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The Effect of Gender, Not Math Anxiety, on Working Memory Tasks

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ABSTRACT

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The effect math anxiety has on various tasks are overwhelming. Math anxiety has been shown to relate to poor educational attainment and avoidance of math courses (Hembree 1990). Research has shown that math anxiety can affect simple process like counting (Maloney, Risko, Ansari, & Fugelsang, 2010) to taxing working memory while solving a math problem (Ashcraft & Kirk, 2001). Additionally, gender also plays a role in math attitudes. Often times when primed with negative stereotypes, females perform worse on math tasks as compared to other females who were not primed and their male counterparts. To date, little is known about how math anxiety or gender might affect the performance on math-based working memory span tasks. The goal of this paper is to investigate the role math anxiety may have in inhibiting performance on span tasks that require math processing. In addition, we hope to investigate any potential capacity differences between individuals of varying degrees of anxiety.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Math anxiety is defined as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations.” (Richardson & Suinn, 1972). Contrary to Johann von Neumann, those with math anxiety may never get used to manipulating or computing numbers. Those who suffer from math anxiety can experience an array of negative reactions ranging from physical to emotional. These reactions can have a number of negative consequences within the math field.

Hembree’s (1990) results show that attitudes regarding math can affect performance. Math anxiety correlates -.34 with mathematics achievement scores (grades 5-12; for college, r = -.31), and -.30 with course grades (grades 9-12; for college, r = -.27). Consequently, highly math anxious students take fewer mathematics courses, earn lower grades in the courses they do take, and tend to avoid taking additional math courses if possible. In addition, they tend to avoid mathematically-oriented college majors and career paths (for reviews, see Ashcraft, Krause, & Hopko, 2007; Ashcraft & Moore, 2009; Ashcraft & Rudig, 2012).

Studies have linked math anxiety to an avoidance of math and/or numerical tasks. In his meta-analysis, Hembree (1990) documents that people with high math anxiety express a variety of poor attitudes about math. The correlations with math anxiety are -.37 for perceived usefulness of math, -.64 for motivation in math, -.82 for self-efficacy (grades 6-11; for college, r = -.65), and -.75 for enjoyment of math (grades 5-12; for college, -.47). At the college/university level, math anxiety correlates -.32 with the intent to take more math classes, thus stifling the pursuit of math oriented careers.

Another form of avoidance that can occur at a more local level is referred to as the speed-accuracy trade off. An individual with high levels of math anxiety may want to escape a math situation, such as a math test, as quickly as possible, without any regard to their grade or the accuracy of their answers (Ashcraft & Faust, 1994). This was evidenced in an experiment that used a verification task and confusion problems. A confusion problem is one in which the solution to a particular problem could be true. For example, 4+3=12 would be correct if the operation was multiplication instead of addition. The authors found that high math anxious individuals were faster than their low math anxious peers. However, the high math anxious individuals made 12.8% errors, incorrectly accepting the answer to be true, whereas low math anxious individuals made 5.2% of the errors.

The same pattern of results occurred when the split effect was examined. A split refers to the difference between a stated answer and the true answer to a problem. For example, 5+1=7 refers to a +1 split because seven is one above the true answer, six. Faust, Ashcraft, & Fleck (1996) found that high math anxious individuals generated more flawed scores (11.13%) as the splits increased, this compared to the low math anxious individuals' error rates (5.36%). However, high math anxious individuals were quicker than their low math anxious peers. Both of these results point to evidence regarding local avoidance. In other words, high math anxious individuals were more likely to sacrifice accuracy for speed to avoid completing the problem.

In order to eliminate the notion that high math anxious individuals are incompetent in the math domain, Faust et al.(1996) designed a third experiment that did not place a time restriction on the participants while completing the task. In this experiment, poor performance among high math anxious individuals was virtually eliminated; showing that the timed nature may contribute to the feelings of anxiety these individuals may have when they are completing math tasks.

Taken together, the results of these two studies suggest that high math anxious individuals are not simply incompetent in the math domain, but have a genuine fear and dislike for math, avoiding it at a global and local level.

Aside from the disadvantages avoidance can have on standardized tests and general careers in the math fields, there is another detriment that may not be as well understood, and that is performance on complex span tasks. Specifically, we suspect that performance may especially be hindered on tasks that require the effortful processing of numbers. As we will review, math anxiety also impairs working memory resources (Ashcraft, 1992; Ashcraft & Kirk, 2001) and using a complex span task that involves the manipulation of numbers may hinder the capacity of those who are high in math anxiety. We expect the current study to yield two important findings. Firstly, these results may show that there is a detriment to using a working memory task that could elicit math anxiety effects. Typically in complex span tasks, an individual must reach 85% accuracy in the processing component of the task (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005) in order to be included in experimental analyses. This was done to exclude potentially low motivated participants. We will argue that this practice will bias the sample by excluding high math anxious participants who succumb to the negative aspects of math anxiety (i.e.; avoidance, fewer working memory resources etc.) that, in turn, affect the processing component of these complex span tasks.

Secondly, we seek to understand the differences in working memory capacity between high and low math anxious individuals. We suggest that those who are high in math anxiety will have differences in capacity compared to their low math anxious counterparts when completing math tasks. We suspect this capacity difference will be caused by the anxiety that arises from the processing component of the task. The taxation of this component may hinder/change the storage

ability among high and low math anxious individuals. Once we understand these differences in capacity we will then investigate these same differences among individuals with high and low math achievement. We will begin with an overview of the differences between the Reading Span (RSPAN) and Operation Span (for) tasks, both of which we plan to use for the study.

Before we describe the complex tasks, we will briefly point out the differences between working memory and short-term memory. George Miller (1956) made the suggestion that we have the ability to maintain 7 plus or minus 2 items in short-term memory. Today this is described as short-term memory, which involves storage of information (e.g. storing information on a grocery list). Later researchers (Baddeley, 1986; Baddeley & Hitch, 1974) coined the term working memory, and ultimately found that working memory involves storage and processing of stimuli. Today we understand that the working memory system is central in the involvement of mental effort in everyday tasks (Miyake & Shah, 1999). The working memory system is limited in the amount of processing and storage, extent of interaction, or degree of control that it can accomplish in a given situation.

Complex Span Tasks

Early in the study of short-term memory, many tasks were created to measure the number of items that individuals could store and recall. These tasks were dubbed Simple Span tasks. Daneman and Carpenter (1980) and others (Baddeley & Hitch, 1974) suggested that a task made up of merely storage and recall was not adequate enough to determine an individual's working memory capacity because they concluded that working memory was compromised of more than storage. The authors felt that a new task, which required storage and recall as well as a processing component, was needed to measure the complex nature of working memory.

In order to adequately measure the complex nature, Daneman and Carpenter (1980) added an additional component to the simple span task. This addition was called the processing component. This component required individuals to manipulate information while storing and eventually recalling previous information. In effect, working memory span tasks tell researchers the amount of information a person can store and successfully recall while at the same time completing some other "processing" task. This is similar to everyday tasks that people are faced with: holding a number of pieces of information in memory that may or may not be needed to solve a problem while at the same time completing some other separate task.

The first complex span task was the RSPAN (for reading span) and was developed by Daneman and Carpenter (1980). These authors created 3 sets of 2,3,4,5, and 6 sentences that required participants to recall the last words of the sentences for each set. The person's working memory span was the level at which two out of the three words were correctly recalled in the order in which they were presented. An individual's span score could fall in the range of two through six. An individual's span score was reflected in their storage ability, not their processing ability. In their second experiment, Daneman and Carpenter (1980) added a verification task. Participants indicated whether the sentences, drawn from general knowledge materials, were true or not within 1.5 seconds. This addition of a verification task prevented participants from using a strategy to remember more words at the end of the sentence.

Since this experiment, there have been different variations of the RSPAN task. For example, Kane, Hambrick, Tuholski, Wilhelm, Payne, and Engle (2004) isolated letters at the end of the sentences for individuals to recall. In some cases, researchers used isolated words, which were different from the last words in the sentence. Thresholds of accuracy were also implemented. The original experiment did not account for accuracy in the processing component.

To correct for this, various researchers implemented an 85% threshold for accuracy (Conway et. al., 2005; Engle & Conway, 1996; Engle, Tuholski, Laughlin, & Conway, 1999). For example, the participants had to achieve at least 85% accuracy on the processing task to be included in the sample. Finally, Turner and Engle (1989) updated the RSPAN task by lowering the number of words to be recalled from 15 to 12. Regardless of the changes, the RSPAN still measured an individual's working memory capacity.

One concern that Daneman and Carpenter (1980) voiced, with regard to the RSPAN, was that those with superior reading ability might perform better than those with lesser reading ability on the RSPAN task. They suggest that during the RSPAN task, a superior reader may have fewer computational demands on working memory. Therefore these individuals would have less demand on the processing component of their working memory, which will free up more resources for remembering words or letters at the end of the sentence. Thus this claim suggests there is a specific domain, in this case reading, that can influence performance on complex span tasks. In order to directly address this claim, Turner and Engle (1989) developed the Operation Span task (OSPAN).

Turner and Engle (1989) claimed that working memory tasks should transcend task dependence. They specifically state that a "memory span task could be embedded in a concurrent processing task that is unrelated to any particular skills measure and still predict success in the higher level task" (p.130) To test this they developed the OSPAN task. The main difference from the RSPAN task was that the OSPAN task required participants to verify the correctness of a math equation rather than a sentence. For example, the math equation follows a consistent formula: multiplication or division of 2 single digits and the addition of a third single digit (i.e. (6/3)+3=5). As with the RSPAN, a single syllable word is presented at the end of the equation

for participants to recall. The OSPAN task consisted of three sets of 2,3,4,5, and 6 math operations. Turner and Engle (1989) did not find any differences in performance between the math and reading based working memory tasks. This led the authors to claim that the complex span task was domain general, and that individual differences in particular domains do not affect performance.

Other researchers have taken a closer look at the OSPAN task and its immunity to individual differences. One study manipulated the difficulty of the operation span task by manipulating single or double-digit multistep arithmetic verification problems (Conway & Engle, 1996). The authors did not find performance differences on the storage component between these two tasks. However, like the RSPAN task, it should be noted that the authors implemented an 85% threshold for accuracy. This was to ensure that participants remained motivated to complete the OSPAN task efficiently. Unfortunately, this cutoff score may have eliminated those who have high math anxiety or lower math ability. Therefore, we may not have an accurate representation of the processing or storage ability of high math anxious participants.

In general, the research above shows that performance on the RSPAN and OSPAN tasks determines working memory capacity and this is reflected in the storage component of the span task, not the processing component. However, we feel that the processing component may influence capacity abilities. Even though Turner and Engle suggest that the complex span tasks accurately reflect working memory capacity, we feel that this claim may not be justified. We suspect that high math anxious individuals may have been included in the group that was often thrown out for not achieving 85% accuracy. The goal of this experiment is to examine the effect math anxiety may have on the processing component of these tasks and how this may affect the

overall capacity of working memory. To date, no one has examined processing and capacity differences separately among high and low math anxious individuals.

Since the processing component of the OSPAN involves the manipulation of math procedures, we will review the relationship between working memory and math performance.

Working Memory and Math Performance

One of the key mechanisms attributed to math problem solving is the utilization of the working memory system (Ashcraft & Kirk, 2001; LeFevre, DeStefano, Coleman, & Shanahan, 2005). There are various math procedures that utilize the working memory system. These procedures range from counting (Camos & Barrouillet, 2004; Hecht, 2002), addition (Kirk & Ashcraft, 2001), subtraction (Seyler, Kirk, & Ashcraft, 2003), and multiplication (Imbo & Vandierendonck, 2007b).

Ashcraft and Krause (2007), describe three characteristics of any math problem that can vary and require more or less working memory resources. One of their arguments is how easily the solution can be retrieved from memory. This fits in with the argument made by Ericsson and Delaney (1997) in which they state that practice in a domain leads to the development of domain specific long term retrieval structures that interact with the conscious working memory. With regards to math, those solutions that are more easily retrieved from long term memory require less use of working memory.

To test this idea, Seyler, Kirk, & Ashcraft, (2003) investigated subtraction of basic facts. Participants showed an exaggerated problem size effect in Experiment 1. This was evidenced by an increase in latencies for problems with a two-digit minuend (for 11 – 4, the minuend is 11). This pattern suggests that the larger problems relied heavily on relatively slow procedures for solution. In other words, solutions for large problems were not always retrieved from memory.

On the hypothesis that such slower procedures demand the resources of working memory; Seyler et al. 2003 conducted another test. They pre-tested the participants on a working memory span task, and categorized them into low, medium, and high span groups. Then authors tested them on simple subtraction facts in the dual-task procedure. The secondary task required them to hold 2, 4, or 6 randomly selected letters in working memory, then report them in order after solving the subtraction problem.

The results were very forthright. Firstly, errors in letter recall increased more sharply in the dual task when the load on working memory increased, compared to the errors observed in the control task (letter recall only). This suggests that mental subtraction seems to rely on the resources of working memory. Secondly, individuals with lower working memory spans made far more errors in the dual task than in the control condition. This performance difference between dual and control condition was much smaller for the high span group. Low span participants were particularly disadvantaged at doing subtraction when the dual task setting diverted their working memory resources. Finally, this disadvantage, for the low span group, depended on how heavily working memory was loaded. When the load was light (2 letters), there were no group differences, but when the load was heaviest (6 letters), the low span group made more letter recall errors (56%) compared to the high span group (31%). This study demonstrates that working memory resources were necessary for adults to perform elementary subtraction. Denying them of sufficient working memory resources stifled their performance significantly.

In addition, the total number of steps required to solve a problem will deplete working memory resources as the number of steps increase. This was evidenced in an earlier experiment conducted by Ashcraft and Kirk 2001(experiment1). Their main goal was to understand the impact the carry operation had on working memory resources. Specifically they were interested

in the taxation that the carrying operation had on the processing component. They presented participants with addition problems ranging from basic addition facts, up to two column addition. Half of the problems they presented required carrying. They found that problems that required carrying were a full 1200ms slower than the problems that did not require carrying. In addition to the reaction time, people made more errors when the problems included carrying than when the problems were basic facts.

These series of studies show that working memory processing is an integral part to successfully completing arithmetic problems. Firstly, the numerical values that are to be manipulated tax working memory more if those numbers are larger and if they require the use of the carry operation when computing. Secondly, the total number of steps required to solve a problem will deplete working memory resources as the number of steps increases. Finally, some computations require little more than accessing a solution from long term memory. As mentioned earlier, working memory is comprised of both storage and processing. Additionally, working memory is central to effortful processing. This research suggests that math computation mainly affects the processing component of working memory. Those with limited processing or storage may have a more difficult time computing mathematical problems that fit under the above findings. Additionally, problems on the OSPAN task require two steps, suggesting that working memory resources may be used at a greater extent than previously expected. Next we will explore math anxiety and its impact on working memory.

Math Anxiety and Working Memory

Working memory is thought to be a system that is responsible for active maintenance of information in the face of distraction. Some evidence suggests that anxious individuals' performance on any given task is more impaired by distracting stimuli than those who are non-

anxious (Calvo & Eyesenck, 1996; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998). Eyesenck and Calvo (1992) proposed the Processing Efficiency Theory, which theorizes that the worry component of anxiety taxes working memory. Eyesenck and Calvo (1992) suggest that worry interferes with the processing and storage capacity of working memory by interfering with the limited attentional resources. As more resources are consumed through worrying thoughts, efficiency decreases. Efficiency is defined as the relationship between the effectiveness of performance and the effort or resources spent in task performance. Often times this is measured through reaction time. Those with higher anxiety are often slower to complete tasks.

Math anxiety can tax working memory to an extent that individuals may perform poorly on a given math task (Beilock & Carr, 2005). Past research provides evidence that anxiety may create a dual task situation that depletes working memory resources. In an attempt to understand the impact math anxiety has on working memory, Ashcraft and colleagues looked towards Eysenck's processing efficiency theory.

One study conducted by Ashcraft & Kirk (2001) set out to test Eysenck's theory directly. The authors asked participants of low, medium, and high mathematics anxiety to perform a dual task experiment, using an addition task, with one and two-column addition problems, and a letter recall task. The letter recall task required participants to hold either 2 or 6 letter sequences in their working memory. Their reasoning was that more difficult addition, especially when the problem required a carry, would burden working memory function. The load should be even heavier when participants also had to hold 6 letters in working memory for later recall. High mathematics anxiety should then lead to an even greater drain on working memory due to the worries and ruminations that are thought to deplete processing resources.

Their results were favorable to Eyesenck's theory. As expected, fewer letters were recalled when computing carry problems. This was especially noticeable when working memory was loaded more heavily. When participants were in the condition that required carrying and high working memory load, they were unable to recall all the letters. This was especially true for the high math anxious participants. Error rate in the difficult condition was 39%, versus 14% with a low memory load, and a 15% error rate in the control condition. In comparison, the low mathematics anxious group only had a 20% error rate in the most difficult condition. For the high math anxious, it seemed that they were completing a triple task, in which they had to balance the load of carrying, the letter sequence and their high levels of rumination brought on by their math anxiety. It can be concluded that those who have high math anxiety are operating with fewer resources than those who do not suffer from math anxiety on difficult problems. This study demonstrates that mathematics anxiety creates a deficit in working memory resources. Specifically, this study shows that resources are consumed by anxiety while working on difficult problems.

In an attempt to improve the Processing Effiency Theory, Eyesenck, Derakashan, Santos, and Calvo, (2007) proposed the Attentional Control Theory. They state that anxiety disrupts the balance between the goal-directed and stimulus-driven attentional system. Briefly, the goal directed system involves the top down control of attention and the stimulus driven system involves the bottom up processing. Anxiety increases the influence of the stimulus driven system and decreases the goal-directed system. For the sake of brevity, Eyesenck and colleagues suggest that anxiety will not affect performance on updating tasks such as the OSPAN or RSPAN, unless the individuals are in a threatening or stressful situation. The reasoning behind this is that updating does not require attentional control. However, when placed in a threatening or stressful

situation, demands on the central executive increase. The pressure may impair performance. In a non-stressful situation, Duff and Logie (2001) found small performance impairments on the OSPAN among anxious individuals. Other studies using the reading span found similar results.

Overall these studies show that there are no anxiety effects on updating tasks like the OSPAN or RSPAN. However, all of these theories are supported by evidence from general anxiety. Those who suffer from math anxiety may feel additional stress or threat when confronted with a task that involves number processing.

One study found that math anxious individuals can feel stress when faced with math problems. Matarella-Micke, Mateo, Kozak, Foster, and Beilock (2011) found that demanding math problems were enough to elicit a cortisol response among math anxious individuals. In short, they found those with high working memory and high math anxiety performed worse as their salivary cortisol response increased. This decrement in performance was not due to the increase in cortisol, but that completing a math task was indeed stressful. It is important to note that these participants were not placed in a stress induced situation. They were simply asked to complete novel math problems. This evidence suggests that manipulating any type of number or number process may be enough of a threat to impair performance on an updating task like the OSPAN.

Another study found that the mere anticipation of solving a math problem caused pain. Lyons and Beilock (2012a) set out to examine patterns of brain activity in high and low math anxious individuals during the preparation for and completion of a mathematical task. Before completing either a task that contained mathematical or lexical information, a cue was presented to the participant indicating which task to prepare for. Brain scans were recorded during cue presentation and task completion. High math anxious individuals performed more poorly on

difficult problem types as compared to low math anxious participants. These results indicate that the emotional regulation described is engaged even before calculation begins. This suggests that some individuals may be able to prepare for an upcoming math task, and potentially reduce poor performance. Essentially, authors found that the brain regions associated with pain were activated when individuals high in math anxiety were anticipating the completion of a math task. This activation of pain regions disrupted their performance.

Together, these studies suggest that the mere presence of math tasks is enough to elicit an unfavorable emotional response that disrupts performance. It should be noted that each of these studies used novel math problems and that the OSPAN task consists of non-novel problems. Additionally, the problems in the OSPAN do not fit into the types of problems, outlined by Ashcraft and Krause (2007), which utilize numerous working memory components. In fact, these problems may be retrieved directly from long-term memory since they mostly consist of the basic facts, even though some of these problems include two steps. However, recently there was evidence that math anxiety can affect basic number processes.

First, Maloney, Risko, Ansari, and Fugelsang (2010b) tested high and low mathematics anxious participants in the classic subitizing task. This task required participants to name how many simple objects (filled squares) were displayed on a screen. Their results showed slower counting by high mathematics anxious participants. This was surprising considering counting is not typically considered to be taxing on working memory.

In another experiment, Maloney, Ansari, and Fugelsang (2010a) had high and low mathematics anxious participants perform a number comparison task. Participants had to decide whether a presented digit was larger or smaller than a standard (5). In their second experiment, two digits were presented, and participants chose which was larger. In both studies, high anxious

participants showed a steeper numerical distance effect. In other words, they were slower to judge numbers that were closer together in numerical magnitude than were low anxious participants. In general, Maloney's work is evidence that math anxiety can affect the more basic math problem types than was previously suspected. In particular, it suggests more basic aspects of number processing may differ for high mathematics anxious individuals.

Stereotype Threat

Stereotype threat illustrates another research domain in which individuals experience a performance decrement. Stereotype threat was initially demonstrated by Steele and Aronson (1995) through a landmark study. It describes a phenomenon in which individuals who belong to a stigmatized group often experience anxiety in an evaluative situation when they expect that their own performance may falter and thus confirm the negative stereotype about their group. In their initial test, Steele and Aronson tested African-American and European-American students on a verbal problem-solving task. When the task was described neutrally there were no group differences, but when the task was described as diagnostic of intellectual ability, African American participants performed worse, presumably due to the arousal of a racial stereotype.

The stereotype threat effect can apparently apply to anyone, to the degree that an existing and plausible stereotype exists for both the domain of knowledge or activity being tested and the social, gender, or ethnic group to which the individual belongs. The effect is strengthened for individuals who value success more strongly in the area being tested (Spencer, Steele, & Quinn, 1999), and for those who identify more strongly with the stereotyped group (gender or ethnic identity; e.g., Schmader, 2002). Likewise, low domain identity, or low group identity, diminish the effects of stereotype threat. Schmader, Johns, and Forbes (2008) devised a model that illustrates various pathways that stereotype threat can manifest itself. The authors argue that

stereotype threat disrupts performance via 3 distinct, yet interrelated, mechanisms: (a) a physiological stress response that directly impairs prefrontal processing, (b) a tendency to actively monitor performance, and (c) efforts to suppress negative thoughts and emotions in the service of self-regulation. This model fits some current research explaining math related issues among females.

Several studies have used mathematics performance as a way of demonstrating the stereotype threat effect. For example, Aronson, Lustina, Good, Keough, Steele, and Brown (1999) exposed Caucasian men to the negative stereotype that Caucasians do more poorly than Asians on math. Under this circumstance, the Caucasian men did more poorly than those not exposed to the stereotype. Beilock, Rydell, and McConnell (2007) tested women on the modular arithmetic task, telling some that the task was being used to investigate why women do more poorly than men, and others that the researchers were merely studying problem solving. Under stereotype threat, accuracy dropped from 89% to 79% in the difficult mathematics condition; with no threat, performance actually improved from 86% to 92% from baseline to post-test, presumably due to practice. The decrease due to stereotype threat was only obtained on the difficult problems, those requiring the resources of working memory. This shows that performance on simple problems that do not rely on working memory, were uniformly high in accuracy, and experienced no drop in accuracy due to stereotype threat. Due to lack of working memory resources, problem-solving performance suffers.

Beilock et. al. (2007) show that working memory can suffer under stereotype threat. To date, only one study utilized working memory tasks under a stereotype threat situation. Schmader & Johns (2008) utilized the operation span task and primed women with negative stereotypes about their math performance. Overall, these authors found that women who were

primed with negative stereotypes performed worse on the OSPAN task, worsening their working memory span score, whereas women who were not primed (and men) performed better. It is important to note that this study does not capture potential individual differences we would suspect. These authors induced stereotype threat and only used one type of working memory task. Other research has suggested that stereotype threat can be implicit and does not necessarily need to be explicitly induced (Kiefer & Sekaquaptewa, 2007). It would be worthwhile to investigate the OSPAN when stereotype threat is not induced as well as an additional task that does not require the use of math equations.

Up to this point, we have seen that math computation utilizes working memory capacity. Additionally, we see that math anxiety can act as a distractor in the presence of completing a math problem. This evidence, along with the overall emotional reaction to math, suggests that math anxiety may impair performance on the processing component of the OSPAN task. It is possible that math anxiety may act as an additional distractor by eliciting stress or even pain responses to the math problems on the OSPAN. This disruption could additionally disrupt the storage component of working memory.

Statement of the Problem

The research outlined in this paper suggests that math anxiety is enough to impair working memory resources as well as performance on the OSPAN task. However, to date, there has been no investigation of the impact math anxiety may have on performance on the OSPAN and RSPAN.

Those with math anxiety, according to the processing efficiency theory, will not have full use of their resources, thus impairing their performance. As mentioned earlier, Daneman and Carpenter (1980) suggest that superior readers will not have their capacity consumed by

processing. This freedom of processing will enable superior readers to perform better on the RSPAN. Along with this evidence we make the claim that those with math anxiety will perform worse on the processing component of the OSPAN task for similar reasons. We suggest their math anxiety will add an additional distraction on the processing component. This distraction will deter their performance on the processing component of the task. We also note that this detriment in performance will not be evident during the RSPAN task. Due to the performance decrement in the processing component of the OSPAN task, we also predict that this will affect the storage component of working memory. In line with Daneman and Carpenter's (1980) argument, we also predict that math achievement will affect performance on the processing and storage portions of the OSPAN task.

Overall, working memory span correlates with a vast number of abilities, including performance on other cognitive (Daneman & Carpenter, 1980; Engle, 2002; Masson & Miller, 1983; Turner & Engle, 1989), social (Schmader & Johns, 2003), academic (Engle Tuholski, Laughlin, & Conway 1999), and intelligence (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002) tests. Additionally, cognitive psychologists are not the only people who use these tests. Other human behavior specialists from clinical to social psychologists use these span tasks in their own practice or research (Conway et. al., 2005). Therefore, it is imperative that more research be conducted in order to understand the impact math anxiety may have on an individual's performance on the OSPAN task. This information should be disseminated to other researchers in the field so that they may use a more appropriate measure to evaluate an individual's working memory span.

CHAPTER 2

CURRENT STUDY

Individuals will complete the Operation Span Task (Turner & Engle, 1989) as well as the Reading Span Task (Turner & Engle, 1989). It is hypothesized that high math anxious individuals will perform more poorly on the processing component of the OSPAN task compared to the processing component on the RSPAN. We also believe there will be differences between high and low math anxious individual's storage because of the disruptions math anxiety will have on the processing component. Because working memory involves storing and processing, we hypothesize that the interruption of processing will hinder capacity. For example, a person with high math anxiety could have difficulty solving the arithmetic questions associated with the OSPAN, leaving less attention available for the storage component of the task, thus causing them to remember fewer words and achieve a lower working memory span score. In other experiments using the OSPAN, these participants may be thrown out of the experiment they are participating in. This same person may have less difficulty with a different computation like comprehending sentences on the RSPAN, leaving them with more attention available for the storage component involved in a reading span task, enabling the recall of more words and achieving a higher span score. This is what we are predicting, that those who are high in math anxiety will be impaired in a task like the OSPAN but will be less impaired on a task that does not require math, in this case the RSPAN. We also predict that there will be gender differences in performance on these tasks. First we expect men to outperform women in the OSPAN task. Second we expect females to perform better on the RSPAN task as compared to the OSPAN. We don't expect any differences between males and females on RSPAN performance.

Finally, we will manipulate the order of administration of the Abbreviated Math Anxiety Scale. Recently, Moore, McAuley, and Ashcraft (in prep) found that the order of administering the anxiety self-report scale and the math task influenced performance on a novel math task. Specifically, we found that those who were given the AMAS prior to beginning the task showed the typical patterns of math anxiety effects. In contrast, those who were given the self-report last did not show these patterns. We concluded that administering the self-report scale first might prime the individual's self-concept with regards to math performance. Our results and conclusions fell in line with the Emotion Accessibility Model Proposed by Robinson and Clore (2002), and have become something we want to investigate further. Our final predictions are that when given the self-report scale first, which is the typical method, participants will access their semantic memories of their anxiety, thus influencing the pattern of their performance. These patterns will reflect the typical patterns found in math anxiety research; participants will have lower OSPAN scores. When given the self-report last, participants' patterns will not reflect what is typically found in math anxiety research. However, participants will draw on their emotional self-report from the most recent task, potentially increasing their math anxiety scores.

CHAPTER 3

METHODOLOGY

EXPERIMENT 1

Participants

Participants were drawn from the UNLV department of psychology's subject pool. The there were 69 participants.

Procedure and Instruments

In this experiment, the Abbreviated Math Anxiety scale was always given after the Demographic questionnaire, but before the span tasks were administered. The span tasks were counterbalanced to account for order effects. In both experiments, participants were given the Wide Range Achievement Test after both span tasks.

Demographic Questionaire. The simple demographic questionnaire consisted of questions about the subject's age, gender, year in school, level of math achievement, and experiences with math throughout formal school.

Abbreviated Math Anxiety Scale (AMAS). The AMAS is a nine-item measure of math anxiety. Items on the AMAS are responded to using a 5-point likert-scale, with 1 denoting low math anxiety and 5 denoting high math anxiety. The total score is the sum of items. Additionally, there are sub scores of learning math anxiety (LMA) as well as math evaluation anxiety (MEA). The LMA consists of 4 questions concerned with learning and measures of math anxiety and the MEA consists of five questions concerning being evaluated in math. This measure has an internal consistency of (.90). The LMA sub scale has an internal consistency of (.85) and the MEA has a (.88).In the current experiment, the median math anxiety score will be taken to determine groups of high and low math anxious participants.

Operation Span (OSPAN). Participants verified whether individual math equations are correct while trying to remember a set of 2,3,4,5, or 6 single syllable nouns. Sets sizes were presented randomly for each participant. Participants were shown a math equation and determined whether the equation was correct or incorrect (e.g. ‘‘(8 / 4) – 2 = 4”) within 5 seconds, which constituted the processing component of the OSPAN task. Half of the math equations were correct and half were incorrect. Participants gave their response by typing “y” or “n”. After they gave their response, they were presented with a single syllable word for 1 second. At that point, the next math equation was presented, followed by another word; this pattern continued until all equations and words were presented for all randomized set sizes. At the end of a set, participants were instructed to recall and type the words into the computer one at a time in the order they were presented, which constituted the storage component of the OSPAN task. Participants were encouraged to guess if they were not sure about a particular word. Participants were allowed to respond with “dk” (i.e., “don't know”) if they could not make a guess. There were three trials of each set size (e.g., 2, 3, 4, 5, and 6 sets) for a total possible score of 60. Processing component accuracy was the overall percentage of correct responses to math equations and accuracy was broken down by set size. Based on Friedman and Miyake (2005), storage component performance was calculated as the number of overall correct words recalled in the order they were presented. Storage component performance was analyzed as a percentage of words recalled in each set size due to the greater number of words that were recalled for higher set sizes. Overall percentage of correct math equation responses were calculated, as well as the percent correct for each word set size.

Reading Span (RSPAN). Participants read individual sentences while trying to remember a set of 2, 3, 4, 5 or 6 single syllable nouns. This was a similar procedure to the OSPAN. Sets increased

in size for all participants. Participants read a sentence and determined whether the sentence made sense (e.g., "The man ate the pizza") or not (e.g. ‘‘The pizza ate the man") within 5 seconds, which constituted the processing component of the RSPAN task. Half of the sentences made sense while the other half did not make sense. After, participants gave their response by typing "y" or "n". Then, they were presented with a word for one second. At that point, the next sentence was presented, followed by another word. This pattern continued until all sentences and words were presented for all randomized set sizes. At the end of a set, participants were instructed to recall and type the words into the computer in the order they were presented, which constituted the storage component of the RSPAN task. Participants were encouraged to guess if they were not sure about a particular word. Participants were allowed to respond with "dk" (i.e., "don't know") if they cannot make a guess. There were three trials of each set size (i.e., 2, 3, 4, 5, and 6 sets) for a total possible score of 60.

Scoring was done in a similar manner as was done for the OSPAN task. Processing component accuracy was the overall percentage of correct responses to sentence queries. Processing component accuracy was broken down by set size. Based on Friedman and Miyake (2005), storage component performance was calculated as the number of overall correct words recalled in the order they are presented. Storage component performance was also analyzed as a percentage of words recalled in each set size due to the greater number of words that were recalled for higher set sizes. Overall percentage of correct sentence structure responses were calculated, as well as the percent correct for each word set size.

Wide Range Achievement Test (WRAT). The math portion of the WRAT measures an individual's ability to perform basic math computations through calculating written mathematics problems. It is completed using pencil and paper. There are 40 total problems that range from

easy to hard. It has an internal validity of .92. Correct answers were summed and the total score served as the math ability score.

EXPERIMENT 2

Participants

Participants were drawn from the UNLV department of psychology's subject pool. There were 72 participants that participated in this experiment. No participant was removed due to scoring at or less than chance on the processing portion of the operation span or reading span task.

Procedure and Instruments

In this experiment, the Abbreviated Math Anxiety scale was always given after the Span tasks and before the WRAT. The span tasks were counterbalanced to account for order effects.

CHAPTER 4

RESULTS

Demographics

The first experiment (when AMAS was given first) included 69 participants (56 female and 13 male). The second experiment (when AMAS was given last) included 72 participants (51 female and 21 male). The median math anxiety score in experiment 1 was 23 and experiment 2 was 25. Individuals who scored above those numbers were labeled as high math anxious and those who scored below were labeled as low math anxious. For the females in experiment 1, the average math anxiety score was 23 and for males it was 21. In experiment 2, females had an average math anxiety score of 24 and males had an average score of 23. The median math achievement score in experiment 1 was 29 and in experiment 2 was 28. Individuals who scored above those numbers were labeled as high math achieving and those who scored below were labeled as low math achieving. In experiment 1, females had an average score of 28 for math achievement and males had an average score of 31. In experiment 2, females and males had an average math achievement score of 28.

Overall, there were seven participants who scored below the 85% threshold in the processing component. Of the seven participants, three were from the first experiment and four were from the second experiment. All of the participants who did not meet the criteria were female, four of them were high in math anxiety and three of them were low in math anxiety. Five of the participants were low in math achievement and two were high in math achievement.

First Experiment-AMAS First

Overall span task analyses (i.e., ANOVA's for processing and storage components) were completed for the first experiment. A repeated measures 2 (Type of span task: OSPAN and

RSPAN) X 5 (Set size: 2, 3, 4, 5, and 6) ANOVA was completed to test for processing component accuracy differences between the two span tasks.

The processing component of the OSPAN task consisted of math equation verifications and the processing component of the RSPAN task consisted of sentence semantics verification. The two span tasks (i.e., OSPAN and RSPAN) and all 5 set sizes were treated as within-subjects variables.

Processing Speed-Overall. A significant main effect was found for type of span task, with a slower processing speed, represented by the mean time per item, associated with the OSPAN task (M=5871ms, SE=130) than the RSPAN task (M=4957ms, SE=88.64), $F(1,68)=$ 100, MSE=144200267 $p<.001$, $\eta_p^2=.597$ possibly indicating a higher level of difficulty of the processing component of the OSPAN task. In general, processing speed was longer as set size grew (M= 5215 at set size 2, up to M= 5540 at set size 6).

Percent Accuracy-Overall. A significant main effect was found for type of span task, with a higher accuracy associated with the processing component of the RSPAN task (M = .979, SE = .003) than the OSPAN task (M = .950, SE = .005), $F(1, 68) = 27.72$, $MSE = .146$, $p<.0001$, $\eta_p^2 = .290$, possibly indicating a higher level of difficulty of the processing component of the OSPAN task. The main effect for set size was not significant, $F<1.858$, $p=.508$. The interaction between type of span task and set size was not significant, $F<1$, $p = .746$.

Recall-Overall. A second Span Task X Set Size ANOVA was completed to test for recall differences between the two span tasks. A significant main effect was found for type of span task, with a higher percentage of words correctly recalled in the order they were presented for the OSPAN task (M = .56, SE = .014) than the RSPAN task (M = .49, SE = .014), $F(1, 68) =$ 29.38, $MSE = .88$, $p<.0001$, $\eta_p^2 = .302$. Similar words for recall were used in the storage

component of both span tasks, so this difference could be explained by a difference in difficulty of the processing component of the task or proactive interference within the RSPAN task. A second main effect was found for set size on storage performance, $F(4, 272) = 305.951$, $MSE = 8.75$, $p<.0001$, $\eta_p^2 = .82$, showing that the percentage of words recalled declined as set size increased; in other words, difficulty increased as set size increased due to the increase in words required for recall. There was no interaction between set size and type of task $F<12.16$, $p=.079$.

Experiment 1							
Math Anxiety				**Math Achievement**			
Sex		Frequency	Percent	Sex		Frequency	Percent
Female	Low Math Anxiety	29	55.8%	Female	Low Math Achievement	28	51.9%
	High Math Anxiety	23	44.2%		High Math Achievement	26	48.1%
Male	Low Math Anxiety	10	76.9%	Male	Low Math Achievement	2	16.7%
	High Math Anxiety	3	23.1%		High Math Achievement	10	83.3%
Experiment 2							
Math Anxiety				**Math Achievement**			
Sex		Frequency	Percent	Sex		Frequency	Percent
Female	Low Math Anxiety	21	42.9%	Female	Low Math Achievement	19	44.2%
	High Math Anxiety	28	57.1%		High Math Achievement	24	55.8%
Male	Low Math Anxiety	9	75.0%	Male	Low Math Achievement	10	55.6%
	High Math Anxiety	3	25.0%		High Math Achievement	8	44.4%

Table 1 displays the chart of the breakdown of gender, math achievement, and math anxiety for experiments 1 and 2.

Math Achievement Effects

The next analysis considered the hypothesis that those individuals with low math achievement would perform significantly worse on the processing component of the OSPAN task (i.e., math based) than the processing component of the RSPAN task (i.e., reading based). In this analyses, math achievement was the between subjects factor.

Processing Speed-Math Achievement. There was a significant main effect of math achievement, showing that overall, high math achievement individuals were faster (M = 5015, SE = 136.23) in comparison to their low math achievement counterparts (M = 5685, SE = 134.16), $F(1,63) = 11.99$, $p<.001$, MSE=71263029, $\eta_p^2 = .160$.

There was a significant interaction between task and math achievement $F(1,63)$ 30.872, MSE=30591951, $p<.001$, $\eta_p^2 = .33$. As shown in figure 1 the difference between the groups' processing speed on the RSPAN task was minimal, and both math achievement groups were slower to perform the OSPAN task than the RSPAN task. But the high math achievement group only slowed down 520ms on the OSPAN task, compared to a 1399ms slow down on OSPAN for the low math achievement group. This suggests that achievement was strongly affecting performance on the task that involved math questions.

Percent Accuracy-Math Achievement. The main effect of math achievement was significant $F(1,64)$ $p<.05$, $\eta_p^2=.069$ in that low math achievement individuals got fewer answers correct (M=.957, SE=.005) as compared to their high math achievement counterparts (M= .970, SE=.004). Additionally, achievement interacted with task $F(1,64)=5.38$, $p<.05$, $\eta_p^2=.078$. As shown in Figure 2, the groups performed better on the RSPAN and both math achievement groups performed worse on the OSPAN task as compared to the RSPAN task. However, the high math achievement group had a 2% decline in accuracy on the OSPAN task, compared to the 4%

decline in accuracy on the OSPAN task among the low math achievement group. This further suggests that achievement was strongly affecting performance on the task that involved math questions.

Recall Accuracy-Math Achievement. A significant main effect was found for math achievement, with high math achievement individuals recalling more words (M=.57, SE=.02) than low math achievement individuals (M=.45, SE=.02), $F(1,60)= 21.08$, MSE=2.21, $p<.0001$, $\eta_p^2=.32$. This suggests that the high math achievement individuals had a superior processing ability, thus enabling them to recall more words for the storage component of the task. Task did not interact with math achievement $F<1$, $p=.404$. Additionally set size did not interact with math achievement $F<1$, $p=.117$.

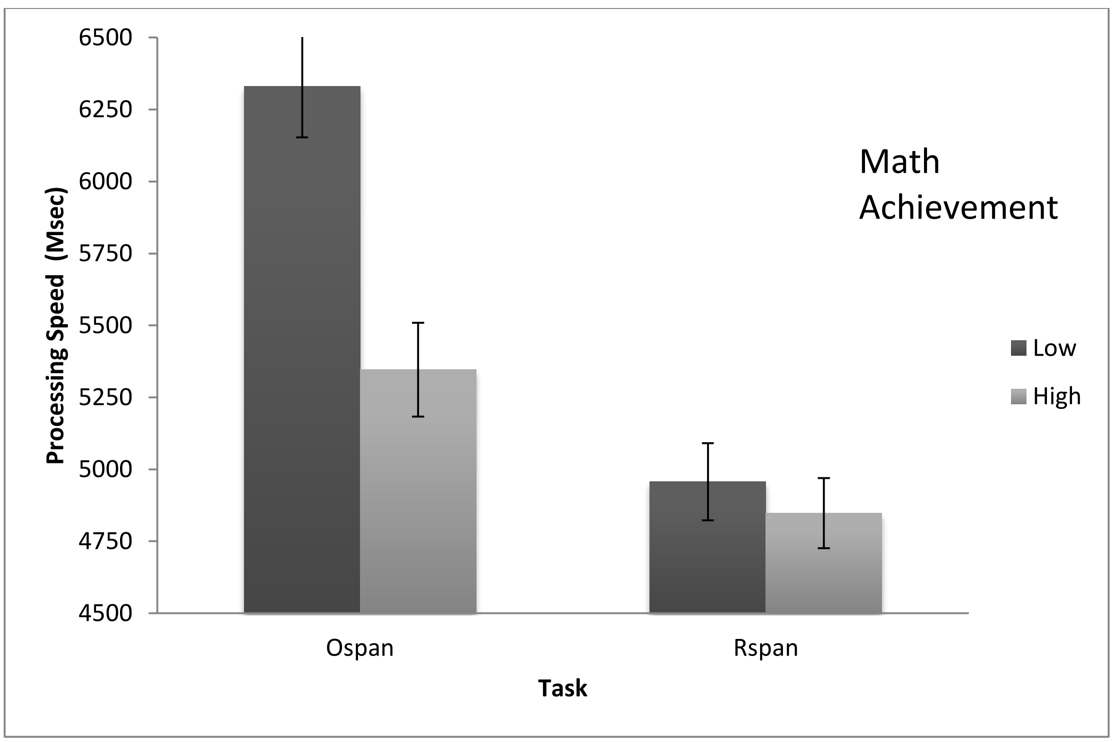

Figure 1. The interaction between task and math achievement showing that low math achievement individuals were slower on the OSPAN in comparison to the high math achievement individuals and were slower on the RSPAN

Math Anxiety Effects

The next analysis considered the exploratory hypothesis that high math anxious individuals would perform significantly worse on the processing component of the OSPAN task (i.e., math based) than the processing component of the RSPAN task (i.e., reading based). In this analyses, math anxiety was the between subjects factor.

Processing Speed-Math Anxiety. There was no significant main effect of math anxiety $F<1$, $p=.793$, and math anxiety did not interact with task, $F<1$, $p=.361$ or set size $F<1$, $p=.319$.

Percent Accuracy-Math Anxiety. There was not a significant main effect of math anxiety $F<1$, $p=.058$. Nor did math anxiety interact with task, $F<1$, $p=.926$ or set size, $F<1$, $p=.377$.

Recall-Math Anxiety. There was no significant main effect for math anxiety $F<1$ and $p=.056$. Math anxiety did not interact with task $F<1$ and $p=.07$ or set size $F<1$, $p=.531$.

Gender Effects

The next analysis considered the exploratory hypothesis that females would perform significantly worse on the processing component of the OSPAN task (i.e., math based) than the processing component of the RSPAN task (i.e., reading based). In this analyses, gender was the between subjects factor.

Processing Speed-Gender. Again, there was no main effect of gender $F<1$ $p=.065$. There was an interaction between task and gender $F(1,67) = 4.271$, MSE=5768879, $p<.05$, $\eta_p^2=.06$. Figure 3 shows this interaction in that there was virtually no difference in processing speed between males and females on the RSPAN task. Everyone was slower on the OSPAN, however, males slowed down 535ms on the OSPAN whereas females slowed 1011ms. This interaction

suggests that females, often stigmatized at being poor at math, performed worse on the math type problems.

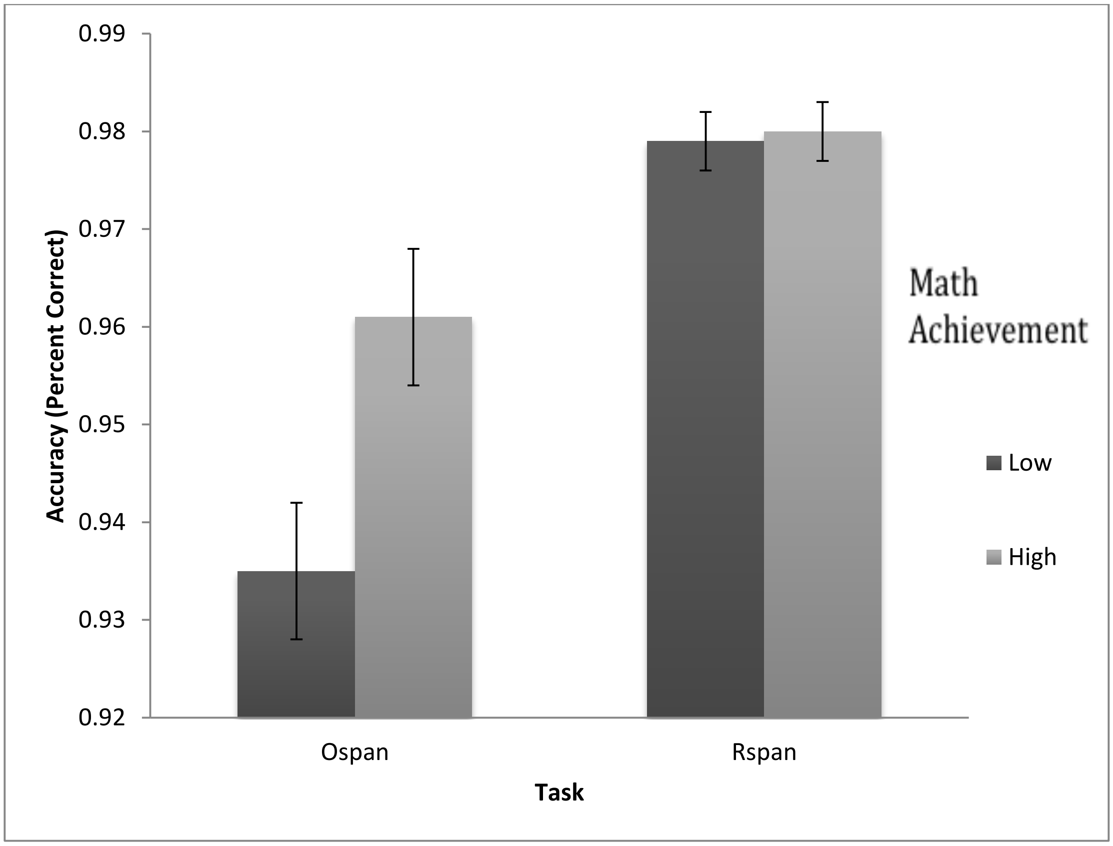

Figure 2. The interaction between task and math achievement showing that high math achievement individuals were more accurate on the OSPAN as compared to the low math achievement individuals and that low math achievement individuals were more accurate on the RSPAN in comparison to the OSPAN

Accuracy-Gender. There was no main effect of gender $F<1$ $p=.08$. Interestingly, there was a significant interaction between gender and task $F(1,67)= 4.78$, MSE=.024, $p<.05$, $\eta_p^2 =.067$. As shown in Figure 4, there was no difference in percent accuracy between males and females on the RSPAN, and everyone seemed to perform worse on the OSPAN. However, males maintained similar percent accuracy on both the OSPAN and RSPAN as compared to females whose accuracy declined 4% on the OSPAN. This further suggests that females had more trouble completing the math type problems as compared to males or problems on the reading span.

Recall-Gender. Interestingly, there was a main effect of gender $F(1,67)=7.19$, MSE=.71, $p<.01$, $\eta_p^2=.10$ where females recalled fewer words (M=.51, SE=.01) as compared to males (M=.58, SE=.02). Interestingly, gender did not interact with task $F<1$, $p=.671$ or set size $F<1$, $p=.761$. This suggests that perhaps task did not interfere with the ability of females to recall fewer words, but that females in general have a lower storage capacity as compared to males.

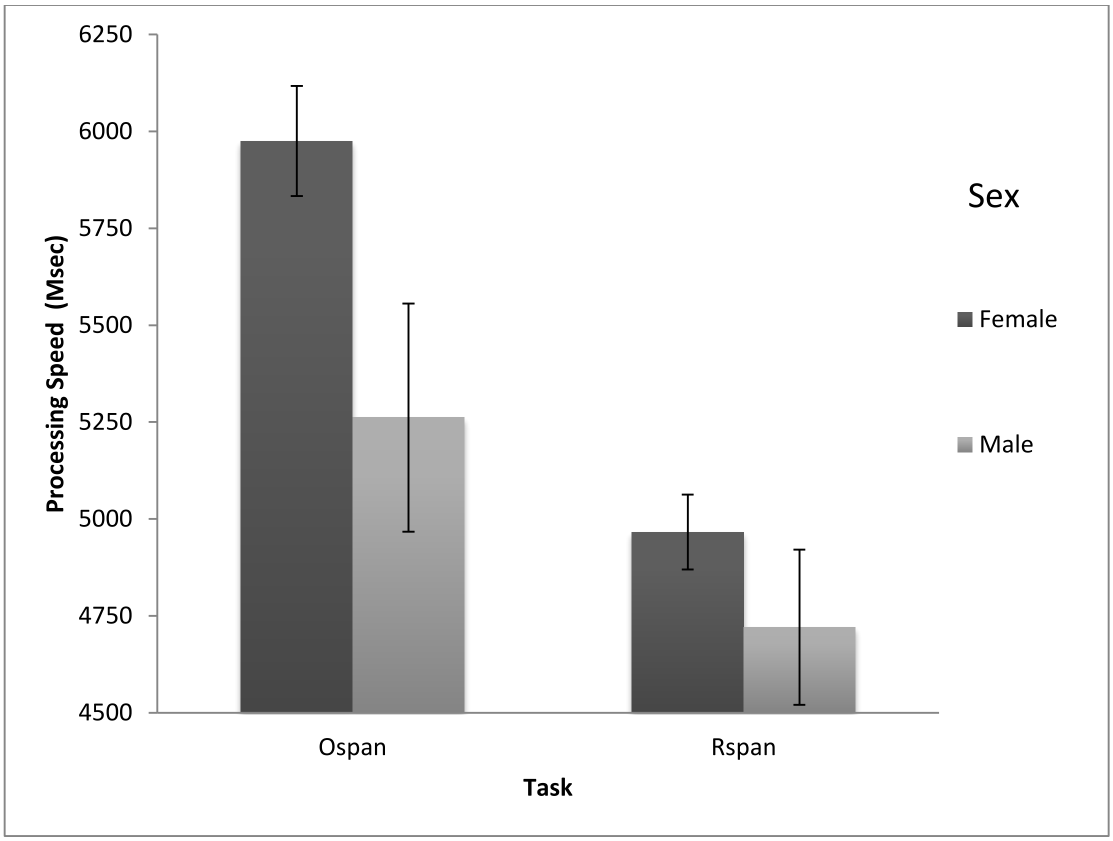

Figure 3. The interaction between task and gender showing that females were slower on the OSPAN in comparison to the males and were slower on the RSPAN

The results from the first experiment suggest that gender may play a role in performance on these working memory tasks. To investigate this further, similar analyses were run for experiment 2.

Second Experiment-AMAS Last

Overall span task analyses (i.e., ANOVA's for processing and storage components) were

completed for experiment two when the AMAS was given last. A second repeated measures 2 (Type of span task: OSPAN and RSPAN) X 5 (Set size: 2, 3, 4, 5, and 6) ANOVA was completed to test for processing component performance differences between the two span tasks.

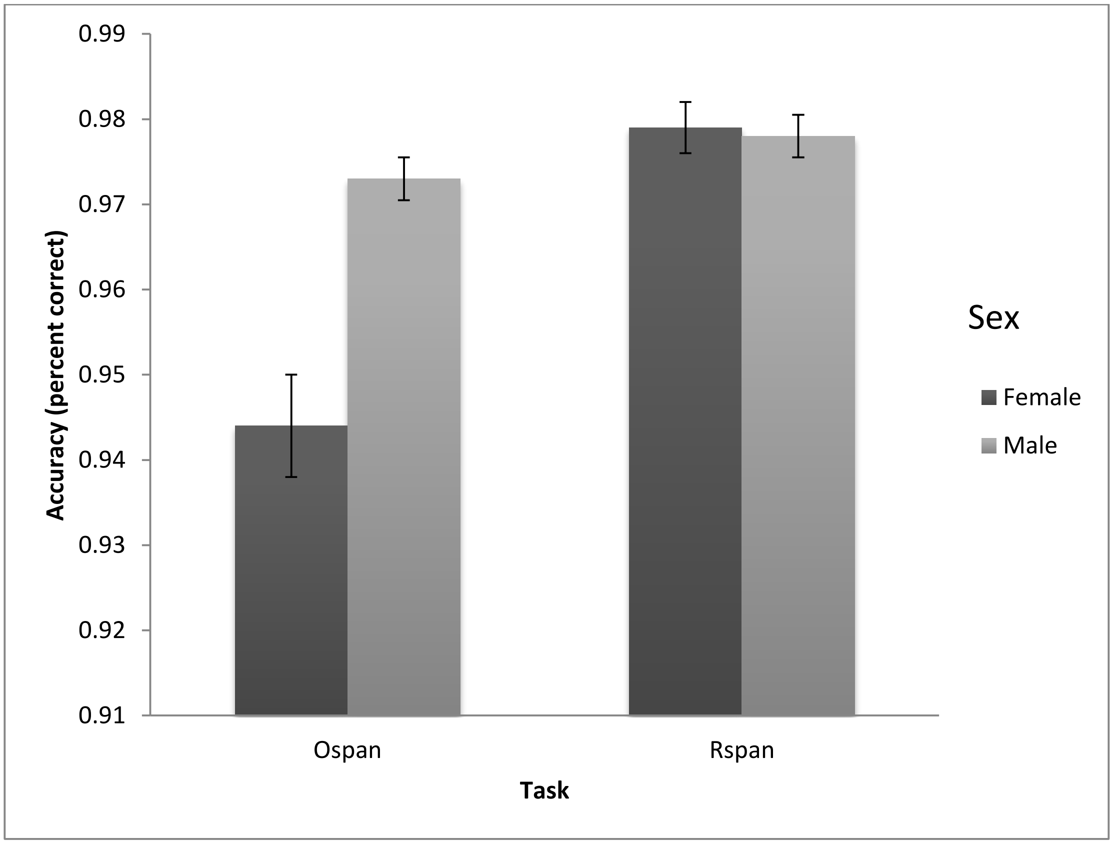

Figure 4. The interaction between task and gender showing that that males were more accurate on the OSPAN as compared to the females and that females were more accurate on the RSPAN in comparison to the OSPAN

Processing speed-Overall. A significant main effect was found for type of span task, with a slower processing speed, as measured by average time per item, associated with the OSPAN task (M=5232ms SE=164.14) than the RSPAN task (M=4397ms, SE=131.56), $F(1,70)=68.12$, MSE= 123795540 $p<.001$, $\eta_p^2 =.493$ possibly indicating a higher level of difficulty of the processing component of the OSPAN task. In general, processing speed was

longer as set size grew (M= 4755ms at set size 2, up to M= 4928ms at set size 6).

Accuracy-Overall. A significant main effect was found for type of span task, with a higher accuracy associated with the processing component of the RSPAN task (M = .97, *SE* =.003) than the OSPAN task (M = .94, *SE* = .007), $F(1, 70) = 13.72$, $MSE = .161$, $p < .0001$, $\eta_p^2 = .054$, possibly indicating a higher level of difficulty of the processing component of the OSPAN task. The main effect for set size was not significant, $F<1$, $p=.911$. Set size and task did not interact $F<1$, $p=.529$.

Recall-Overall. Second, a Span x Task ANOVA was completed to test for recall differences between the two span tasks.

A significant main effect was found for type of span task, with a higher percentage of words correctly recalled in the order they were presented for the OSPAN task (M = .55, *SE* = .014) than the RSPAN task (M = .49, *SE* = .014), $F(1, 68) = 29.38$, $MSE = .88$, $p < .0001$, $\eta_p^2 = .302$. Similar words for recall were used in the storage component of both span tasks, so this difference could be explained by a difference in difficulty of the processing component of the task or proactive interference within the RSPAN task. A second main effect was found for set size on storage performance, $F(4, 272) = 305.951$, $MSE = 8.75$, $p < .0001$, $\eta_p^2 = .82$ showing that the percentage of words recalled declined as set size increased; in other words, difficulty increased as set size increased due to the increase in words required for recall. There was no interaction between task and set size $F<1$, $p=.987$.

Math Achievement Effects

The hypothesis that individuals with low math achievement will score significantly lower on the processing component of the OSPAN task than the processing component of the RSPAN task, as compared to the high achievement group, was tested. To test this, math achievement

became the between subjects factor in this second experiment.

Processing speed-Math Achievement. There was no main effect of math achievement $F<1$, $p=525$. Additionally, math achievement did not interact with task $F<1$, $p=.306$ and set size $F<1$, $p=.984$.

Percent Accuracy-Math Achievement. The main effect of math achievement was not significant $F<1$, $p=.880$. Math achievement did not interact with task $F<1$, $p=.274$ or set size $F<1$, $p=.768$.

Recall- Math Achievement. There was no main effect of math achievement $F<1$, $p=.664$. Math achievement also did not interact with task $F<1$, $p=.737$ or set size $F<1$ and $p=.893$

Math Anxiety Effects

Next, the hypothesis those individuals with low math anxiety will score significantly lower on the processing (i.e., math based) component of the OSPAN task than the processing (i.e., reading based) component of the RSPAN task was tested. In this analyses, math anxiety was the between subjects factor.

Processing speed-Math Anxiety. As in experiment 1, there was no significant main effect of math anxiety $F<1$, $p=.593$. Additionally, it did not interact with task $F<1$, $p=.586$ or set size $F<1$, $p=.267$.

Percent Accuracy- Math Anxiety. There was no significant main effect for math anxiety $F<1$, $p=.815$. Math anxiety did not interact with task $F<1$, $p=.958$ or set size $F<1$, $p=.228$.

Recall-Math Anxiety. There was no main effect of math anxiety $F<1$, $p=.190$. Math anxiety did not interact with task $F<1$, $p=.280$ or set size $F<1$, $p=.098$.

Gender Effects

Next, gender differences in performance were examined.

Processing Speed-Gender. There was a main effect of gender $F(1, 69)$ 5.54, MSE=72286332, $p<.05$, $\eta_p^2=.074$. Overall, females were slower (M=5014ms, SE=159.91) as compared to their male counterparts (M=5305ms, SE=255.35). Finally, the interaction between task and gender remained significant $F(1, 69)= 5.90$, MSE=10012640, $p<.05$, $\eta_p^2=.078$. Figure 5 illustrates the similar pattern to that found in experiment 1, in that males and females were slower on the OSPAN as compared to the RSPAN. However, males were only 456 ms slower, whereas females were 984ms slower. This interaction suggests that females perform worse on math-based tasks as compared to males.

Percent Accuracy- Gender. There was no main effect of gender $F<1$, $p=.068$. The interaction of gender and task remained significant $F(1, 69)= 5.02$, MSE=.056, $p<.05$, $\eta_p^2=.068$. Figure 6 shows that males and females performed worse on the OSPAN task as compared to the RSPAN task, however, males only declined by .01% on the OSPAN whereas females declined by 5% on the OSPAN task. This suggests that females may be prone to performing worse on the math-based task as compared to non-math based tasks.

Recall-Gender. Interestingly, the main effect of gender that was apparent in the first experiment was not in the second $F<1$, $p=.08$. Gender did not interact with task $F<1$, $p=.658$ or set size $F<1$, $p=.551$.

Experiments Combined

The next experiment considered the hypothesis that there would be differences between the two experiments. In this analysis, data from both experiments were combined and the same mixed design 2 (Type of span task: OSPAN and RSPAN) X 5 (Set size: 2, 3, 4, 5, and 6)

ANOVA was completed to test for processing component and accuracy differences between the two span tasks.

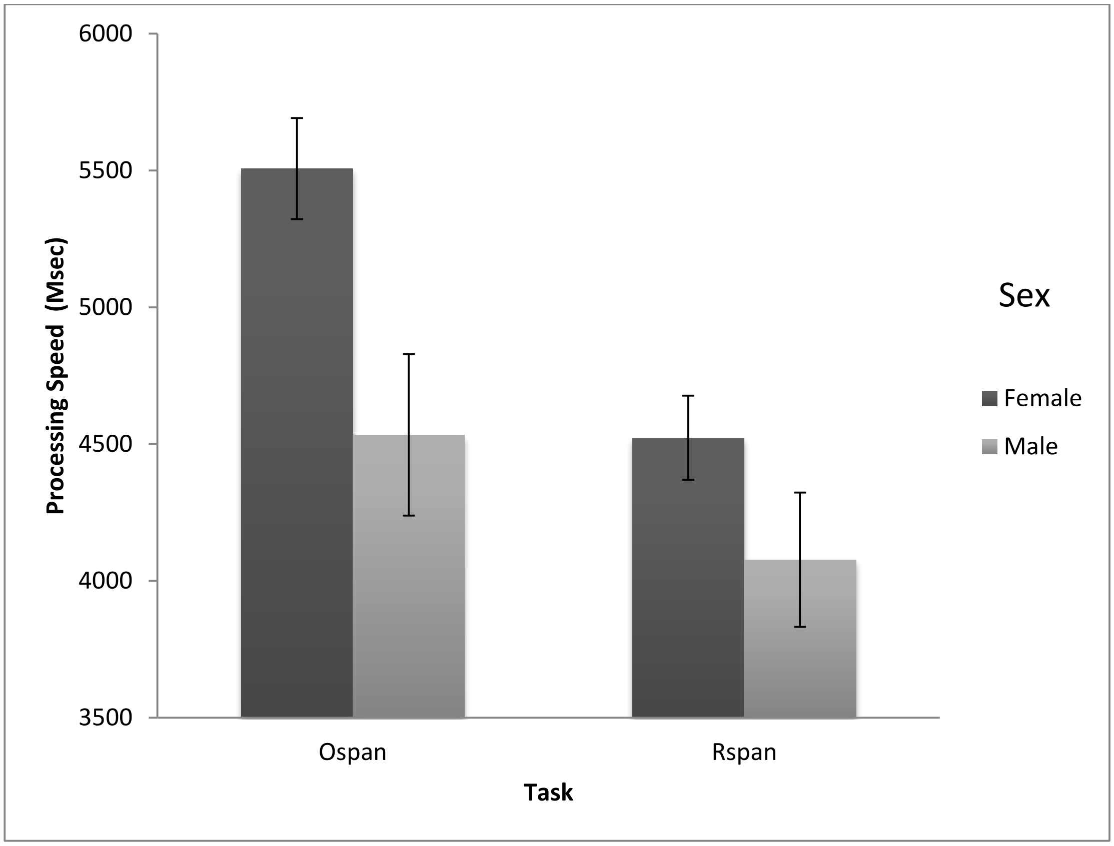

Figure 5. The interaction between task and gender showing that females were slower on the OSPAN in comparison to the males and were slower on the RSPAN

The between subjects factor was experiment 1 and experiment 2. The main effect of task $F(1,138)$= 164.42, MSE= 267738961 $p<.001$, η_p^2= .544 remained in that all individuals were slower on the OSPAN task by approximately 875 ms as compared to the RSPAN task. Additionally, the main effect of set size remained significant $F(4, 552)$= 8.98, MSE=2386238 $p<.001$, η_p^2=.062 in that individuals were slower on set size 2 (M=5002) to set size 6 (M= 5234). No other interactions were significant. Finally, the main effect experiment was significant $F(1,138)$= 11.73, MSE=125721458, $p< .01$, η_p^2=.078 in that people in experiment 1 were 599 ms slower than those in experiment 2. This may be caused by the fact that the AMAS was given

prior to the first experiment started, even though math anxiety was not significant $F<1$, p=.089. When percent accuracy was the dependent variable, task remained as the only significant main effect $F(1,138)= 35.93$, MSE=.307, $p<.01$, $\eta_p^2=.206$ in that accuracy on the OSPAN task decreased by 3% as compared to the RSPAN. There was no main effect of set size $F<1$, p=.76 or experiment $F<1$, p=.23. When storage was the dependent variable, the main effect of experiment was not significant $F<1$, p=.89

Additional Analysis

Processing Speed-Math Anxiety. Further analyses were conducted looking at the timing of the AMAS and OSPAN. For this analysis, participants who answered AMAS right before completing the OSPAN were analyzed. A mixed ANOVA (2 Task x 5 Set Size) was run where reaction time was the dependent variable and math anxiety was the between subjects factor. Although the results were not significant F<1, p=.084, the data were trending in the right direction in that math anxious individuals were slower than the low math anxious individuals on the OSPAN. Additionally, high math anxious individuals were slower on the OSPAN in comparison to the RSPAN. These trends suggest that the nature of the math task inhibited those who were high in math anxiety. This trend may have been exacerbated due to answering the AMAS first. Figure 7 illustrates this trend.

Correlations between Math Achievement and Gender. As discussed earlier, math achievement effects were found in the first experiment and not the second. To examine this further, correlations were run between math achievement and gender and compared across the two experiments. The findings indicate that achievement played a larger role in the first experiment than the second. Table 2 illustrates these correlations. It appears that administering

the AMAS first in experiment 1 may have induced a particular anxiety that made math achievement the more dominant factor driving performance on the OSPAN tasks.

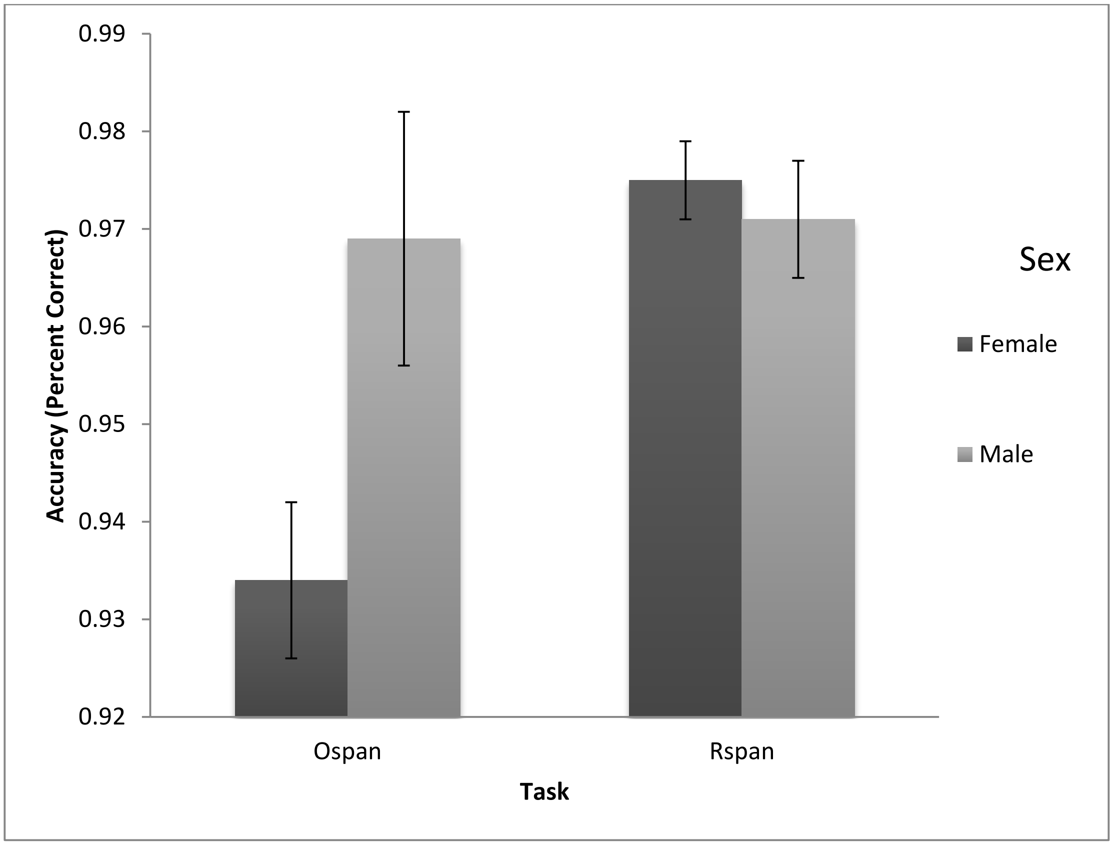

Figure 6. The interaction between task and gender showing that that males were more accurate on the OSPAN as compared to the females and that females were more accurate on the RSPAN in comparison to the OSPAN

When the AMAS was given after the tasks, gender may have been the dominating factor that drove performance on the OSPAN.

Summary of Results

Overall, in both experiments, all individuals seemed to be slower on the OSPAN task as compared to the RSPAN task. Additionally, participants performed better on RSPAN task as compared to the OSPAN task. The effect of math achievement was only apparent in the first

experiment in that low math achievement individuals were slower and made more errors on the OSPAN as compared to the RSPAN. Between the two experiments, there was no math anxiety effect in performance on the OSPAN as compared to the RSPAN. The only effect that remained across both experiments was gender. Females were slower and made more errors on the OSPAN as compared to the RSPAN and in comparison to their male counterparts.

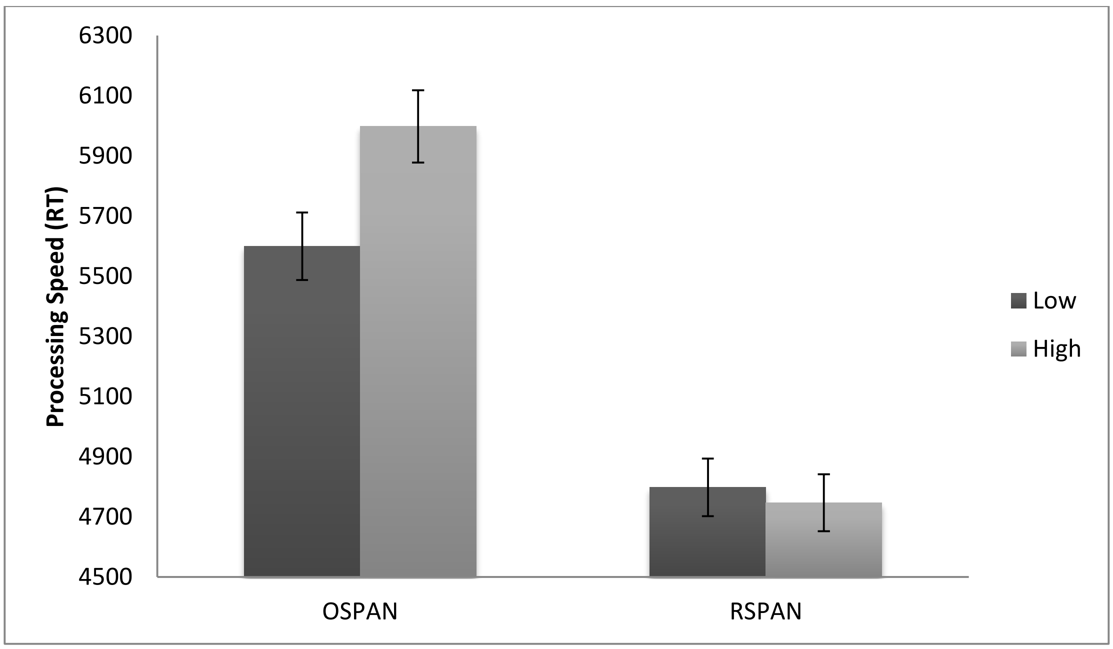

Figure 7. The trending interaction between task and math anxiety, showing that when the AMAS was given immediately before the OSPAN higher math anxious individuals were slower than their low math anxious counterparts

Correlations Between Achievement, Sex, and Performance for Experiments 1 and 2

Scale	WRAT	Sex	OspanSet 2	OspanSet 3	OspanSet 4	OspanSet 5	OspanSet 6
			Experiment 1				
WRAT	1	.276*	-.387**	-.454**	-.388**	-.376**	-.383**
Sex		1	-0.228	-.290*	-.249*	-0.17	-0.235
			Experiment 2				
WRAT	1	-0.049	-0.153	-0.08	-0.111	-0.028	-0.105
Sex		1	-.289*	-.321**	-.234*	-.335**	-.339**

Table 2. Breakdown of correlations between set size, math achievement, and gender for experiments 1 and 2

CHAPTER 5

DISCUSSION

Working memory is a central construct of cognitive psychology. An individual's working memory capacity was originally measured using simple recall tasks, called simple span tasks, which determined the number of separate items that an individual could store and recall. Later, as research on working memory has grown, more complicated measures have been created. An individual's working memory capacity has been found to relate to a host of behaviors and activities, such as reading comprehension (Daneman & Carpenter, 1980) and performance on academic (Engle, et al., 1999) and intelligence (Conway et al., 2002) tests.

The OSPAN and RSPAN tasks are the most frequently and widely used instruments that measure working memory capacity. The two span tasks are used interchangeably throughout the field of psychology. Researchers (Conway et al., 2005) suggest the current working memory span tasks, such as the OSPAN, are not domain specific, but actually tap into domain general executive attention and control. Furthermore, these authors state that working memory capacity does not fluctuate due to task characteristics. Spurred by Baddeley and Hitch's (1974) suggestion that a true measure of working memory is more than just a recall task and that simple span tasks were not sufficient to measure working memory, Daneman and Carpenter (1980) created the RSPAN task which is made up of two components: a processing and a storage component.

Researchers (Turner & Engle, 1989; Conway et al., 2005) use a person's storage component score as the participant's actual working memory capacity and suggest that the processing component is just a secondary task that inhibits or interferes with the use of strategies such as rehearsal to improve storage performance. In fact, Engle (e.g.,Turner & Engle, 1989) implicitly acknowledges the processing component's role in determining a person's working

memory capacity by applying a performance threshold as an exclusion criterion. To account for low motivation, these authors placed an 85% accuracy threshold on the processing component. In this case, individuals would have to reach an accuracy of 85% on the processing component or their data would be thrown out as a result of low motivation. Aside from a loose measure of motivation, performance on the processing component was viewed with an additional concern. Daneman and Carpenter (1980) hypothesized that individuals with high reading ability may complete the processing component of the reading span (i.e., reading sentences) more quickly and allow for alternative cognitive strategies that would not be available to individuals with low reading ability. This concern, that greater abilities associated with the nature of the processing task could influence overall span task performance, was also raised by Turner and Engle (1989) for both the reading span and operation span processing component. However, Daneman and Carpenter (1980) failed to measure processing task performance and Turner and Engle (1989) failed to report their sample's performance on the processing component.

This is the central question of this experiment: are there differences between the processing components of the two span tasks that could potentially hinder performance? Specifically, why would an individual perform better on the processing component of the RSPAN task than the OSPAN task? There is wide spread acknowledgement that some participants in research experiments lack motivation. But, do they lack motivation only on one task, specifically, on the math based processing component of the OSPAN task? There may be an alternative explanation for the poor performance on the OSPAN task processing component beside a general lack of motivation, one concerning the math aspect of the processing component of the OSPAN task: individuals may perform much worse on the processing component of the OSPAN task compared to the RSPAN task due to high math anxiety or low math achievement.

Hypothesis 1, which stated that high math anxious individuals would score lower than other math anxiety groups on the processing component of the OSPAN task, was not supported. Although their processing speed and accuracy were trending toward significance, neither high nor low anxious groups showed a serious performance deficit in the OSPAN task. The two math anxiety groups did not perform differently on the RSPAN task-processing component. This result indicates that math anxiety may not have a significant influence on performance on the math based OSPAN task. Attentional Control Theory may explain the lack of math anxiety differences. Essentially, this theory states that working memory tasks do not measure attention and that anxiety is primarily a result of an attention deficit. Perhaps math anxiety is susceptible to the same attentional deficits. It could also be that the problems, even though they require two steps, are not difficult enough to arouse math anxiety, therefore; math anxiety differences were not found.

Hypothesis 2 predicted that math achievement groups would score significantly differently on the processing component of the OSPAN task as compared to the RSPAN task. This hypothesis was supported in that those who were low in math achievement were significantly slower and made more errors on the OSPAN task as compared to the RSPAN. This hypothesis supports Daneman and Carpenter's original concern that those who have superior ability in a particular domain will excel in the processing component in that particular task. It should be noted that we did not find any accuracy differences in storage, but that could be due to the fact that these individuals had unlimited time to complete the processing component, therefore; their storage component was not affected. Furthermore, it should be noted that these effects were only found in the first experiment, when the AMAS was given first. This suggests that perhaps the assessment of math anxiety acted as a sort of priming mechanism for math

achievement. Given that the normed OSPAN and RSPAN task are automated, it may be that superior processing ability will allow for better recall on those specific tasks rather than the tasks used in the current experiment.

I also made hypotheses regarding some additional variables. I hypothesized that processing speed would increase in the first experiment as compared to the second. In general, individuals were slower in the first experiment as compared to the second experiment. There were no differences in error across the experiments. Results showed that there were no differences in error or processing speed among high and low math anxious individuals, suggesting that math anxiety may not play a large role in the processing component.

Another additional hypothesis was that gender differences would emerge based on the type of working span task. Additionally, it was hypothesized that females would also perform worse compared to their male counterparts. As the results show, there does seem to be some influence of gender on task differences in performance. In general results from both experiments showed that females were slower and made more errors on the OSPAN as compared to the RSPAN. They were also slower and made more errors as compared to their male counterparts. Finally, the results also showed that females recalled fewer words on the OSPAN as compared to the RSPAN. According to Schmader et. al., 2008, completing a math task may have been enough to trigger a state of imbalance that led to cognitive monitoring. According to Nosek, Banaji, and Greenwald (2002) stereotype threat stems from a situationaly-induced state of imbalance that a particular individual is motivated to overcome (My group does not have this ability, I am like my group, but I think I have this ability). Due to this imbalance, an individual's math achievement becomes the main variable that drives performance on the OSPAN task. The results from the second experiment suggest that there may have been an implicit stereotype threat activation

(Huguet & Regner, 2007; Stricker and Ward, 2004) that occurred when the AMAS was presented after completion of the experiment. This suggests that perhaps checking female on the demographic form or simply the description of what working memory tasks measure was enough to induce stereotype threat in females. Furthermore, research has shown that females can pick up on "anti-math" attitudes from various sources. For example, Beilock, Gunderson, Ramirez, & Levine (2010) found that young females were more susceptible to poor math attitudes if they had a high math anxious female teacher in first and second grade. This research suggests that poor math attitudes have been with females for much of their life.

Results from these gender differences in performance suggest that explicit statements about how poorly females perform on math tasks may not be needed in order to induce stereotype threat. Furthermore, in the event that a female is made aware of her identity and potential stereotypes associated with that identity, their achievement in a particular domain could help or hurt them. As seen in this experiment, females who were primed with math anxiety overcame potential pitfalls in their performance through their achievement in the math domain. We know from developmental research that young girls may be more exposed to negative beliefs about math from a young age (Beilock et. al., 2010), thus it is imperative that special attention is given to females throughout their schooling to encourage math. Avoiding math courses may have especially detrimental effects on females who work in domains that have negative stereotypes associated with the female identity.

Although both of these experiments only yielded seven individuals who did not pass the 85% criterion set forth by Engle and colleagues, the results from this experiment point to Daneman and Carpenter's (1980) original concern over individual differences. Seven individuals resulted in a loss in 5% of our data. Specifically most of the individuals who would have been

excluded were females, suggesting that ability in particular areas is not the only individual difference that could affect performance on these tasks. The results from both the achievement and gender groups show that individual differences can play a role in performance on a particular task. This experiment shows that those superior in math achievement performed better than those who were not superior in math achievement on the OSPAN. It appears that implicit stereotype threat associated with the OSPAN task was enough to cause performance deficits among females. Not only did they perform worse on the processing component, but they also recalled fewer words when working on the OSPAN as compared to the RSPAN and their male counterparts. These results suggest ability in a domain may not be the only individual difference psychologists using these tasks may encounter. Finally, this is the first study to show gender differences in performance on working memory tasks. Schmader and Johns (2003) conducted the only study that demonstrated gender differences in working memory tasks was conducted by They found differences in OSPAN performance, but this was after explicitly inducing stereotype threat before completing the task. Additionally, they did not have another non-math task like the RSPAN, to compare performance differences. They did not account for differences in math achievement, thus suggesting that performance differences may not be due to gender differences, but that math achievement may also play a significant role.

Limitations

There were some limitations to this study that should be addressed. First, there were not an equal number of males and females who participated in this study. Although this was not a formal hypothesis, the trends shown here should be taken cautiously as there were relatively few males (n=33 out of a total n=138). Future studies should ensure that there are equal groups of

both males and females, to ensure these gender differences are based on the type of task being given and not because one group outnumbers the other.

Second, it should be noted that the automated operation span and reading span task were not used in this study. Typically, the automated tasks use a fixed processing time for each processing component. The timing is based on participant's performance on the practice problems in the beginning. Since this task was experimenter driven, the practice section was not designed in a way to set processing time for the entire experiment. An additional experiment should aim to use the automated tasks to see if the limited processing time affects individuals of varying degrees of ability in their performance in the OSPAN and RSPAN task.

APPENDIX I: DEMOGRAPHIC QUESTIONAIRE

Math Demographics

The following questions are designed to determine your math history. Please place your answers in the spaces provided.

_______ 1. What is your age?

_______ 2. What is your gender: M or F?

_______ 3. How many math courses did you take in high school: 0, 1, 2, etc.?

_______ 4. What was your average math grade in high school: A, B, C, D, F?

_______ 5. How many math courses have you taken in college: 0, 1, 2, etc.?

_______ 6. What was your average math grade in college: A, B, C, D, F?

_______ 7. Have you completed algebra class: Y or N?

_______ 8. Have you completed trigonometry (trig): Y or N?

_______ 9. Have you completed geometry: Y or N?

_______ 10. Have you completed calculus: Y or N?

_______ 11. Have you completed statistics: Y or N?_____

___________ 12. What year are you now: Freshman, Sophomore, Junior or Senior?

___________ 13. What is your racial/ethnic background: African-American, Hispanic/Latino, Native American, Asian/Pacific Islander, Caucasian (white) or Other?

_______ 14. On a scale from 1 to 10, with 1 being "not at all" and 10 being "very much," how much do you enjoy math?

_______ 15. On a scale from 1 to 10, with 1 being "not at all" and 10 being "very much," how math anxious are you?

APPENDIX II: ABBREVIATED MATH ANXIETY SCALE

Abbreviated Math Anxiety Scale

Please rate each item in terms of how anxious you would feel during the event specified. Use the following scale and record your answer in the space to the left of the item:

1	2	3	4	5
Low Anxiety	Some Anxiety	Moderate Anxiety	Quite a bit of Anxiety	High Anxiety

_____ 1. Having to use the tables in the back of a math book.

_____ 2. Thinking about an upcoming math test one day before.

_____ 3. Watching a teacher work an algebraic equation on the blackboard.

_____ 4. Taking an examination in a math course.

_____ 5. Being given a homework assignment of many difficult problems which is due the next class meeting.

_____ 6. Listening to a lecture in math class.

_____ 7. Listening to another student explain a math formula.

_____ 8. Being given a "pop" quiz in a math class.

_____ 9. Starting a new chapter in a math book.

APPENDIX III: WIDE RANGE ACHIEVEMENT TEST

WRAT 3 ARITHMETIC/A MEASURE OF NUMBER COMPUTATIONS

S. Code # ____________

REDUCE ALL ANSWERS TO LOWEST TERMS

$1 + 1 =$ ___	$5 - 1$	$2 + 7 =$ ___	$8 - 4 =$ ___	$32 + 24 + 40$
1	2	3	4	5
$9 + 3$	$36 - 15$	$3 \times 4 =$ ___	$68 + 23$	7×6
6	7	8	9	10
23×3	$33 - 17$	$6 \div 2 =$ ___	$4\overline{)16}$	17×4
11	12	13	14	15
$724 - 597$	$229 + 5048 + 63 + 1381$	$\frac{15}{5} =$ ___	$9\overline{)4527}$	$\frac{1}{3} + \frac{1}{3} =$ ___
16	17	18	19	20
$2\frac{1}{2} + 1\frac{1}{2} =$ ___	823×96	$.42 =$ ___ %	$\frac{1}{4} \times \frac{1}{2} =$ ___	38×2.4
21	22	23	24	25

WRAT 3 ARITHMETIC/A MEASURE OF NUMBER COMPUTATIONS

$\frac{3}{10} \div \frac{3}{4} =$ Ans: ___	$6\frac{1}{4} + 1\frac{5}{8} + 4\frac{1}{2}$	$\frac{2}{5}$ of $35 =$ ___	$27\overline{)384}$	6.23×12.7
26	27	28	29	30
$2 -$ ___ $= \frac{1}{4}$	$10\frac{1}{4} - 7\frac{2}{3}$	Add: $-X - Y - 23$; $X - Y + 22$	15% of 175 = Ans: ___	Write as common fraction in lowest terms: .075 = ___
31	32	33	34	35
$\frac{r^2 - 5r - 6}{r + 1}$ Ans: ___	$3p - q = 10$; $2p - q = 7$; $p =$ ___ $q =$ ___		Reduce: $\frac{K^2 + K}{K^2} \cdot \frac{3K - 3}{K^2 - 1}$ Ans: ___	$f(x) = 3x^2 + x - 7$ Find $f(-2)$ Ans: ___
36	37	38	39	40

APPENDIX IV: IRB APPROVAL

INFORMED CONSENT
Department of Psychology

Title of Study: Evaluation of Working Memory Tasks
Investigators: Mark H. Ashcraft, Alex Moore, Nathan Rudig, Gabriel Allred, AmyJane McAuley, Sarah Salas
Contact Phone Number: 895-0175

Purpose of the Study

You are invited to participate in a research study on the relationships between math attitudes, skills, and working memory tasks conducted for Dr. Ashcraft in the Psychology Department. The purpose of the study is to better understand how attitudes and math skills influence behavior on various measures of math performance and working memory tasks.

Participants

You are being invited to participate in this study because you are a student in psychology.

Procedures

In this study, you will complete two working memory tasks. After you have completed this you will be asked to take a brief paper and pencil task that will take approximately 15 minutes. Finally you will be asked to fill out a series of questionnaires that will ask about some of your attitudes.

Benefits and Risks of Participation

Although there are no direct benefits of this testing to you, most students find it interesting to see what a real psychology experiment is like. You may ask the experimenter any questions you might have about these procedures, at any time during the experiment. At the end of the session, the experimenter will provide you with a full explanation of the reasons for this research; you may also ask questions then, or you may call Dr. Ashcraft at 895-0175.

There are no risks beyond those of everyday life associated with this testing.

Costs/Compensation

There are no costs to you for participating in this study. You will not be compensated for participating, although your participation will be reported in order for you to fulfill the research participation requirement of the Psychology Department Subject Pool.

Informed Consent

Contact Information
If you have any questions or concerns about the study, you may contact Dr. Ashcraft at 895-0175. For questions regarding your rights as a research subject, or for any complaints or comments regarding the manner in which the study is being conducted, you may contact the UNLV Office of Research Integrity at 702-895-2794.

Voluntary Participation
Your participation is entirely voluntary, of course; you may withdraw your participation at any time, if you wish, and there will be no penalty.

Confidentiality
Your results will be recorded confidentially, and only Dr. Ashcraft will have access to the list that links your name to your i.d. number. Dr. Ashcraft will keep this list so that a future follow-up study might be possible; if you are contacted for such a follow-up, you of course would again be free to participate or not, as you wish at that time. All results of the experiment are reported anonymously, so your name will never be part of any report on these results. All records will be stored in a locked facility at UNLV for at least 3 years after completion of the study. After the storage time, the information gathered will be added to an anonymous archive, for future reference in continuing research projects on this topic.

Participant Consent: I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

1. Signed ____

2. Printed Name __________________________Student I.D.# ____________

3. Time in Experiment _______ (minutes)   5. Date ____________

4. May we contact you for a follow-up study? ___ yes ___ no

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