding fingers as the digits were presented. Though the number of subjects in each experiment was small (N<8 in each experiment), the results of combining a physical activity with verbal encoding of digits increased span an average of two digits. Reisberg, et al. (1984) theorized that the finger loop strategy effectively increased digit span because it distributed the cognitive work load between the phonological immediate memory and the newly created motor activity storage system.

In the study described above, the increased verbal span may have been due to factors other than those intentionally included in the study. For example, subjects’ familiarity with stimuli has emerged as a factor in verbal span (Case, 1995). Training increased children’s performance in a counting activity. Similarly, the increase demonstrated in the finger loop assisted verbal span may be the result of increased familiarity of the task.
gained through the practice required to use the technique. Unequal amounts of time in the presentation and recall of the stimuli may also contribute to different span lengths between the control condition's version of the digit span task and the finger loop version. Fischer (2001) found that in a commonly used spatial span task, longer presentation and recall time increased span length, presumably due to increased opportunity for encoding and rehearsal of information. Reisberg, et al. (1984) do not indicate if presentation and recall times were standardized between the control and experimental conditions. One may assume, therefore, that any additional time required to tap the fingers would allow for additional encoding and rehearsal opportunities, possibly leading to longer spans.

In another study designed to investigate the contribution of verbal memory to spatial span, shapes were presented to subjects in a circular diagram similar in appearance to a sunflower (Dunlap, 1998); objects were displayed in the outer petal-like section of the diagram. In each set, the number of shapes presented increased. Subjects were instructed to remember the placement of the shapes, and then were tested on the location of one of the shapes from the sequence. The shapes, which were either easy (recognizable objects; e.g. apple, arrow, or butterfly), medium (may look like more than one object; e.g. could be labeled a spaceship or a garden tool), or difficult (abstract shapes without orientation) to name, provided the verbal component of the task. The location of the shapes within the petal-like structure of the diagram provided the spatial component of the task. It was found that the locations of the easier to name objects were also easier to recall and resulted in greater span lengths. These results suggest that verbal working memory can contribute to spatial working memory to enhance spatial span.
In this study, the naming requirement, however, may not have engaged only the short-term retention of information in verbal working memory, but also the retrieval of information from long-term memory. If an object is easier or harder to name, it suggests that an association exists between the object and previously learned information, that is, information stored in long-term memory. Since the results indicate a main effect for the degree of nameability of the objects, it suggests that considerable contribution to spatial span came from long-term memory. The hypothesis that verbal working memory can enhance spatial span, therefore, may not have been tested in this particular study.

Measuring separate working memory systems is inherently flawed by the combinatory nature of tasks and stimuli used to engage working memory components. The contributions from unintentionally included memory systems and long-term memory may hinder accurate span measurement. However, decreases in performance when modality specific interference tasks are presented suggests that separate working memory systems are taxed by modality specific stimuli, and do, therefore, exist in some separate form. As noted by Toms et al. (1994), though separate memory systems are indicated, they appear to function interdependently. The study of combining separate working memory systems, therefore, requires tasks in which stimuli are measurably distinct and draw on separate working memory resources, yet are still complimentary. The current study addresses this issue.
Current Study

The current study investigates a stimulus presentation technique designed to increase the amount of information that can be held in working memory. By simultaneously employing two independent working memory resources, spatial working memory and verbal working memory, it is hypothesized that working memory span will be enhanced as demonstrated by an increase in spatial span. Subjects will be presented with the opportunity to spatially and verbally encode the location of blocks on a revised version of the Corsi Block Task (CBT). Instead of using identical blocks, the revised task uses ten different colors of blocks, each board using one block of each color. The location of the blocks provides the spatial encoding component of the task and the colors of the blocks allows for an additional verbal encoding component. The combination of spatial and verbal memory systems, it is theorized, will increase the number of blocks in sequence subjects are able to correctly recall. Previous studies investigating increased working memory capacity through the combination of separate memory systems have used tasks that either require considerable contribution from a general processing mechanism, for example, long-term memory, or are confounded by task administration procedures. Therefore, research in the area concerning the combination of basic level, separate working memory systems has yet to be conducted.

Two independent variables will be considered in the current study. The first independent variable is sex. Research indicates that males perform better than females on spatial ability tasks (Voyer, et al., 1995), while females perform better than males on verbal ability tasks (Halpern, 2000). The questions inspired by research finding sex
differences expands the current study's hypothesis to consider the possibility of significant differences in performance of spatial and verbal span tasks between males and females.

A second independent variable, verbalization of visually presented linguistic stimuli (in this case, color), will also be included. Baddeley (1998) suggests that color must be intentionally encoded verbally in order to enter the phonological loop. Otherwise it remains visually encoded. If, as Baddeley theorizes, the visuospatial sketchpad (VSSP) is responsible for visual and spatial information, visually encoding colors may tax the VSSP, interfering with spatial span rather than enhancing it. To address the issue regarding the encoding of color, half of the subjects will engage in a verbalization component during the combination verbal-spatial span task. Saying the colors out loud, hence creating an auditory presentation of the stimuli, should cause the subjects to encode the information directly into the phonological loop.

The dependent variables are span scores. Since the combination task includes verbal and spatial working memory, separate measures of verbal span and spatial span are necessary in order to establish the relative contribution of each to the span length of the combination task. Spatial span will be measured using a version of the Corsi Block Task. Verbal span measures include Word Span and Color Span. In addition, scores on the Raven's Progressive Matrices, a measure of analytical intelligence, will be used to assess the role of intelligence in working memory span.
The hypotheses put forth in this study are as follows:

1. Verbalization of colors in a combination verbal/spatial task will enhance spatial working memory span more in females than in males.

2. Verbal span will be greater with auditorily presented stimuli than with visually presented stimuli.

3. Spatial working memory span will be greater in males than in females.

4. Verbal working memory span will be greater in females than in males.

5. The addition of verbal stimuli to a spatial task will enhance spatial working memory span in both males and females.
CHAPTER 2

METHOD

Participants

Participants were 50 male and 51 female University of Nevada, Las Vegas, undergraduate students accessed from the Educational Psychology Department subject pool during the Spring 2002 semester by way of voluntary sign-up for research credit. This research credit served as partial fulfillment of course requirements. Ages ranged from 18 to 59; the average age was 25. It was assumed that the subjects: 1) were of average intelligence; 2) level of effort was randomly distributed across conditions; 3) and were not color-blind.

Materials

This study was designed to investigate the interaction between verbal and spatial working memory. A description of each task follows.

Raven’s Progressive Matrices

The Raven’s Progressive Matrices, a nonverbal test of analytic intelligence, requires abstract thought for solving problems (Carpenter, Just, & Shell, 1990). In this task,
problems consist of a 3 by 3 pattern matrix with the lower right corner bit from each pattern missing. The goal is to determine which piece from a group of eight pieces correctly completes the puzzle. The test consists of two parts: a practice set with 12 patterns and the actual test with 36 patterns.

**Corsi Block Task**

The Corsi Block Task (CBT) consisted of ten, two centimeter wooden blocks secured to a 28 cm by 35 cm, white, painter's canvas board. The blocks were numbered from one to ten on the side visible to the researcher and unmarked on the side visible to the subject. The blocks were randomly arranged on each of the thirty-six boards (five boards for each sequence length from four to nine, and one sample board).

**Corsi Colored Block Task**

The Corsi Colored Block Task (CCBT) boards were assembled using 2 centimeter wooden blocks, each painted one of 10 different colors: red, orange, yellow, green, blue, purple, pink, black, brown, and gray. For each board, one block of each color was randomly assigned a number from one to ten. Each numbered block was then glued to an 28 cm by 35 cm, white, painter's canvas board in the identical location as the corresponding number on the previously prepared CBT boards. This created two boards with identical placement of blocks: one board with plain blocks for the CBT and a matching board with colored blocks for the CCBT.

A pilot test of the CCBT was conducted during the Fall 2001 semester. The pilot test was conducted in order to determine the appropriate number of blocks needed for the task. If verbal and spatial working memory resources combine cumulatively, maximum...
performance on the CCBT could be as high as 14, plus or minus 2. On the other hand, if verbal and spatial working memory resources combine in some other additive fashion, the number of blocks needed would be substantially less than 14 plus or minus 2. Therefore, twenty-seven undergraduate students volunteered to participate in the pilot study as partial fulfillment for a course requirement. The task was administered one-on-one in the Cognitive Interference Laboratory. Directions for the CCBT were identical to the directions for the CBT. Because this was a pilot study focusing on task characteristics rather than outcome, two trials for each sequence length were used instead of the full version of five trials for each sequence length. The task was also abbreviated in the number of trials administered; subjects moved on to the next higher sequence only if they accurately recalled at least one of the current sequences. Two boards were prepared at each span length from 4 to 10. The results indicated that subjects were unlikely to exceed a span of 8 on this task.

The directions for the CCBT were modified as a result of the pilot study; a verbalization component was added. Half of the male subjects and half of the female subjects in the current study were directed to state aloud the colors of the blocks tapped as the researcher tapped them. Subjects were not, however, required to repeat the colors when recalling the block sequence. The purpose of this addition was to test the hypothesis that forced verbal encoding of color is required for verbal storage of the color of objects.
**Word Span**

Color words corresponding to the ten colors of the blocks in the CCBT were used. The presentation order of the colors was determined by first creating a table reflecting the number of colors needed for each trial and set, including a practice set. The table was filled in with numbers from zero to one as they appeared in a table of random numbers, skipping repeated numbers within one sequence. The colors were assigned a number from zero to one and arranged corresponding to the order prepared from the random numbers. Each set contained five trials of color sequences. The first set had five trials with sequences of four colors each. The second set had five trials with sequences of five colors each, and so on, finishing with five trials with sequences of eight colors each. The word span task, including directions, practice sets, and one minute breaks in between sets, was recorded on a standard cassette tape. Administration time for the task was 15 minutes.

**Color Span**

Color span consisted of two spiral bound books of random sequences of 8 cm colored squares printed on 14 cm by 21 1/2 cm sheets of cardstock. Book One contained a practice set and sequences from four to six colors in length. Book Two contained sequences from seven to nine colors in length. The same ten colors used in the CCBT and word span task were used in this task. No color repeated within the same trial. There were five trials of color sequences in each set. The first set had five trials with sequences of four colors each. The second set had five trials with sequences of five colors each, and so on, finishing with five trials with sequences of nine colors each. The presentation
order of the colors was determined by reversing the order of the colors in the word span task.

Ten boards were prepared for the non-verbal recall of the color sequences by attaching ten blocks, one of each color used in the task, to 23 cm by 28 cm white painter’s canvas boards. The blocks were arranged in two rows of five blocks each, in random color order. Blocks were numbered from one to ten on the side visible to the researcher. For ease in scoring, each color was assigned the same number. Red, for example was one, orange was two, yellow was three, and so on. Subjects were instructed to tap the blocks to identify the sequence of colors as they appeared in the Color Span task.

Exit Survey

The Exit Survey questions were designed to investigate the subjects’ perception of their strategies and performance on the CBT and CCBT. The questions were as follows:

1. On the block tapping tasks, how did you remember which blocks to tap?
2. Did you use a different way to remember which blocks to tap on the colored/plain blocks?
3. Was it easier or harder to remember which blocks to tap on the colored blocks?
   Why?

For Conditions One and Three:

4. You watched as I tapped the blocks. If you would have said the colors out loud as I tapped the blocks, do you think that would have helped you remember which blocks to tap?
For Conditions Two and Four:

4. You said the colors out loud as I tapped the blocks. Do you think that helped you remember which blocks to tap?

Procedure

Data was collected by the author, as well as by a research assistant under the direction of the author. Approval for research involving human subjects was obtained from the University of Nevada, Las Vegas Institutional Review Board. Subjects participated in three one-hour sessions. The conditions were as follows:

Condition One:

Session I: Raven’s Progressive matrices
Session II: CBT and Color span task
Session III: CCBT without verbalization and Word span task

Condition Two:

Session I: Raven’s Progressive matrices
Session II: CBT and Color span task
Session III: CCBT with verbalization and Word span task

Condition Three:

Session I: Raven’s Progressive matrices
Session II: CCBT without verbalization and Word span task
Session III: CBT and Color span task

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Condition Four:

- Session I: Raven's Progressive matrices
- Session II: CCBT with verbalization and Word span task
- Session III: CBT and Color span task

With the exception of the Raven's Progressive Matrices, which was administered in a classroom setting with groups of no more than twenty subjects, all tasks were administered one-on-one in the Cognitive Interference Laboratory (CIL) at the University of Nevada, Las Vegas. During testing in the CIL, subject and researcher sat across from each other at a 30" wide testing table. All testing supplies were easily accessible to the researcher from the seated position.

Twenty-five subjects were assigned to each of the four conditions, except Condition Three, which had 26. An ordered list of conditions and subject numbers was used to record subject assignment. For Conditions One and Two (13 males and 13 females, and 13 males and 12 females, respectively), subjects completed the CBT and the color span task during Session II. The same subjects completed the CCBT and the word span task for Session III, with Condition Two subjects engaging in the verbalization component of the CCBT. Subjects in Conditions Three and Four (each with 12 males and 13 females) completed the CCBT and word span task during Session II, with Condition Four subjects engaging in the verbalization component of the CCBT. The same subjects completed the CBT and the color span task during Session III. The administration procedure for each task follows.
Raven's Progressive Matrices

The Raven's Progressive Matrices was presented in two booklets: the first was a practice set and the second was the actual test. After a 5 minute practice session, subjects had 40 minutes to complete the actual test. Subjects made their responses on the given answer sheet as directed. Only the actual test items were considered in scoring. Correct responses were counted as one point each, with a maximum possible score of 36.

Corsi Block Tapping Task and Corsi Colored-Block Tapping Task

Task instructions, administration, and scoring for the CBT and CCBT were identical, with one exception. For the verbalization component, the 50 subjects assigned to Conditions Two and Four were directed to state out loud the color of the blocks as they were tapped by the researcher during the CCBT. The subjects were instructed to tap the same blocks in the same order as tapped by the researcher.

The task boards were stacked face down beside the researcher. For presentation to the subject, the corners of each board were aligned with two yellow dots on the table between the researcher and subject. Using a consistent rhythm, the researcher tapped the appropriate number of blocks with the eraser end of an unsharpened pencil, following the pattern established by the numerical order of the blocks. Five trials were administered at each sequence length followed by a one minute break in which subjects worked on a word search puzzle. The minimum sequence length was four and the maximum was nine. Completed boards were stacked face down next to the boards ready for use.

With both the CBT and the CCBT, as the subject responded, the sequence of blocks tapped by the subject was simultaneously written on scratch paper by the researcher. The
sequence was recorded on the scoring form (see Appendix A) during the one minute
break between sets. The full response sequence was not used in determining the span for
these spatial tasks, but will be useful for future comparisons with similar tasks. The
longest sequence in which the subject correctly recalled at least three of the five trials
indicated the subject's spatial memory span, as defined by these tasks. In other words,
span length was one less than the first series in which fewer than three of the five
presented sequences were recalled correctly. Even if a subject accurately recalled at least
three sequences of a subsequent series, the first series failing to meet the criteria was used
to determine span length.

**Word Span**

To assure consistent administration, the word span task was presented on audio tape.
Subjects were instructed to recall the color words in the same order as presented. A
practice set preceded the actual task. The practice set consisted of two trials with
sequences of three colors each. Five trials were administered at each sequence length
followed by a one minute break in which subjects worked on a word search puzzle. The
minimum sequence length was four and the maximum was eight. Subjects recalled the
sequence verbally and their responses were recorded by the researcher on the appropriate
scoring form (see Appendix B).

Verbal span was determined by the longest sequence the subject correctly recalled at
least three of the five trials. Span length was one less than the first series in which fewer
than three of the five presented sequences were recalled correctly. Even if a subject
accurately recalled at least three sequences of a subsequent series, the first series failing to meet the criteria was used to determine span length.

**Color Span**

Colors used in this task were the same ten colors used in the CCBT and Word Span task. Subjects were instructed to turn the cards one by one, using the tone from a metronome to help set a steady pace. The practice set consisted of two trials with sequences of three colors each. Five trials were administered at each sequence length followed by a one minute break in which subjects worked on a word search puzzle. The minimum sequence length was four and the maximum was eight.

Subjects' responses for the color span task were made by tapping the sequence on the colored blocks of the response boards. The ten non-verbal response boards were rotated during the task to prevent using the block locations as a memory strategy during the presentation of the colors. As the subjects responded, the researcher wrote the corresponding number of the color on scratch paper, transferring the sequence to the appropriate record sheet (see Appendix C) during the one minute breaks between sets. The longest sequence in which the subject correctly recalled at least three of the five trials indicated the subject's color span. Subjects failing to meet this criteria for the sequence of four were assigned a span length of three. Even if a subject accurately recalled at least three sequences of a subsequent series, the first series failing to meet the criteria was used to determine span length.
Exit Survey

At the end of Session III, subjects were asked four questions. Subjects were allowed to respond to each question without time limitations. The researcher asked follow-up questions as needed to clarify subjects' responses. Subjects were identified by subject number only. Interviews were recorded on cassette tape for later transcription.
Subjects participated in an experiment consisting of four tasks measuring working memory and one task measuring general ability. The task at the center of this study, the Corsi Colored-Block Task, was a combination task in which both verbal and spatial working memory were hypothesized to contribute to the task's span measurement. Two tasks, Word Span and Color Span, measured verbal span. Color Span may have also measured the visual-to-verbal transfer of information. The Corsi Block Task measured spatial span. The Raven's Progressive Matrices was used to estimate general ability. The following discussion of results includes analysis of the Raven's Progressive Matrices followed by the analysis of specific hypotheses. Results from the exit questionnaire conclude this chapter.

On the Raven's Progressive Matrices, one point was awarded for each correct answer on the actual task portion of the test. Scores were analyzed using an independent t-test with scores on the Raven's Progressive Matrices as the dependent variable and sex as the independent variable. No significant differences were observed. \( t_{(99)} = -1.76, p > .05 \). See Table 1 for means and standard deviations.
Table 1

Sex Differences on All Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raven's</td>
<td>20.80</td>
<td>6.54</td>
<td>22.80</td>
<td>4.75</td>
<td>21.81</td>
<td>5.77</td>
</tr>
<tr>
<td>CCBT</td>
<td>5.70</td>
<td>.76</td>
<td>5.71</td>
<td>.83</td>
<td>5.70</td>
<td>.79</td>
</tr>
<tr>
<td>CBT</td>
<td>5.35</td>
<td>1.08</td>
<td>5.31</td>
<td>.86</td>
<td>5.34</td>
<td>.97</td>
</tr>
<tr>
<td>Word Span</td>
<td>4.68</td>
<td>.96</td>
<td>5.10</td>
<td>.83</td>
<td>4.89</td>
<td>.92</td>
</tr>
<tr>
<td>Color Span</td>
<td>4.22</td>
<td>.95</td>
<td>4.78</td>
<td>.99</td>
<td>4.50</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Analysis of Specific Hypotheses

Hypothesis 1 predicted that verbalization of colors in a combination verbal/spatial task would enhance spatial working memory span more in females than in males. The longest sequence in which the subject correctly recalled at least three of the five trials indicated the subject's spatial memory span, as measured by the Corsi Colored-Block Task (CCBT). See Table 2 for means and standard deviations. An analysis of Hypothesis 1 was conducted using a 2x2 ANOVA with sex (Males, Females) and verbalization (Yes, No) as the independent variables and CCBT memory span as the dependent variable. The interaction was not significant, $F_{(1, 97)} = 2.13, p > .05$. Neither the main effect for sex, $F_{(1, 97)} = .00, p > .05$, nor the main effect for verbalization, $F_{(1, 97)} = .04, p > .05$, was significant.
Hypothesis 2 predicted that verbal span would be greater with auditorily presented stimuli than with visually presented stimuli. The longest sequence in which the subject correctly recalled at least three of the five trials indicated the subject's verbal memory span as measured by the Word Span and Color Span tasks. An analysis of Hypothesis 2 was conducted using a dependent t-test with Word Span and Color Span as the dependent variables. The differences were significant, $t_{(100)} = -4.05$, $p < .05$. Word Span was significantly longer than Color Span. See Table 1 for means and standard deviations.

Hypothesis 3 predicted that spatial span would be greater in males than in females. The longest sequence in which the subject correctly recalled at least three of the five trials indicated the subject's spatial span as measured by the Corsi Block Task (CBT). An analysis of Hypothesis 3 was conducted using an independent t-test with sex (Males, Females) as the independent variable and the CBT as the dependent variable. The results were not significant, $t_{(99)} = .238$, $p < .05$. See Table 1 for means and standard deviations.
Hypothesis 4 predicted that verbal span would be greater in females than in males. The longest sequence in which the subject correctly recalled at least three of the five trials indicated the subject’s verbal memory span as measured by the Word Span and Color Span tasks. An analysis was conducted using independent t-tests with sex (Males, Females) as the independent variable and Word Span and Color Span as the dependent variables. The results were significant for Word Span, \( t(99) = -2.346, p < .05 \), and Color Span, \( t(99) = -2.922, p < .05 \). Span length for females was significantly longer than span length for males on both the Word Span and Color Span tasks. See Table 1 for means and standard deviations.

Hypothesis 5 predicted that the combination of verbal stimuli with a spatial task would enhance spatial working memory span in both males and females. The longest sequence in which the subject correctly recalled at least three of the five trials indicated the subject’s spatial span as measured by the CCBT. An analysis of Hypothesis 5 was conducted using a dependent t-test with the CBT and CCBT as the dependent variables. The results were significant, \( t(100) = -3.55, p < .05 \). Span on the CCBT was significantly longer than span on the CBT. See Table 1 for means and standard deviations.

Further analysis was necessary to explain the factors contributing to the significant differences between CBT and CCBT. Scores for males and females were analyzed separately because there were significant differences between males and females on Word Span and Color Span. A stepwise multiple regression procedure was used with Raven’s Progressive Matrices, Color Span, Word Span, and CBT as predictors, and CCBT as the criterion. See Tables 3 and 4 for intercorrelation matrices for all variables for males and females, respectively. For males, only one predictor entered the regression.
equation: \( CB T, r^2 = .31, F_{(1,48)} = 21.17, p < .05 \). Partial correlations for excluded variables are as follows: Raven's .08, Color Span .12, and Word Span .12. For females, only one predictor entered the regression equation: Word Span, \( r^2 = .13, F_{(1,49)} = 7.34, p < .05 \). Partial correlations for excluded variables are as follows: Raven's .25, CBT .07, and Color Span .10.

Table 3
Intercorrelation Matrices for All Variables for Males

<table>
<thead>
<tr>
<th></th>
<th>Raven's</th>
<th>CCBT</th>
<th>CBT</th>
<th>Word Span</th>
<th>Color Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raven's</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCBT</td>
<td>.28</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBT</td>
<td>.41</td>
<td>.55</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Span</td>
<td>.51</td>
<td>.20</td>
<td>.19</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Color Span</td>
<td>.29</td>
<td>.21</td>
<td>.20</td>
<td>.37</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 4
Intercorrelation Matrices for All Variables for Females

<table>
<thead>
<tr>
<th></th>
<th>Raven's</th>
<th>CCBT</th>
<th>CBT</th>
<th>Word Span</th>
<th>Color Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raven's</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCBT</td>
<td>.27</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBT</td>
<td>.29</td>
<td>.08</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Span</td>
<td>.51</td>
<td>.36</td>
<td>.04</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Color Span</td>
<td>-.05</td>
<td>.29</td>
<td>-.08</td>
<td>.59</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Exit Survey

A transcription of the Exit Survey was analyzed for patterns. Responses were categorized and tallied. Separate averages were calculated for males and females, then for all subjects. All 50 male subjects were included in the analysis. However, the survey data for 3 female subjects was lost, leaving only 48 female subjects included in the analysis. The following is a discussion of the findings.

Questions 1 and 2 asked subjects what strategies they used to remember the block locations on the CBT and CCBT. Specifically, Question 1 asked, “On the block tapping tasks, how did you remember which blocks to tap?” Question 2 asked, “Did you use a different way to remember which blocks to tap on the colored/plain blocks?” On the CBT, 54% of males (n = 27) chose to concentrate on the direction, path, pattern, or order of the blocks sequence to remember which blocks to tap, compared to 25% of females (n = 12). Another popular strategy, used by 46% of females (n = 22) and 18% of males (n = 9), on the CBT block sequence was to concentrate on remembering the location, area, or section of the board the blocks were in. On the CCBT, the most popular strategy used by both males, 58% (n = 29), and females, 73% (n = 35), was the order of the colors. The next most popular strategy was both color and location, with 24% of males (n = 12) and 10% of females (n = 5). See Tables 5 and 6 for a complete summary of strategies used to remember block locations for the CBT and CCBT, respectively.

Question 3 asked, “Was it easier or harder to remember which blocks to tap on the colored blocks?” Fifty-nine percent of subjects (n = 58) felt that it was easier to remember the location of the blocks on the CCBT compared to the CBT. Twenty-three
percent of subjects (n = 23) felt that it was easier to remember the location of the blocks on the CBT compared to the CCBT. See Table 7 for a complete summary of Question 3 responses.

For Conditions One and Three, Question 4 asked, “You watched as I tapped the blocks. If you would have said the colors out loud as I tapped the blocks, do you think that would have helped you remember which blocks to tap?” Overall, 54% of subjects (n = 27) felt that naming the colors out loud would have helped them remember the location of the blocks, while 26% (n = 13) felt that naming the colors out loud would not have helped. See Table 8 for a complete summary of Question 4. Conditions One and Three responses.

For Conditions Two and Four, Question 4 asked, “You said the colors out loud as I tapped the blocks. Do you think that helped you remember which blocks to tap?” Overall, 67% of subjects (n = 32) felt that naming the colors out loud helped them remember the location of the blocks, while 13% (n = 6) felt that naming the colors out loud did not help. See Table 9 for a complete summary of Question 4. Conditions Two and Four responses. See Table 10 for a comparison of responses by sex.
<table>
<thead>
<tr>
<th>Response</th>
<th>Males</th>
<th>% Of Males</th>
<th>Females</th>
<th>% Of Females</th>
<th>N =</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location – area, sections</td>
<td>9</td>
<td>18.00%</td>
<td>22</td>
<td>45.83%</td>
<td>31</td>
<td>31.63%</td>
</tr>
<tr>
<td>Direction–path, pattern, order</td>
<td>27</td>
<td>54.00%</td>
<td>12</td>
<td>25.00%</td>
<td>39</td>
<td>39.80%</td>
</tr>
<tr>
<td>Rhythm, sound</td>
<td>2</td>
<td>4.00%</td>
<td>0</td>
<td>0.00%</td>
<td>2</td>
<td>2.04%</td>
</tr>
<tr>
<td>Counting</td>
<td>1</td>
<td>2.00%</td>
<td>6</td>
<td>12.50%</td>
<td>7</td>
<td>7.14%</td>
</tr>
<tr>
<td>Grouping, chunking</td>
<td>4</td>
<td>8.00%</td>
<td>0</td>
<td>0.00%</td>
<td>4</td>
<td>4.08%</td>
</tr>
<tr>
<td>Connect w/lines, shapes</td>
<td>6</td>
<td>12.00%</td>
<td>4</td>
<td>8.33%</td>
<td>10</td>
<td>10.20%</td>
</tr>
<tr>
<td>Guessed – no strategy</td>
<td>1</td>
<td>2.00%</td>
<td>0</td>
<td>0.00%</td>
<td>1</td>
<td>1.02%</td>
</tr>
<tr>
<td>Motion</td>
<td>0</td>
<td>0.00%</td>
<td>3</td>
<td>6.25%</td>
<td>3</td>
<td>3.06%</td>
</tr>
<tr>
<td>Block woodgrain</td>
<td>0</td>
<td>0.00%</td>
<td>1</td>
<td>2.08%</td>
<td>1</td>
<td>1.02%</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100.00%</td>
<td>48</td>
<td>100.00%</td>
<td>98</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
Table 6

Strategies Used in Remembering Block Locations on the CCBT

<table>
<thead>
<tr>
<th>Response</th>
<th>Males</th>
<th>% of</th>
<th>Females</th>
<th>% of</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n =</td>
<td></td>
<td>n =</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location – area, sections</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Direction – path, pattern, order</td>
<td>1</td>
<td>2.00%</td>
<td>1</td>
<td>2.08%</td>
<td>2</td>
<td>2.04%</td>
</tr>
<tr>
<td>Colors – order, sequence</td>
<td>29</td>
<td>58.00%</td>
<td>35</td>
<td>72.92%</td>
<td>64</td>
<td>65.31%</td>
</tr>
<tr>
<td>Colors – 1st letter, stories, associations</td>
<td>5</td>
<td>10.00%</td>
<td>4</td>
<td>8.33%</td>
<td>9</td>
<td>9.18%</td>
</tr>
<tr>
<td>Color and Location</td>
<td>12</td>
<td>24.00%</td>
<td>5</td>
<td>10.42%</td>
<td>17</td>
<td>17.35%</td>
</tr>
<tr>
<td>Rhythm, sound</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Counting</td>
<td>0</td>
<td>0.00%</td>
<td>1</td>
<td>2.08%</td>
<td>1</td>
<td>1.02%</td>
</tr>
<tr>
<td>Grouping, chunking</td>
<td>2</td>
<td>4.00%</td>
<td>1</td>
<td>2.08%</td>
<td>3</td>
<td>3.06%</td>
</tr>
<tr>
<td>Connect w/lines, shapes</td>
<td>1</td>
<td>2.00%</td>
<td>2</td>
<td>4.17%</td>
<td>3</td>
<td>3.06%</td>
</tr>
<tr>
<td>Guessed – no strategy</td>
<td>1</td>
<td>2.00%</td>
<td>0</td>
<td>0.00%</td>
<td>1</td>
<td>1.02%</td>
</tr>
<tr>
<td>Motion</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100.00%</td>
<td>48</td>
<td>100.00%</td>
<td>98</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Table 7

Comparison of Task Difficulty on the CCBT and CBT

<table>
<thead>
<tr>
<th>Response</th>
<th>Males</th>
<th>% of Males</th>
<th>Females</th>
<th>% of Females</th>
<th>N</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easier</td>
<td>28</td>
<td>56.00%</td>
<td>30</td>
<td>62.50%</td>
<td>58</td>
<td>59.18%</td>
</tr>
<tr>
<td>Harder</td>
<td>9</td>
<td>18.00%</td>
<td>14</td>
<td>29.17%</td>
<td>23</td>
<td>23.47%</td>
</tr>
<tr>
<td>Not Sure</td>
<td>7</td>
<td>14.00%</td>
<td>3</td>
<td>6.25%</td>
<td>10</td>
<td>10.20%</td>
</tr>
<tr>
<td>Same</td>
<td>6</td>
<td>12.00%</td>
<td>1</td>
<td>2.08%</td>
<td>7</td>
<td>7.14%</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100.00%</td>
<td>48</td>
<td>100.00%</td>
<td>98</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Note: Question 3 asked subjects to compare the difficulty of remembering the block locations on the CCBT with the CBT. The question asked, “Do you think the colored blocks were easier or harder to remember?”

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Table 8

Helpfulness of Color Verbalization on the CCBT; Non-Verbalization, Conditions One and Three

<table>
<thead>
<tr>
<th>Response</th>
<th>Males</th>
<th>% of Males</th>
<th>Females</th>
<th>% of Females</th>
<th>N =</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpful</td>
<td>14</td>
<td>56.00%</td>
<td>13</td>
<td>52.00%</td>
<td>27</td>
<td>54.00%</td>
</tr>
<tr>
<td>Not Helpful</td>
<td>5</td>
<td>20.00%</td>
<td>8</td>
<td>32.00%</td>
<td>13</td>
<td>26.00%</td>
</tr>
<tr>
<td>Not Sure</td>
<td>5</td>
<td>20.00%</td>
<td>3</td>
<td>12.00%</td>
<td>8</td>
<td>16.00%</td>
</tr>
<tr>
<td>Same</td>
<td>1</td>
<td>4.00%</td>
<td>1</td>
<td>4.00%</td>
<td>2</td>
<td>4.00%</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>100.00%</td>
<td>25</td>
<td>100.00%</td>
<td>50</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Note: Subjects were asked to speculate if verbalizing the colors on the CCBT would have helped them remember the block locations. Question 4 for the non-verbalization condition asked, "You watched as I tapped the colored blocks. If you would have said the colors out loud, do you think that would have helped you remember which blocks to tap?"
Table 9
Helpfulness of Color Verbalization on the CCBT; Verbalization, Conditions Two and Four

<table>
<thead>
<tr>
<th>Response</th>
<th>Males</th>
<th>% of Males</th>
<th>Females</th>
<th>% of Females</th>
<th>N</th>
<th>% Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpful</td>
<td>16</td>
<td>64.00%</td>
<td>16</td>
<td>69.57%</td>
<td>32</td>
<td>59.18%</td>
</tr>
<tr>
<td>Not Helpful</td>
<td>2</td>
<td>8.00%</td>
<td>4</td>
<td>17.39%</td>
<td>6</td>
<td>23.47%</td>
</tr>
<tr>
<td>Not Sure</td>
<td>7</td>
<td>28.00%</td>
<td>3</td>
<td>13.04%</td>
<td>10</td>
<td>20.83%</td>
</tr>
<tr>
<td>Same</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>100.00%</td>
<td>23</td>
<td>100.00%</td>
<td>48</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Note: Subjects were asked to speculate if verbalizing the colors on the CCBT helped them remember the block locations. Question 4 for the verbalization condition asked, “You said the names of the colors as I tapped the blocks. Do you think that helped you remember which blocks to tap?”
Table 10

Helpfulness of Color Verbalization on the CCBT: Comparison of Responses by Sex

<table>
<thead>
<tr>
<th>Response</th>
<th>Males</th>
<th>% of Males</th>
<th>Females</th>
<th>% of Females</th>
<th>N</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpful</td>
<td>30</td>
<td>60.00%</td>
<td>29</td>
<td>60.42%</td>
<td>59</td>
<td>60.20%</td>
</tr>
<tr>
<td>Not Helpful</td>
<td>7</td>
<td>14.00%</td>
<td>12</td>
<td>25.00%</td>
<td>19</td>
<td>19.39%</td>
</tr>
<tr>
<td>Not Sure</td>
<td>12</td>
<td>24.00%</td>
<td>6</td>
<td>12.50%</td>
<td>18</td>
<td>18.37%</td>
</tr>
<tr>
<td>Same</td>
<td>1</td>
<td>2.00%</td>
<td>1</td>
<td>2.08%</td>
<td>2</td>
<td>2.04%</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>100.00%</td>
<td>48</td>
<td>100.00%</td>
<td>98</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Note: See Tables 8 and 9 for wording of Question 4 for non-verbalization and verbalization conditions, respectively.
CHAPTER 4

DISCUSSION

Previous research suggests that the combination of working memory components increases the functional capacity of working memory (Chincotta, et al., 1999; Dunlap, 1998; Reisberg, et al., 1984). However, the combination tasks used in the previous studies failed to measure separate working memory components. The current study investigated the combination of verbal and spatial working memory tasks in order to determine whether this would serve to increase the measured span of spatial working memory. Results of the analysis of the hypotheses are discussed in turn, including a discussion of the strengths and limitations of this study. Finally, suggestions are presented for future research in working memory enhancement.

Hypotheses

Hypothesis 1 predicted that verbalization of colors in a combination verbal and spatial task would enhance spatial working memory span more in females than in males. Baddeley (1998) indicates that features such as color may be stored in iconic memory when presented in ways in which verbal encoding may not occur. To test the possibility that the colors on the CCBT would have to be intentionally encoded into verbal working memory, half of the subjects were required to engage in verbalization on the CCBT.
In addition, because the verbal component of the CCBT could include sex differences, scores for males and females were compared. There was no significant difference in performance on the CCBT between males and females, regardless of the vocalization of colors. Significant sex differences were found in this study on measures of verbal working memory (see Hypothesis 4 discussion). Because the CCBT is a combination of verbal and spatial working memory, sex differences in performance were expected. The non-significant sex differences in performance suggest that males and females were successfully using different combinations of working memory resources to remember the location of the blocks on the CCBT, resulting in similar span lengths.

Follow-up questions during the Exit Survey revealed that many subjects who were not required to vocalize the colors were subvocally naming the colors as the blocks were tapped. The non-significant difference between vocalization and non-vocalization conditions suggests that subvocally naming the colors may be as effective as vocalizing the colors.

Hypothesis 2 predicted that verbal span would be greater with auditorily presented stimuli than with visually presented stimuli. Research indicates that verbal span is greater with auditorily presented stimuli than in visually presented stimuli (Baddeley, 1998). There was a significant difference in span length between Word Span, the auditorily presented task, and Color Span, the visually presented task. The average span length for the visually presented Color Span task was less than the span for the auditorily presented Word Span task.
There are at least three possible explanations for the differences in these span measurements. First, the increased power due to the large sample size in this study may have caused a false statistically significant result. Second, the administration of the Color Span task may have interfered with an accurate span measurement. Turning the cards was awkward and led to inconsistent presentation timing. Some subjects expressed frustration with the difficulty of turning the cards. In addition, tapping their response on the non-verbal response boards produced a delay in response time. This short delay could have reduced the subjects' ability to retain and, hence, recall the color sequence. These task administration difficulties could have taxed working memory capacity, thus reducing the ability to hold and recall the information, reducing Color Span scores.

The third possible explanation for the difference between Word Span and Color Span could be due to the visual-to-verbal encoding of information necessary for the colors to reach the phonological loop. Verbal span measured with visually presented words is shorter than verbal span measured with auditorily presented words (Watkins & Peynircioglu, 1983). The colors could require similar encoding to visually presented words, thus a shorter span length with the Color Span task would be expected.

Hypothesis 3 predicted that spatial span would be greater in males than in females. Research indicates that performance on spatial ability tasks is superior in males (Voyer, et al., 1995). A comparison of scores on the CBT, however, indicates no significant differences between males and females. Perhaps the differences found in previous research were unique to the components of spatial ability tasks. Similar factors, therefore, may not be present in spatial span tasks.
Hypothesis 4 predicted that verbal span would be greater in females than in males. Research indicates that performance on verbal ability tasks is superior in females (Halpern & Wright, 1996). A comparison of scores on the Word Span and Color Span tasks indicates that females have a higher verbal span than males. This is consistent with findings in previously discussed research.

Hypothesis 5 predicted that the combination of verbal stimuli with a spatial task would enhance spatial working memory span in both males and females. As previously stated, CBT has demonstrated reliability and validity as a spatial span measurement task. The addition of a verbal component (i.e., color) to this spatial task allowed for the possibility of combining resources from verbal and spatial working memory systems as demonstrated by an enhanced span. The statistically significant differences between CBT and CCBT suggest that verbal working memory and spatial working memory functions may be combined to enhance spatial span. The spatial span of the combination task was expected to be enhanced as much as the length of the verbal span and spatial span combined. The average Word Span was 4.89. The average CBT span was 5.34. Had the separate lengths of the verbal and spatial spans combined, it would have produced an average span length between 9 and 10 on the combination task. The average span length on the combination task was actually 5.7. It appears that working memory resources used for the CCBT were combined in some as-yet-to-be-determined additive, rather than cumulative, fashion.

The smaller than cumulative span on the CCBT (i.e. less than 9/10) could be due to the presentation mode of the verbal material. The colors were presented visually.
obviously requiring the subjects to first encode the colors visually and transfer them to verbal memory. The extra step of encoding and transferring this stimuli could have taxed working memory processes, thus diminishing the capacity of the immediate memory system as a whole. Similarly, the involvement of visual memory in encoding the colors could have interfered with the visual encoding of the location of the blocks, yielding only a slightly enhanced spatial span. Many of the subjects commented that they felt the colors were confusing and they did not know what to look at, the colors or the locations of the blocks. What they could have been expressing is the feeling of an overwhelmed working memory system.

Yet, the span of the combination task (CCBT) was significantly longer than the span of the plain, spatial task (CBT). This suggests that, even though visual working memory may have reached maximum capacity in the presentation of the task, some information was transferred to the phonological loop and visuospatial sketchpad. However, using a visual presentation of verbal information may have interfered with spatial memory, because the location of the blocks was also visually encoded.

A regression analysis of the CCBT indicated that for males and females, different variables contributed to performance on the CCBT. For males, the spatial task (CBT) shared significantly more variance with the CCBT than either of the two verbal tasks (Color Span and Word Span). For females, one of the verbal tasks (Word Span) shared significantly more variance with the CCBT than the spatial task or the other verbal task. These results suggest that males and females were relying on different memory resources
to complete the CCBT task. Males were relying more on the spatial component of the CCBT, while females were relying more on the verbal component.

Exit Survey

At the conclusion of testing and prior to receiving debriefing information, subjects were questioned about the thoughts and strategies they used during the CBT and CCBT. For analysis, categories were made for all possible responses. There were 12 categories for Questions 1 and 2, and 5 categories each for Questions 3 and 4. Responses were analyzed for patterns.

Questions 1 and 2 appeared difficult for the subjects to answer. The questions required the subjects to reflect on strategy use during the CBT and CCBT. At times during the interview process, it seemed that subjects were not able to reflect on the actual strategies they may have used, and instead reported what they would have done had they given the process some thought. A case in point involves a subject who could not remember having participated in the CBT. After attempting to refresh the subject’s memory by showing him one of the task boards, he reported using a feasible strategy. This researcher was not convinced that the subject actually recalled the task or the strategy he used. Other subjects reported using strategies that seemed overly complex for a short-term memory task. Upon further questioning, some subjects changed their answers completely or deleted the superfluous components of the strategies they previously reported using.
Overall, 60% of subjects felt that remembering the location of the blocks was easier with the additional color component of the CCBT. About one-quarter of the subjects, however, felt that the colors made the task more difficult. Seven subjects (six males and one female) reported that remembering the block locations was equally difficult on both the CBT and CCBT. Interestingly, only one of the seven subjects reported using the same strategy for both tasks.

In response to Question 4, subjects felt that saying the colors out loud helped (Conditions Two and Four) or would have helped them (Conditions One and Three) remember the location of the blocks. However, as previously discussed with hypothesis 1, no significant differences were found between the span lengths of the verbalization and non-verbalization conditions on the CCBT. The subjects' belief that saying the colors out loud did or would help may have been due to information received from teacher training courses. Some subjects stated that they believed they were auditory learners and were confident that verbalization was beneficial. Others stated hypothetical reasons, such as seeing and saying the colors is like learning the information twice, therefore it must be helpful in remembering the block locations.

Additional follow-up questions may have helped subjects clarify their answers, but it also may have led to further inconsistencies in the responses. The open ended, conversational style of the Exit Survey was helpful in revealing the thinking and strategies subjects reported using. However, it also required the researcher to make judgments and assumptions when analyzing responses. Using a Likert scale in addition
to open ended questions would have removed some of the inconsistencies that may be a part of the Exit Survey analysis.

**Future Research**

Future research in combining working memory systems should first focus on the separate measurements of those systems, taking into account each system's unique encoding specifications as well as possible sex differences. Refinements in scoring and task administration should also be included in future research on combined working memory tasks.

The mode of stimuli presentation should be representative of the unique functions of the separate memory systems. For example, presenting the colors auditorily may separate the verbal and spatial stimuli of the CCBT. Instead of requiring the subjects to verbalize the colors vocally or subvocally, the colors of the blocks could be spoken by the researcher, recorded and played during administration, or incorporated into computer administration of the task. Auditory presentation would allow for direct encoding into the phonological loop (Baddeley, 1998), thus reducing the demand on visual working memory.

Sex differences in working memory should also be considered in future research. For example, the current study found sex differences favoring females on verbal working memory tasks, but no sex differences on the spatial task. With a verbal advantage, one may assume that females would perform better on the spatial/verbal combination task. However, analysis indicates no sex differences on the combination task. This suggests
that males and females rely on different ratios of working memory system involvement in combination tasks (recall for males relative contribution of CBT to CCBT was 31%; for females relative contribution of Words Span to CCBT was 13%). Therefore, identical tasks may not have the same enhancement effect for both males and females. In addition to further investigation into sex differences in working memory, future studies in combing working memory should include the possibility of combination tasks specific to each sex.

Less conservative scoring criteria may be used for future data analysis of the subjects’ recall of the blocks, such as the recalled sequence regardless of the order, or the total number of accurately recalled sequences. Less conservative scoring may yield more variance in scores, leading to different results than those found in the current study. Revised scoring criteria may also allow for analysis of errors in recall, providing correlational data with errors in the verbal working memory span tasks. This information could offer further guidance in designing techniques for combining working memory systems.

Finally, computer administration of the tasks would increase the presentation and scoring consistency between trials and subjects. On the CCBT, for example, it may be difficult to coordinate the verbal presentation of the colors with the spatial presentation of the blocks. Computer administration would easily incorporate both the verbal and spatial presentation of the task.
APPENDIX A

Corsi Block Tapping Task and
Corsi Colored-Block Tapping Task
Recording Sheet
CORSI BLOCK TAPPING TASK

<table>
<thead>
<tr>
<th></th>
<th>Actual Sequence</th>
<th></th>
<th>Actual Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Actual Sequence</td>
<td></td>
<td>Actual Sequence</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Actual Sequence</td>
<td></td>
<td>Actual Sequence</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SID</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
APPENDIX B

Word Span Recording Sheet
### WORD SPAN TASK

<table>
<thead>
<tr>
<th>SET 1</th>
<th>SET 2</th>
<th>SET 3</th>
<th>SET 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>gray</td>
<td>blue</td>
<td>purple</td>
<td>black</td>
</tr>
<tr>
<td>green</td>
<td>green</td>
<td>purple</td>
<td>brown</td>
</tr>
<tr>
<td>pink</td>
<td>pink</td>
<td>red</td>
<td>red</td>
</tr>
<tr>
<td>yellow</td>
<td>yellow</td>
<td>green</td>
<td>yellow</td>
</tr>
<tr>
<td>blue</td>
<td>orange</td>
<td>purple</td>
<td>orange</td>
</tr>
<tr>
<td>orange</td>
<td>blue</td>
<td>brown</td>
<td>gray</td>
</tr>
<tr>
<td>purple</td>
<td>purple</td>
<td>blue</td>
<td>pink</td>
</tr>
<tr>
<td>black</td>
<td>brown</td>
<td>yellow</td>
<td>black</td>
</tr>
<tr>
<td>green</td>
<td>red</td>
<td>blue</td>
<td>gray</td>
</tr>
<tr>
<td>pink</td>
<td>yellow</td>
<td>orange</td>
<td>black</td>
</tr>
<tr>
<td>yellow</td>
<td>green</td>
<td>black</td>
<td>orange</td>
</tr>
</tbody>
</table>
APPENDIX C

Color Span Recording Sheet
### COLOR SPAN TASK

#### SET 1

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>brown</td>
<td>8</td>
<td>black</td>
<td>1</td>
<td>red</td>
<td>8</td>
<td>black</td>
</tr>
<tr>
<td>7</td>
<td>pink</td>
<td>6</td>
<td>purple</td>
<td>6</td>
<td>purple</td>
<td>1</td>
<td>red</td>
</tr>
<tr>
<td>5</td>
<td>green</td>
<td>5</td>
<td>blue</td>
<td>2</td>
<td>orange</td>
<td>7</td>
<td>pink</td>
</tr>
<tr>
<td>10</td>
<td>gray</td>
<td>4</td>
<td>green</td>
<td>7</td>
<td>pink</td>
<td>3</td>
<td>yellow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### SET 2

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>yellow</td>
<td>9</td>
<td>brown</td>
<td>2</td>
<td>orange</td>
<td>1</td>
<td>red</td>
</tr>
<tr>
<td>6</td>
<td>purple</td>
<td>1</td>
<td>red</td>
<td>4</td>
<td>green</td>
<td>5</td>
<td>blue</td>
</tr>
<tr>
<td>2</td>
<td>orange</td>
<td>7</td>
<td>pink</td>
<td>5</td>
<td>blue</td>
<td>9</td>
<td>brown</td>
</tr>
<tr>
<td>4</td>
<td>green</td>
<td>8</td>
<td>black</td>
<td>3</td>
<td>yellow</td>
<td>3</td>
<td>yellow</td>
</tr>
<tr>
<td>5</td>
<td>blue</td>
<td>6</td>
<td>purple</td>
<td>7</td>
<td>pink</td>
<td>10</td>
<td>gray</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### SET 3

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>pink</td>
<td>3</td>
<td>yellow</td>
<td>2</td>
<td>orange</td>
<td>8</td>
<td>black</td>
</tr>
<tr>
<td>4</td>
<td>green</td>
<td>1</td>
<td>red</td>
<td>5</td>
<td>blue</td>
<td>3</td>
<td>yellow</td>
</tr>
<tr>
<td>8</td>
<td>black</td>
<td>9</td>
<td>brown</td>
<td>6</td>
<td>purple</td>
<td>10</td>
<td>gray</td>
</tr>
<tr>
<td>5</td>
<td>blue</td>
<td>6</td>
<td>purple</td>
<td>9</td>
<td>brown</td>
<td>7</td>
<td>pink</td>
</tr>
<tr>
<td>2</td>
<td>orange</td>
<td>5</td>
<td>blue</td>
<td>3</td>
<td>yellow</td>
<td>4</td>
<td>green</td>
</tr>
<tr>
<td>6</td>
<td>purple</td>
<td>4</td>
<td>green</td>
<td>10</td>
<td>gray</td>
<td>1</td>
<td>red</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### SET 4

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>pink</td>
<td>10</td>
<td>gray</td>
<td>3</td>
<td>yellow</td>
<td>8</td>
<td>black</td>
</tr>
<tr>
<td>9</td>
<td>brown</td>
<td>7</td>
<td>pink</td>
<td>1</td>
<td>red</td>
<td>9</td>
<td>brown</td>
</tr>
<tr>
<td>1</td>
<td>red</td>
<td>6</td>
<td>purple</td>
<td>10</td>
<td>gray</td>
<td>1</td>
<td>red</td>
</tr>
<tr>
<td>2</td>
<td>orange</td>
<td>3</td>
<td>yellow</td>
<td>9</td>
<td>brown</td>
<td>2</td>
<td>orange</td>
</tr>
<tr>
<td>5</td>
<td>blue</td>
<td>8</td>
<td>black</td>
<td>6</td>
<td>purple</td>
<td>10</td>
<td>gray</td>
</tr>
<tr>
<td>6</td>
<td>purple</td>
<td>9</td>
<td>brown</td>
<td>4</td>
<td>green</td>
<td>5</td>
<td>blue</td>
</tr>
<tr>
<td>8</td>
<td>black</td>
<td>1</td>
<td>red</td>
<td>2</td>
<td>orange</td>
<td>4</td>
<td>green</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES


VITA

Graduate College
University of Nevada, Las Vegas

Miriam E. Dunbar

Home Address:
1567 Figueroa Dr.
Las Vegas, NV 89123

Degree:
Bachelor of Science, Elementary Education. 1995
University of Nevada, Las Vegas

Special Honors and Awards:
First Place: Poster Presentation at the Graduate Research Forum. University of Nevada, Las Vegas. April 6, 2002

Publications:

Thesis Title: Investigating the Relationship of Verbal Span and Spatial Span in a Combination Task

Thesis Examination Committee:
Chairperson. Dr. Alice J. Corkill, Ph.D.
Committee Member. Dr. Frank N. Dempster, Ph.D.
Committee Member. Dr. CarolAnne Kardasch, Ph.D.
Graduate Faculty Representative. Dr. Mark Guadagnoli, Ph.D.