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Metacognition Moderates Math Anxiety and Affects Performance on a Math Task

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by

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(Under the Direction of Lawrence Locker, Jr.)

ABSTRACT

Math anxiety is a general fear or tension associated with thinking about or engaging in tasks requiring mathematical computations or interpretations. Past research paid little attention to the role of metacognition. It was expected that metacognition would moderate the effects of math anxiety such that performance, reaction time, and confidence would decrease as anxiety levels increased. Participants completed a math anxiety scale, a modular arithmetic task, and a state metacognition scale. Participants also provided information regarding their confidence in how well they answered each math question correctly as well as their estimation of their overall performance. As expected, metacognition moderated math anxiety and predicted that performance would decrease as anxiety increased, except at high metacognition levels. Further, metacognition predicted confidence in accuracy such that individuals with high metacognitive ability were more confident in their ability to correctly answer the problems. This study supports and extends past research findings on the importance of metacognitive processes (evaluation, monitoring, checking, and planning behaviors) and their interaction with anxiety.

INDEX WORDS: Math anxiety, Metacognition, Math, Math performance

METACOGNITION MODERATES MATH ANXIETY AND AFFECTS PERFORMANCE ON A MATH TASK

by

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DEDICATION

This thesis is dedicated to my parents, Landis and Carol Legg, whose unconditional love and support will forever motivate me to reach for the stars. Thank you for raising me to appreciate education and the pursuit of my goals. I would also like to dedicate this thesis to my soon-to-be-husband, Edward Carter II. I would not be in graduate school if it were not for him. I love you all more than you'll ever know.

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"The mind, once stretched by a new idea, never regains its original dimensions."
- Oliver Wendell Holmes

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Math Anxiety

Math anxiety is defined as a general fear or tension associated with anxiety-provoking situations that involve interaction with math. In a world in which Eastern cultures reliably outperform Western cultures on math performance, the outcomes associated with math anxiety hold far reaching implications (Ginsburg, Choi, Lopez, Netley, & Chi, 1997; Siegler & Mu, 2008; Stevenson, Chen, & Lee, 1993). The fear of bringing math into one's life is a driving reason why some individuals forego enrolling in elective math courses in high school and college, avoid math-intensive majors in college, and ultimately pursue careers that do not involve math in their day-to-day activities (Ashcraft, 2002).

Additionally, those most at risk for experiencing detrimental effects related to math anxiety are women and minorities. The anxiety felt by these at-risk groups can, essentially, prevent them from becoming successful in a society where technology is ubiquitous and where, oftentimes, technological knowledge is required for upward advancement in careers (National Research Center, 1990; National Center of Educational Statistics, 1988). For this reason, it is important for cognitive psychologists to explore the causal variables, internal mechanisms, moderators, and outcomes of math anxiety. The metacognition and stereotype threat literature also offer some clues as to why math anxiety can be detrimental to performance. The results of this study will bridge two currently divergent lines of research, that of metacognition and math anxiety, while also providing new evidence regarding the performance of highly math anxious individuals and their metacognitive abilities.

As noted above, math anxiety is defined as a general fear or tension associated with math performance (Ashcraft & Kirk, 2001). This anxiety, if not functionally attenuated, oftentimes will hinder performance. The resulting poor performance can lead to punishing conditions that serve to dissuade individuals from pursuing math experiences in the future. Past research provided evidence that math anxiety resulting in math avoidance can have long-term outcomes such as pursuing careers that do not involve using math frequently (Hannula, 2002). For example, Hembree (1990) surveyed undergraduate students and found that the people highest in math anxiety were those pursuing careers as elementary school teachers. With this in mind, it is easy to see how American culture fosters math anxiety and may even convey this fear in elementary school, a time when math competence is especially impressionable.

Yenilmez, Girginer, and Uzun (2007) describe several characteristics associated with math anxiety. First, highly math anxious individuals feel helplessness often paired with panic when confronted with math. Sometimes individuals will express feeling as though they have reached their maximum mathematical potential and cannot possibly achieve any further understanding. Additionally, individuals with math anxiety often display paranoia and can feel as though they are isolated in their anxiety and that others are aware of their anxiety. This is an especially relevant characteristic within a classroom where math anxious individuals may feel that all of their classmates understand the current lessons, whereas they perceive they are the only ones who do not comprehend the material.

Similar to depressed individuals, people suffering from math anxiety also demonstrate a passive attitude toward math and an external locus of control. For example, someone with math anxiety may feel as if they just do not possess a “math mind” and thus further learning of math is out of their control. A lack of confidence also typically characterizes math anxious individuals.

They do not feel as though they can become good at mathematical computations, and this is related to a heavier reliance on “rule memorization” as opposed to actually conceptualizing the theoretical importance behind the calculations they attempt to learn.

Behaviorally, math anxious individuals may become jittery, sweat profusely, and have quick, shallow breathing. However, some individuals with math anxiety fall into the helplessness category and often appear apathetic or seemingly prepared to accept poor performance. Also related to behavior implications of math anxiety, highly math anxious individuals may either quickly rush through math examinations in a form of avoidance behavior (Beilock & Carr, 2005) or they may perseverate on tasks.

Working Memory and Its Import to Mathematical Computations

Past research in the field of math anxiety focused on establishing the outcomes, cognitive mechanisms and components related to poor performance due to anxious feelings (Ashcraft, 2002; Ashcraft & Ridley, 2005; Beilock & Carr, 2005; Hembree, 1990; Veenman, Kerseboom & Imthorn, 2000). One of the key mechanisms attributed to math problem solving is the utilization of the working memory system (Ashcraft & Kirk, 2001; LeFevre, DeStafano, Coleman, & Shanahan, 2005). Researchers found support for the theory that math computations involve each of the four major divisions of the working memory system (e.g., Baddeley, 2000). The central executive is credited as being the component that completes the actual computation and delegates tasks and resources to the two slave systems, the phonological loop and the visuo-spatial sketchpad (Baddeley, 1992). When solving math problems without the use of paper and pencil, calculator, or a computer, the phonological loop must verbally rehearse computed numbers in order to maintain them in the working memory system. Finally, the visuo-spatial sketchpad must retain the spatial location of the numbers in the equation and manipulate these locations as the computations are processed. Baddeley (2000) expanded his model to also include a third slave system; the episodic buffer. This system works to access mathematical rules and facts stored in long-term memory and integrate them with computations taking place in the active working memory system. It then becomes obvious why calculating a complex mathematical problem quickly becomes taxing to the working memory system, as all four components play important, interactive roles. Figure 1 illustrates the working memory system.

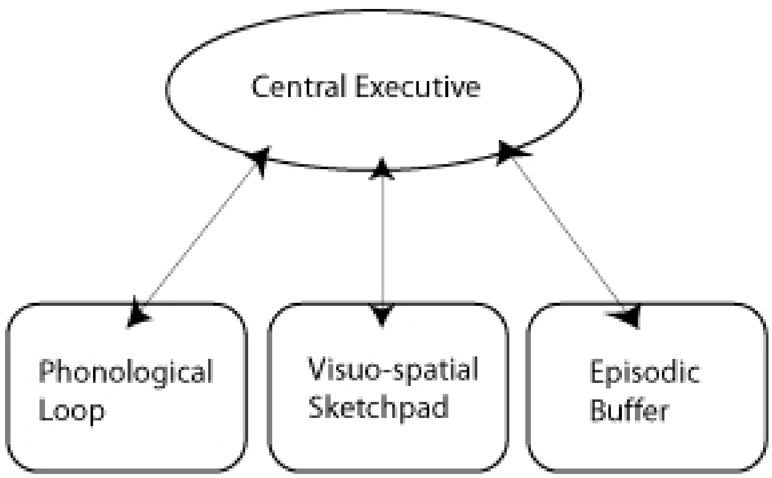

Figure 1. Baddeley's (2000) updated working memory system model.

There are some additional components which serve to determine to what extent the working memory's resources are needed to compute any given math problem. Ashcraft and Krause (2007) describe three characteristics of any math problem that can vary and require more or less working memory resources. First, 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. Second, 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 by the episodic buffer. This is the case when solving simple addition problems such as 2 + 2 = 4. This simple problem has been stored in long term memory so working memory need only access the stored solution, a task which requires very few resources. However, as problems increase in difficulty, working memory must rely more and more on strategies, and long term memory access shifts to retrieval of specific math rules or shortcuts to finding solutions. Hamann and Ashcraft (1985) also found an inverse relationship between problem size and problem frequency in textbooks. They surveyed math textbooks found in elementary schools and concluded that simpler problems were more frequently used, and therefore children more easily transferred these simplistic problems into long term memory. As a consequence, children utilize more of their working memory capacity to solve less frequently seen problems (i.e. more difficult problems).

However, past research provided evidence that practicing problems repeatedly serves to encode them and their computation procedures into long term memory. With sufficient practice, individuals no longer need to rely solely on their active working memory to compute these problems, even if they are difficult (Beilock, Kulp, Holt, & Carr, 2004). All these variables combined (numerical size, number of steps required to solve the problem, the problem type frequency, and practice effects) influence the resources required by the working memory system to solve any given problem.

Math Anxiety's Impact on Working Memory

The variables mentioned can all be considered external variables. Essentially this means that the person performing the math problem has no control over the size of the numbers in the problem or the number of steps required for a solution. Although these external attributes are important in regard to the investigation of the causal variables associated with increased math anxiety, there are many other aspects to explore. Internal variables can also influence the working memory's resources when computing math problems. Anxiety, in particular, can tax working memory to such an extent that even individuals with high math aptitude will begin performing poorly (Beilock & Carr, 2005). Past research provides evidence that anxiety may create a dual task situation that depletes working memory resources (Ashcraft, 2002; Ashcraft & Krause, 2007; Eysenck & Calvo, 1992). The assumption is that individuals with anxiety will ruminate on anxious thoughts that divert mental resources from solving the math problem. The idea that anything creating a dual task, anxiety in this case, that diverts attention away from the task is referred to as distraction theory (Beilock & Carr, 2005; Lewis & Linder, 1997). Ashcraft (2002) additionally notes that anxiety particularly impacts performance when the math problem requires significant utilization of the working memory system, as opposed to problems that are easily calculated via long term memory access.

Individual differences are another component that requires further exploration in regard to math anxiety. Miller (1956) determined that the average working memory span ranges from five to nine units, with an average of seven units. Individuals who have a span of six units or less possess a low working memory span. Individuals with a span of eight or more have a high working memory span. Those with a higher working memory span can employ more resources when dealing with problems requiring the use of the working memory system (Daneman & Carpenter, 1982). To clarify, when the working memory system is confronted with a problem requiring eight steps, for example, to compute the answer, the central executive of an individual with a high working memory span will presumably have more resources to delegate to the three slave systems thus resulting in a more accurate or quicker completion of the problem.

However, in relation to the ability of high working memory span individuals' math performance, Beilock and Carr (2005) explored the hypothesis that high working memory span individuals actually rely more on strategies that *reduce* working memory resources when solving math problems. They suggested that high working memory span individuals will become more prone to diminished performance under high stress situations in which anxiety can deplete resources. Indeed, these researchers concluded that individuals with high working memory spans were negatively impacted proportionally more relative to low working span individuals. In low stress situations the high span participants significantly outperformed low span individuals. However, in an anxiety provoking situation, low span individuals' performance did not change, but the high span individuals' performances dropped to the same level as the low span participants.

Beilock and Carr describe the strategy use utilized by high working memory span individuals to work in an "if you've got it, flaunt it" way. This essentially means that even though these individuals have a superior working memory capacity, they solve problems in a way that still utilizes all of their units of space. On the other hand, low working memory span individuals have to cope with fewer units and therefore have learned how to compensate. This may mean that they do not have the resources to create a strategic plan when confronted with a math problem and consequently solve problems in the most straightforward manner regardless of whether they are in high or low pressure situations. These findings support the notion that individual differences in working memory ability are also factors that need to be considered when examining math performance in high stress situations.

Future Directions for Math Anxiety Research

Currently there is a substantial amount of research on math problem solving and a growing body of literature dedicated to math anxiety and its effect on problem solving abilities (see Ashcraft, 2002, for a review, and Hembree, 1990, for a meta-analysis on the topic).

However, there are still gaps in the research. Ashcraft (2002), for example, called for research examining consequences of math anxiety in relationship to how individuals perceive their own math competence and performance when solving math problems. Of particular interest is how metacognition of math ability (i.e. thinking about one's problem solving and one's own knowledge of their math ability) may additionally compromise working memory resources in anxiety provoking situations. Metacognition, however, is a difficult topic to explore because a well-accepted, testable definition of the concept does not yet exist (Schoenfeld, 1992).

Metacognition

Loosely defined, people usually refer to metacognition as "thinking about thinking." The abstract nature of metacognition creates a problem in developing one all-encompassing, yet still meaningful definition. Explanations of metacognition also vary across disciplines, with educational research operationalizing metacognition differently than psychological and cognitive domains. As metacognitive research is somewhat in its infancy within the cognitive psychology domain, a strict definition is still in development, which can be expected of any construct that is not fully understood. However, Schraw and Moshman (1995) offer a fairly exhaustive definition of metacognition that is widely accepted in both the educational and psychological fields. According to these researchers, metacognition consists of two domains: metacognitive knowledge and regulation of cognition. Each domain can be broken down into three subdomains.

Metacognitive knowledge encompasses all of the knowledge and insight possessed regarding what is already known about cognitions, according to Schraw and Moshman (1995). This domain basically refers to how aware an individual is about his or her own cognitions or thoughts. There are three subdomains of metacognitive knowledge or awareness and these are declarative, procedural, and conditional knowledge. Declarative knowledge is the knowledge about what factors influence learning and affect performance. Knowing that a good night's rest and healthy breakfast can impact test performance is an example of declarative knowledge. Procedural knowledge involves knowing how to perform tasks, using skills automatically, and using strategies efficiently. Driving is an example that benefits from enhanced procedural learning as the skills and strategies used to drive effectively often become automatic and more efficient as one gains more experience with them. The ability to chunk and categorize new information also falls into the domain of procedural knowledge. Finally, conditional awareness includes knowledge of exactly when and why to use specific strategies and when and why to choose alternates. Conditional awareness might come into play often when individuals complete a math task under conditions in which time is short. In this situation, individuals may have to disregard typical solving strategies and adopt alternative time-saving shortcuts.

The second domain Schraw and Moshman (1995) proposed is the regulation of cognition. This domain is implicated in the control of thought processes. There are three subdomains associated with the regulation of cognition: planning, monitoring, and evaluation. Planning involves selecting the appropriate strategies to solve problems and to allocate resources in a manner that allows for efficient and effective problem solving. For example, planning procedures might involve making predictions such as expecting certain questions on a test and thus focusing study efforts on those specific topics while spending less time on unanticipated test material. Whereas planning behaviors tend to occur early on or before a behavior begins, monitoring, the second subdomain of cognition regulation, is the present awareness of understanding and performance. This is the subdomain that regulates checking behaviors during a task and self-testing. Monitoring, for example, is employed when a student attempts to paraphrase a paragraph he just read without looking at the page in order to check for comprehension and retention.

Finally, evaluation often occurs after a task is completed and involves appraising performance or the regulatory components of one's cognitions. This can also involve reevaluating goals or conclusions. For example, rewriting and editing a draft of a manuscript heavily involves the evaluation subdomain as the person must be able to adopt the reader's perspective in order to reevaluate the efficacy of the writing. A person who states, "It made sense when I was writing it, but now I don't know what I was thinking" is employing the evaluation subdomain. Figure 2 illustrates the domains and subdomains described by Schraw and Moshman (1995).

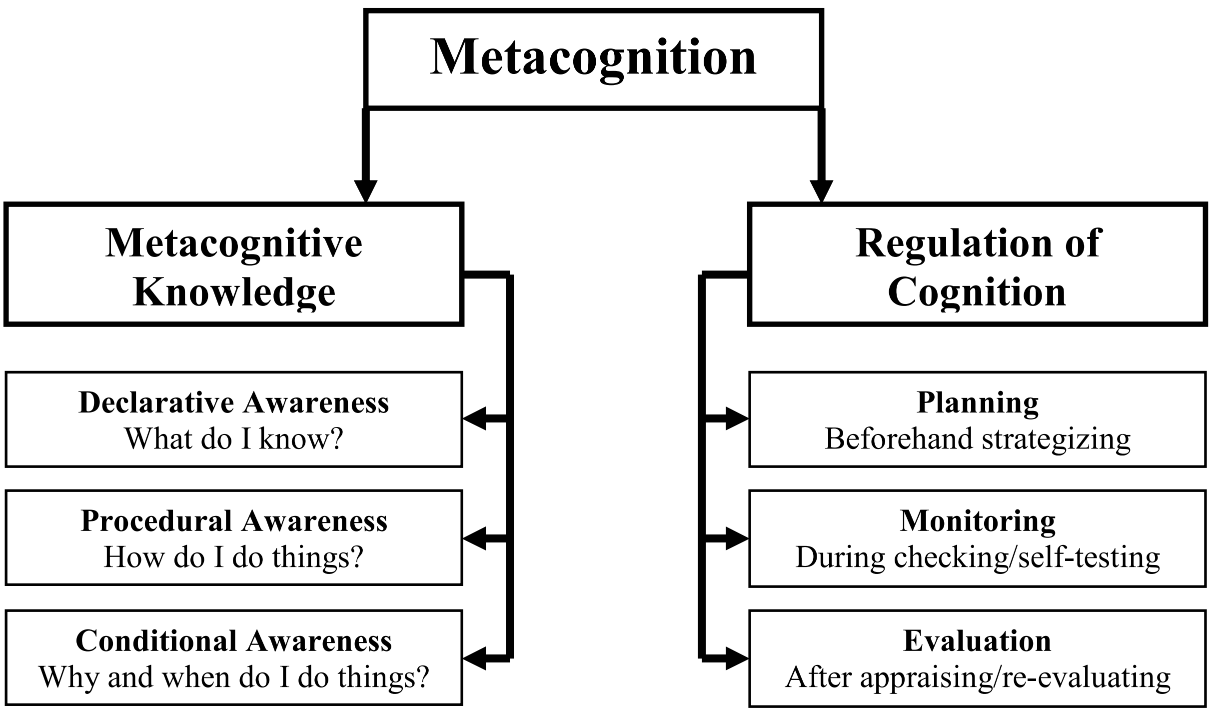

Figure 2. Graphical representation of Schraw and Moshman's (1995) description of metacognition. Image created by the author of this manuscript.

The literature reviewing metacognition as it relates to math performance is sparse. However, some valuable insights can be drawn from research conducted in areas other than mathematical cognition. For example, Beilock, Carr, MacMahon, and Starkes' (2002) experiment provides evidence that highly skilled individuals may suffer from rumination or attenuation to step-by-step processes and skill-focused conditions. Both highly skilled golfers and soccer players performed much better when they did not have to focus on specific steps of the skills they performed (i.e., putting accuracy and dribbling proficiency through a course of cones). Although this research focuses on sensorimotor abilities in highly-skilled individuals, it can still provide support for the idea that over-metacogitating can actually become a detriment to individuals who possess the ability to perform highly (Vallacher, Wegner, & Somoza, 1989). It should be noted, however, that individuals who are in the process of learning skills will perform better when they do attenuate to step-by-step processes (Vallacher & Wegner, 1987). As skills are learned, however, the need to dedicate resources to consideration of each individual step becomes superfluous or even detrimental. In essence, the newly mastered skill becomes less ruled by the monitoring agents and more by the procedural awareness subdomain. This concept also relates to math computation in that practicing math problems serves to encode their processes in long term memory which aids in higher accuracy and quicker response time (Beilock, Kulp, Holt, & Carr, 2004). This evidence also supports the theory of explicit monitoring which essentially posits that high pressure situations can cause individuals to over-attend to step-by-step processes and procedures (i.e. faulty attenuation of metacognition) and thus leads to decrements in performance (Beilock & Carr, 2001; Beilock et al., 2004).

Some metacognitive research explored the relationship to math performance. However, it is difficult to experimentally control and manipulate metacognition. Therefore much of the research utilizes surveys to assess participants’ metacognitive abilities. Lucangeli, Coi, and Bosco (1997) conducted one such study investigating metacognitive abilities in elementary school children and how those metacognitions related to their perception of math. These researchers examined fifth graders' metacognitions and perceptions of their judgment regarding the difficulty of different types of math problems. Consistent with Ashcraft and Krause's (2007) description of characteristics associated with difficult math problems (number size, number of steps required to solve, etc.), the fifth graders perceived problems containing large numbers as more difficult than problems with smaller numbers. The students also performed worse on problems that they perceived as more difficult.

Inaccurate and Accurate Assessments of Performance

Metacognition does not only relate to how people perceive the difficulty of math problems. Although Lucangeli et al.'s (1997) experiment provides evidence supporting how external variables can affect performance more research is still necessary to clarify differences in internal variables such as negative metacognitive thoughts that lead to diminished performance in individuals who have the capacity and ability to succeed but suffer from anxiety.

In relation to this, it is necessary to note that metacognitive skill can involve the ability to accurately assess and evaluate one's own abilities, judgments, and performances. This has previously been referred to as the regulation of cognition domain which involves evaluation and monitoring of performance and cognitions. However, research shows that metacognition does not always produce accurate evaluations (Clayson, 2005; Dunning, Johnson, Ehrlinger, & Kruger, 2003; Kennedy, Lawton, & Plumlee, 2002; Kruger & Dunning, 1999; Sundstrom, 2005). In fact, on average, people tend to overestimate their abilities and believe they are above average when compared to other people (Kruger & Dunning, 1999). The belief that one is above average on any given skill in relation to other people is oftentimes referred to as the above-average effect, the better-than-average effect, the Lake Wobegon effect, and the overconfidence effect.

This phenomenon occurs in a wide variety of areas including judgment of humor, grammar knowledge, logic abilities, and test taking skill. In fact, Kruger and Dunning (1999) argue that people overestimate their abilities because the very skills necessary to perform well on tasks are the same ones that hinder accurate metacognition (i.e. the dual burden of metacognition). For example, Dunning et al. (2003) performed a study in which psychology students were asked to estimate their grades on a test, as well as how they think they performed relative to their classmates. People who performed poorly on the test grossly overestimated their test grade, as well as how they performed compared to other people. This effect is even more startling given that students who performed in the 12th percentile on this test estimated their performance to be, on average, in the 60th percentile. Dunning and his colleagues argue that these low achieving students were ignorant of their poor performance and this led to inaccurate perceptions of their performance. Dunning and colleagues also note that this overestimation of skill, although fairly harmless as it relates to test taking in college, becomes a significant issue when considering that this effect has also been shown in hunters questioned about their firearm knowledge (Ehrlinger, Johnson, Banner, Dunning, & Kruger, 2003, as cited in Dunning et al., 2003) medical residents assessing how well they interview and relate to their patients (Hodges, Regehr, & Martin, 2001, as cited in Dunning et al., 2003), and perhaps most shocking, medical lab technicians who were asked to evaluate their knowledge of medical terminology and problem-solving abilities in the lab (Haun, Zeringue, Leach, & Foley, 2000, as cited in Dunning et al., 2003). Dunning et al. claim that providing low-achievers with problem training and problem solving techniques affords them the opportunity to be able to increase their performance.

On the other end of the spectrum, metacognition does not always lead to accurate predictions for people who perform highly either. Dunning et al. (2003) found that students who performed in the upper quartile (75 percentile and above) on the same psychology test mentioned above ranked themselves as performing worse than other students in the class. For high achievers, their biggest misconception occurs when comparing themselves to other people; this is in contrast to the low achievers who show more inaccuracy when estimating their own performance and overall competence.

Whereas low achievers may show some improvement in personal assessment by receiving metacognitive and problem-solving training, Dunning et al. (2003) suggest that high achievers will benefit most when they are allowed to view other people's responses. Once these high achievers can explore the answers of other people they then can begin to appreciate the quality of their own work. However, low achievers do not benefit in a similar fashion when shown other individuals' work, suggesting that the low achievers are suffering more from the dual burden of metacognition. That is, they lack the beneficial metacognitive skills to accurately identify inaccurate answers and these same skills would be the skills necessary to produce accurate answers in the first place (Kruger & Dunning, 1999; Hodges et al., 2001, as cited in Dunning et al., 2003). This may not necessarily mean that they lack metacognitive skills entirely, just that they may be metacogitating in a maladaptive way such as ruminating on anxious thoughts.

There are some additional exceptions, however, that make the above-average effect more complicated than first assumed. Kruger (1999) and Chambers and Windschitl (2004) both provided evidence indicating that when people perform an easy task, such as dexterity with a computer mouse, they perceive their ability as above average compared to other people.

However, when confronted with a difficult task, such as juggling, people tend to perceive themselves as performing below average. Overall, further research in this area confirms the inaccuracy of low and high achievers. High performers tend to be better judges of their accuracy and comparisons toward others on easy tasks. However, on difficult tasks, high achievers show the highest inaccuracy with low achievers exhibiting more accurate perceptions. In either event, both high and low achievers oftentimes have difficulty placing themselves accurately on a scale of performance compared to their peers.

The metacognition literature is not solely saturated with results showing inaccurate assessment of ability. Metacognition can also result in very accurate evaluations, especially when the task is an easy one or in the case of pre- and post-testing (see Georghiades, 2003 for a review). Given the importance of metacognition in regard to both actual performance as well as perception of performance, the extent to which individual accurately assess their own math performance may provide further insight to the relationship between math anxiety and metacognition. This study will evaluate both the accurate and inaccurate metacognitions that high and low math anxious individuals feel and how this impacts performance.

Insight from the Stereotype Threat Literature

Greater insight on how metacognitive thoughts can affect math performance appears in the stereotype threat literature. Stereotype threat offers valuable information as to why inaccurate assessment of ability may occur in high and low achievers. A stereotype threat is any stereotype about a certain gender, ethnicity, or other diversity classification that negatively impacts performance on a given task due to cognitive and social pressures arising from the knowledge of that stereotype (Steele, 1997). One example of a population affected by stereotype threat is women and the negative stereotype directed at them and their assumed lack of ability to excel in math and science related fields. This stereotype is perpetuated in various ways such as when employers hire males for scientific positions over females or even when Mattel marketed a Barbie doll that said, “Math is hard, I love shopping!” Stereotype threat can produce negative outcomes because the stereotypes themselves are negative (e.g. African Americans are poor students) but can also have a negative impact even when the stereotype is seemingly very positive (e.g. Asians are good at math). In the example of Asians and the “model-minority” stereotype, they experience added pressure to perform well in school and on standardized testing because the stereotype is that their culture is one of hard-working people who value education (Lee, 1994). This pressure, much like math anxiety and the dual-tasks hindering working memory, can lead to poor performance because they do not want to invalidate the stereotype.

It is important to note that stereotype threat is another problem associated with math anxiety that can tax working memory resources (Beilock, Rydell, & McConnell, 2007; Bonnot & Croizet, 2007; Miller & Bichsel, 2003; Ryan & Ryan, 2005; Schmader & Johns, 2003; Spencer, Steele, & Quinn, 1999); similar to the reduction in working memory resources that is also theorized to occur as a result of suboptimal attenuation of metacognitive thoughts. As it relates to working memory, Schmader and Johns (2003) found a decreased working memory span after presenting participants with stereotypes about their race or gender. Bonnot and Croizet (2007) used a dual-task paradigm that also provided evidence for stereotype threat impacting the working memory system by decreasing available resources. Another finding from this study revealed that priming women with the negative stereotype about women’s inferior math ability resulted in poorer performance from the participants, even after controlling for past math experience and achievement.

Research regarding the negative impact of stereotype threat on the working memory system and performance on tasks is especially important when considering the impact of negative metacognitive thoughts. The thoughts from stereotype threat produce, essentially, negative metacognitions. The question then becomes what role metacognition plays for individuals who are not affected or primed by any stereotype threats prior to participating in a task. Aronson (1999) purports that situational pressure alone can produce a negative internal thought process and that there is no need of a history of stigmatization to produce thoughts similar to stereotype threat. Additionally, Steele (1997) and Aronson argue that in order for thoughts to have a negative influence on performance, the individual needs to either place value on the task at hand or care about the social consequences of failing at a given task. If this is the case, then it becomes clearer why high-achieving individuals can suffer most due to negative thought processes resulting from math anxiety and/or negative metacognition. Consider the undergraduate who has been gaining experience in his or her field for several years, painstakingly ensuring good grades in all of his or her classes, and now is faced with the GRE; a three hour long test that holds major importance in the graduate school application process. If negative metacognition has the ability to compromise this student's performance, then there are important implications regarding the consequences of such diminished performance, especially if this individual has superior capacities for performance but is unable to demonstrate them on a standardized test.

Interventions to Reduce Math Anxiety

There is hope for those suffering from math anxiety and possibly the effects of failed attenuation of negative metacognitive thoughts and stereotype threat. Hembree's (1990) meta-analysis on math anxiety explored four different ways math anxiety can be reduced or treated.

Classroom interventions (meant to reduce anxiety within an entire class), behavioral treatments (focused on treating emotionality towards math, cognitive treatments (relieving expressed worry and concern over math), and finally, cognitive-behavioral treatments (reducing emotionality, worry, and concern) were all analyzed. Hembree indicated that individuals receiving behavioral treatment and cognitive-behavioral interventions to reduce anxiety performed at their regular high achievement level after just a few interventions. However, classroom interventions and cognitive treatment methods showed no significant results in diminishing participants' math anxiety. Beilock, Rydell, and McConnell (2007) further built on this by providing experimental evidence that by making individuals aware of stereotype threat and using this to devise training programs for those individuals, they can ultimately counteract the negative impact stereotype threat can have on working memory. Essentially Beilock et al. argue that practicing tasks that may be vulnerable to stereotype threat aids in transferring procedural information into long term memory thus reducing the overall workload required by working memory. Math anxiety may operate in much the same way. Individuals suffering from math anxiety and/or negative metacognition may need only to become aware of the impact of their anxiety and then work towards lessening their reliance on working memory during task performance.

One other issue concerning math performance is how individuals evaluate their performances. It has already been addressed that individuals do not always accurately assess performance either of themselves or how they compare to other people. In relation to this, Kruger and Dunning (1999) and Dunning et al. (2003) assessed the outcomes of metacognition training. These researchers sought to determine what occurs when you provide individuals with the tools necessary to more accurately judge themselves. This happens paradoxically as the training that results in increased ability to ascertain inaccurate or inferior responses will also increase the actual skill needed to perform the task. That is, training reduces the very incompetence that was keeping the individuals from accurate responses in the first place; thus making them more similar in profile to higher achieving individuals (who are usually better at assessing their performances as well). The results of such training demonstrated that although people were more accurate in their estimation of accuracy, people actually became more negative regarding their overall abilities and competence in the given subject matter. They judged themselves much more harshly after being confronted with the fact that personal perceptions are not always accurate accounts of ability. So, in reduction of math anxiety and improving metacognitive skills to optimize working memory potential, it may be important to remember that training (and practice effects again) are important for helping low-achieving individuals. On the other hand, Kruger and Dunning (1999) again found evidence that for high-achieving individuals it may be most helpful for them to examine other individuals' answers so that they can see that their own performance is oftentimes superior to others. This technique could, presumably, cause a substantial reduction in anxiety alone.

Justification of the Current Study

The majority of the metacognitive assessment literature focuses on reading ability and verbal tasks. This literature base offers an excellent foundation by which to explore math anxiety and metacognition. For example, Everson, Smodlaka, and Tobias (1994) found that individuals who have low anxiety are better able to use metacognition in a positive way so that they show better performance against their highly anxious counterparts. On the other hand, when anxiety is high, metacognitions have more of a negative impact and thus result in poorer performance. Everson et al. also found some interacting effects in that high metacognition and low anxiety actually helped individuals perform the best while high anxiety and high metacognition produced the worst performance.

Explicit monitoring theory further explains the results found in Everson et al.'s (1994) experiment. The explicit monitoring theory essentially purports that higher attention to thought processes may result in decrements in performance. Thus, if an individual possesses a highly aware sense of his metacognitions then he may over-metacogitate resulting in perseveration on a task and possibly leading to inaccurate results (if the thoughts are negative). Another example of this can occur when a student over-ruminates on a multiple-choice answer and cannot choose one answer because she is thought to be "thinking too hard about the question." As it relates to the current study, an individual fitting the highly math anxious/high metacognition awareness profile may ruminate and perseverate on the anxiety thus resulting in poor performance. Figure 3 describes four potential outcomes for the four profiles relating metacognition awareness and math anxiety. It is important to note that there is not a current literature base that unequivocally supports each of the possible outcomes and thus, the information in this chart is somewhat exploratory.

Figure 3. Hypothesized characteristics that may result from the combinations of high and low metacognitively aware and math anxious individuals.

	High Metacognitive Awareness	**Low Metacognitive Awareness**
High Math Anxiety	• Individual may ruminate/perseverate on anxiety • Metacognitions are used negatively • May use avoidance behaviors to "get the task over with"	• Individual may not attend to anxiety at all • May not attend to other thought processes either
Low Math Anxiety	• Individual will probably experience optimal performance • Metacognitions are used positively • May take extra time due to checking behaviors	• Individual may appear apathetic or lazy • May not utilize checking or monitoring behaviors

The question then becomes whether individuals with math anxiety who also over-metacognate will suffer from further depletion of working memory resources and therefore show additional decrements in performance. The implications of this question are critical not only for education and teaching techniques, but also lend credence to some criticisms of using standardized testing as a means of classifying individuals' abilities.

Of major significance is the opinion supporting the idea that standardized testing, such as the GRE and SAT, are not adequate measures of aptitude but rather their validity lies in the ability to measure test-taking ability. For example, in Beilock and Carr's experiment (2005) and numerous experiments conducted by Ashcraft and colleagues (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Ashcraft & Ridley, 2005), participants who possess above average working memory span abilities often suffer most when their math anxiety is provoked. This in turn leads to diminished performance that is indistinguishable from people with smaller working memory spans. Because working memory span has been correlated with overall general intelligence (Conway, Kane, & Engle, 2003), this could mean that people who are unable to successfully attenuate their fixation on questioning their math competence in high stakes standardized testing may not be evaluated according to their truly superior intellectual abilities. Additionally, it is becoming more widely accepted that minorities and women who suffer from stereotype threat anxiety may perform more poorly on standardized testing (Ryan & Ryan, 2005). The literature has yet to thoroughly explore the impact of negative metacognition (which effects are similar to stereotype threat) on individuals who have the potential to perform well on such exams.

Taken together, the math anxiety, metacognition, and stereotype threat literature offer valuable insight into why individuals' performance may suffer during math tasks. As Ashcraft (2002) indicated, more empirical evidence must be collected regarding the role of metacognition and people's assessment of their math abilities in order for the math anxiety literature to provide a broader understanding of this oftentimes detrimental problem. The current study will examine the interrelationship between people's awareness of their metacognitive abilities, their math anxiety levels, and math performance.

The design of the current study was developed to investigate how the interaction between individuals' anxiety levels and their awareness of their own metacognition impacts math performance in terms of both accuracy and speed. Based on prior literature, it is hypothesized that individuals who are highly aware of their metacognitions and also have high math anxiety levels will have the fastest reaction time when solving math problems (due to avoidance behaviors, see Ashcraft, 2002), the poorest accuracy, and the most inaccurate perceptions of their performance relative to other people. On the other hand, individuals with low math anxiety and high metacognitive awareness are hypothesized to have the slowest reaction time on math problems (due to greater time spent checking accuracy), the most accurate responses, and the most accurate perceptions of their own performances. Thus, a moderating relationship is hypothesized to exist between math anxiety levels and metacognitive awareness in that metacognitive awareness can either enhance performance by allowing individuals to accurately assess performance or decrease performance depending upon whether individual are or are not highly anxious regarding their math performance.

CHAPTER 2

METHOD

Participants

A total of 56 undergraduates from Georgia Southern University participated in this study and earned credit in their Introduction to Psychology courses for their participation. The mean participant age was 19.77 (*SD* = 2.45). 41 (73.20%) women and 15 (26.8%) men participated in the study. Most participants reported being classified as sophomores (48.20%) while 26.80% were first-year students, 19.60% were juniors, and 5.40% were seniors. 92.20% of the participants had completed at least three high school math courses. 80.30% of the participants had completed at least one college level math course.

Measures

The Revised Math Anxiety Rating Scale (RMARS; Plake & Parker, 1982) was used to assess participants' levels of math anxiety. The RMARS assesses two factors (anxiety for learning math and anxiety due to evaluation of math performance) and has been shown to have good validity and reliability. This scale is included in Appendix B.

Metacognition was measured using the State Metacognitive Inventory (SMI; O'Neil & Abedi, 1996). This 20-item scale has been shown to have good reliability and validity and measures four subscales related to metacognition (planning, monitoring, cognitive strategy, and awareness). This measure was used to assess the extent to which individuals might be more or less metacognitive in their approach to information processing (e.g., solving math problems). The SMI is included in Appendix C.

The Metacognitive Awareness Inventory (MAI; Schaw and Dennison, 1994) was used as an initial measure of trait metacognitive skill. This scale is included in Appendix D. The MAI has good reliability and validity for assessing various components of metacognition including planning, monitoring, and comprehension (Coutinho, 2007). Factor analysis reveals that the MAI measures the two domains of metacognition proposed by Schraw and Moshman (1995), metacognitive knowledge and regulation of cognition.[1]

Additionally, participants also completed a post-math task questionnaire that is included in Appendix E. This questionnaire was primarily utilized to assess how difficult the participants' felt the math task was and how well they think they performed compared to their peers. This was a precautionary scale to ensure that the math task was not too difficult nor too easy. Additionally, this questionnaire was included as a manipulation check consistent with research conducted by Burson, Larrick, and Klayman (2006) in assessing the above-average effect.

Procedure

Following completion of the informed consent, participants completed the RMARS and the MAI. They were then provided instructions on using the computer for the math task. A modular arithmetic task was used because it has been found in previous literature (Beilock & Carr, 2005) to be robust to the effects of mathematical training and the because task is easy enough solve without a calculator or pen and paper. This task has also been shown to be novel even to individuals who have received even a high degree of math training such as chemistry or statistics majors, and thus robust against practice effects. Modular arithmetic involves judging whether a problem results in a whole number or a fraction. Participants saw examples such as 45 – 10 (mod 5). To accurately solve the problem, participants needed to subtract 10 from 45 and then divide 35 by 5. The resulting number (7) is a whole number so the original statement is true.

[1] The reported analyses are based on the State Metacognitive Inventory. Analyses using the Metacognitive Awareness Inventory revealed nonsignificant relationships between math performance and anxiety. In the context of the current study the State Metacognitive inventory may provide a stronger measure as it taps more directly into the degree of metacognitive processing employed during the actual task.

Prior to the experimental trials, participants first completed seven practice trials for which directions were displayed visually as well as explained verbally by the researcher. After completing the practice trials the researcher asked participants whether they had any questions regarding the task and verified that the participants reached a criterion performance level (85% correct or 6 out of the 7 problems) on the practice trials. All participants met this standard.

As past research (Ashcraft, 2002; Beilock & Carr, 2002; Beilock et al., 2005) indicates that math anxiety does not necessarily have pronounced effects on performance unless anxiety concerning the outcome is provoked, participants were informed prior to the task that the ten participants with the highest scores on the actual math task would receive restaurant gift cards.

Participants were then asked to complete the math task consisting of 20 modular arithmetic problems. After completing each problem, participants were asked to judge their accuracy on the preceding problem. They did so by choosing a number on a seven point Likert-type scale indicating their confidence that they provided the correct answer for the previous problem (1 = Not confident at all, 7 = Extremely confident). Math problems were presented one at a time in randomized order on a computer screen using E-Prime (Schneider, Eschman, & Zuccolotto, 2002). Individuals completed the task while sitting alone in a room with a computer while the researcher sat outside of the room.

After completing this task, participants completed the State Metacognitive Inventory, and a demographics survey. The demographics survey is found in Appendix A. Typical demographics such as age, gender, and ethnicity were collected. Additionally, participants were asked to include the math courses they completed in both high school and college.

Finally, the participants receive a debriefing form that described the purpose of the study, asked for their comments and provided details on how they could be notified if they received a gift card. The debriefing form is included in Appendix F. Participants were also verbally debriefed by the researcher in order to ensure comprehension by the participants regarding the purpose of the study and their rights as participants.

At the conclusion of the current study, participants were contacted via email to receive an additional debriefing in which it was explained to them that in actuality their performance on the math task had no bearing on their chances of receiving a gift card. All participants were put into a random drawing and ten people were selected. Participants in the pilot study had a separate drawing in which 5 participants received $10 gift cards to McAlister’s Deli. For the current study, 10 participants each received a $10 gift card to McAlister’s Deli.

CHAPTER 3

RESULTS

Preliminary Analyses

To explore whether any of the measured demographic characteristics related to the dependent measures as covariates, six MANOVAs were conducted with accuracy, reaction time, and confidence entered as dependent variables. The independent variables analyzed were age (dichotomized into 19 and below, and 20 and above), ethnicity, gender, year in school, number of math courses taken in high school, and number of math courses taken in college. Six separate analyses were conducted in order to optimize the chances that any significant covariates would be identified. None of the independent variables significantly related to participants' performance on the modular arithmetic task in terms of either accuracy or reaction time. These variables also did not relate to participants' confidence ratings for the task. These results support the assumption that modular arithmetic is a novel task that consistently reflects people's math performance despite characteristics that may differ among individuals such as the number of math courses an individual completed in the past. Because none of the MANOVAs produced significant results, no covariates were entered into the primary analyses.

Additionally, the manipulation check, used to ensure an appropriate level of difficulty, revealed that participants found the task to be of moderate difficulty (not too easy nor too hard) and also thought that their peers would find the task moderately difficult. Participants provided an estimate of the difficulty on a 4 point Likert-type scale with 1 constituting an extremely easy task and 4 indicating an extremely difficult task. The mean rating for this question was 2.39 (SD = .76). Participants also indicated how difficult they perceived the task would be for their peers.

This question was on the same Likert-type scale. The mean response for this prompt was 2.36 (*SD* = .80).

Primary Analyses

A moderating relationship was hypothesized to exist between math anxiety and math performance with metacognition serving as the interaction term. Figure 4 graphically indicates the relationship.

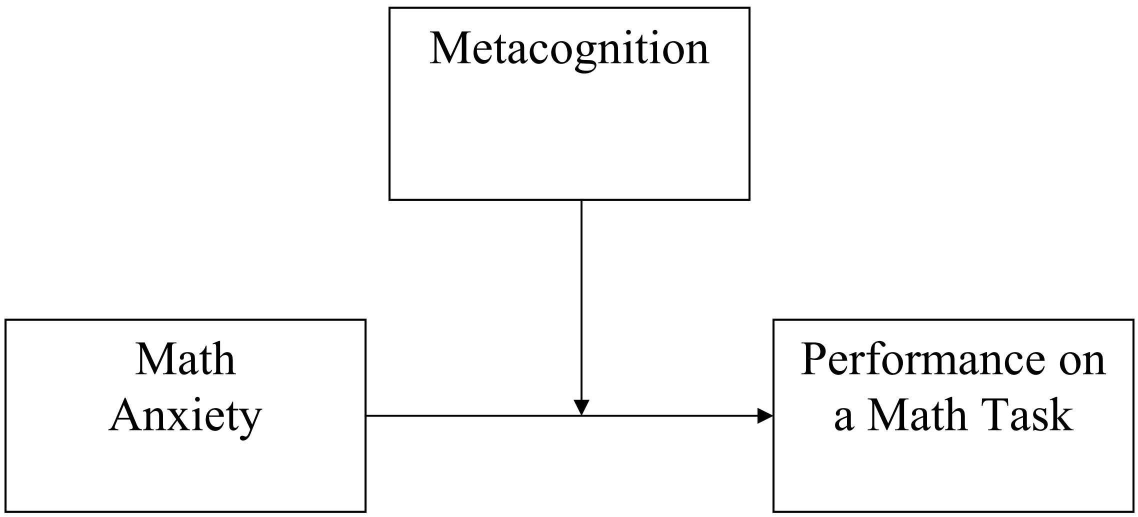

Figure 4. Figure illustrates the moderating relationship between math anxiety and performance on a math task, with metacognition serving as the interaction term.

The moderating relationship was calculated according to the procedures set forth by Baron and Kenny (1986). Multicollinearity among predictors was prevented by computing centered scores for math anxiety and state metacognition (Aiken & West, 1991). This was computed by subtracting the mean of the math anxiety scores (and the SMI scores) from each individual score. An interaction term was created by multiplying the centered scores by (centered RMARS X centered SMI).

Each regression analysis was performed with the centered math anxiety scores, the centered metacognition scores, and the interaction term entered in separate blocks. Three regression equations were used to assess the relationship of metacognition and math anxiety to accuracy, reaction time, and judgments of accuracy. ModGraph was used to graph the prediction equations (Jose, 2008).

The two main effects were also significant. Math anxiety significantly predicted performance, $B = -.06$, ß = -.35, t (55) = -2.75, $p < .01$. Individuals with higher anxiety performed worse than those with low anxiety. The main effect of state metacognition also predicted performance, $B = .08$, ß = .31, t (55) = 2.41, $p < .05$. Additionally, a moderating relationship between metacognition and anxiety was found for accuracy on the math task, $B = .12$, ß = .33, $R^2 = .21$, F (3, 55) = 4.66, $p < .01$. State metacognition moderated math anxiety in that at high anxiety levels, individuals performed increasingly worse as their state metacognitions decreased. Accuracy did not differ at low anxiety levels regardless of state metacognitions. The results for accuracy are presented in Figure 5.

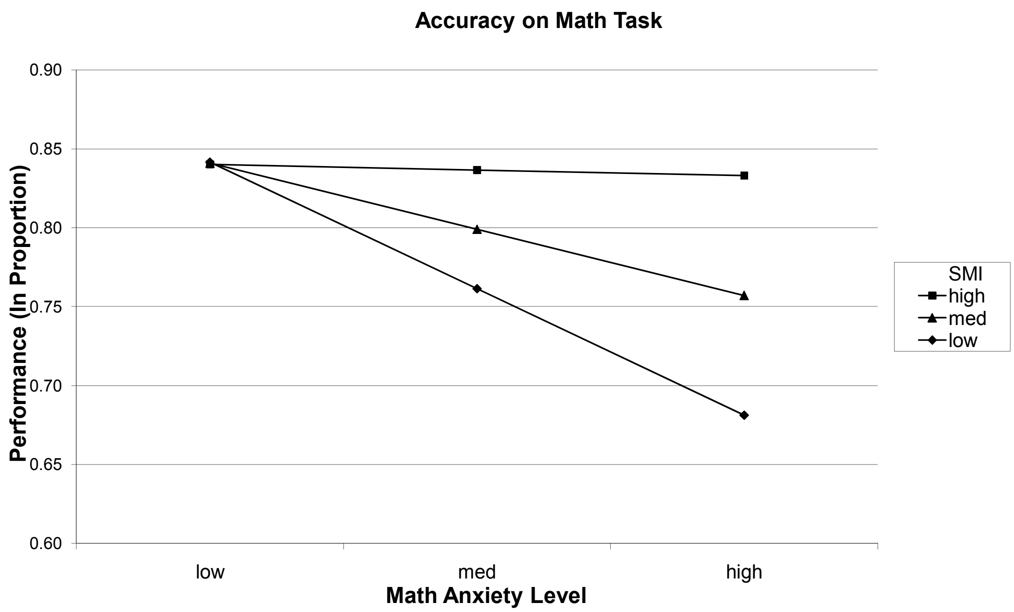

Figure 5. Graph of the regression equation for accuracy.

No relationship was found between metacognition and anxiety and reaction time. $B = -2193.41$, $ß = -.15$, $R^2 = .06$, F (3, 55) = 1.04, $p > .05$. However, a slight trend emerged in the data suggesting that reaction time slows as anxiety levels increase. Further, individuals with low anxiety levels and low metacognitive ability did exhibit a tendency to complete the task in a shorter amount of time. These results are presented in Figure 6.

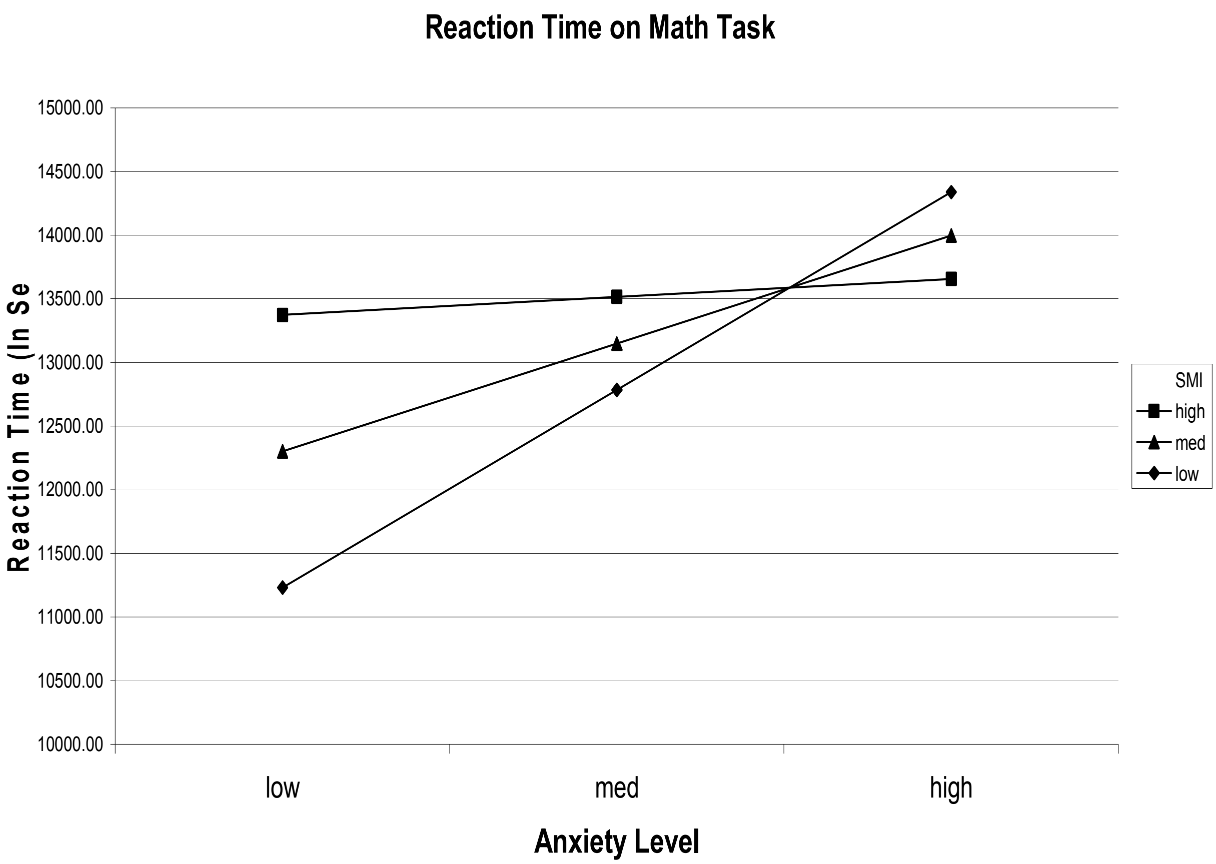

Figure 6. Graph of the regression equation for reaction time.

However, one main effect emerged. Metacognition was related to confidence in accuracy on the math task, *B* = .78, ß = .43, R^2 = .18, *F* (3, 55) = 4.66, *p* <.01, R^2 = .18, *t* (55) = 3.28, *p* =.01. Specifically, state metacognition predicted how confident individuals were on the math task. Individuals with high levels of state metacognitions reported greater confidence in their ability to correctly solve the math problems. Metacognition did not significantly moderate anxiety for confidence in performance although the overall model was significant, R^2 = .18, *F* (3, 55) = 3.91, *p* <.01. The results are presented in Figure 7.

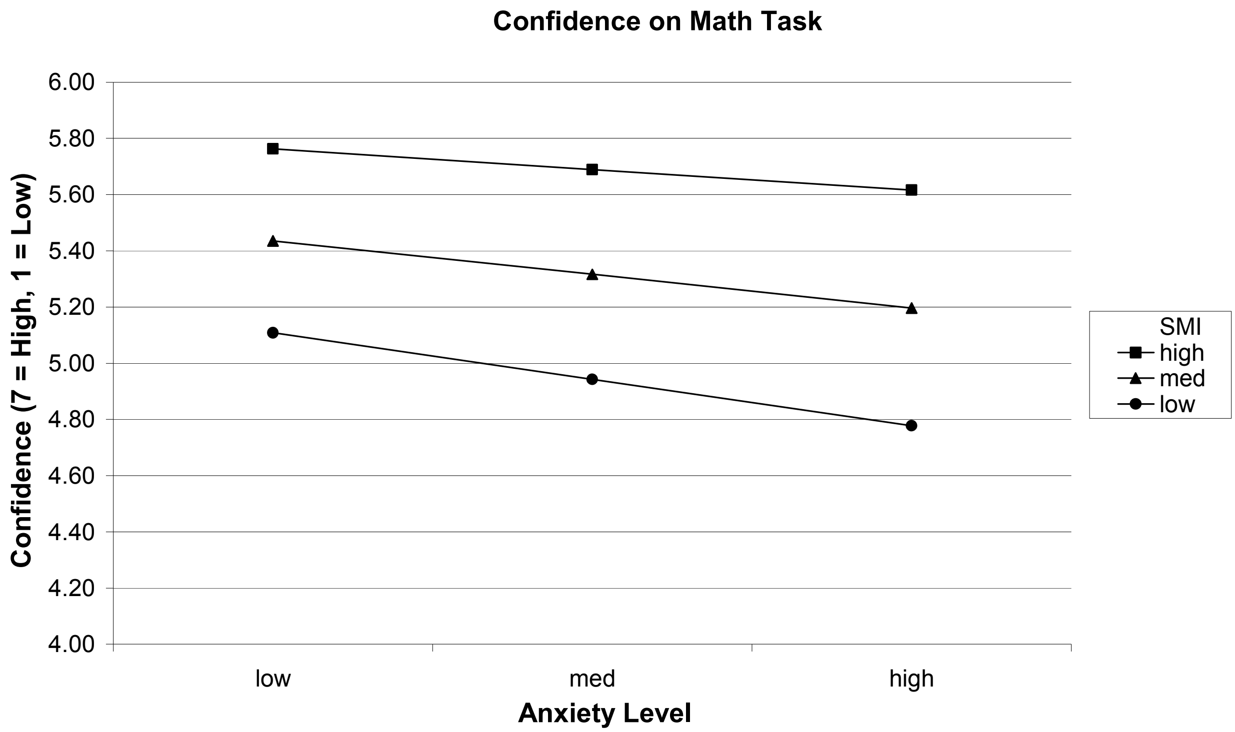

Figure 7. Graph of the regression equation for confidence ratings.

CHAPTER 4

DISCUSSION

The results of this study demonstrate that metacognition does have a moderating relationship with math anxiety that relates to accuracy as well as confidence of accuracy. However, the pattern of results did not indicate that high metacognitive ability lead to deleterious effects of anxiety. Rather, metacognition leads to a lesser impact of anxiety on performance. That is, whereas performance was at ceiling for individuals with low anxiety regardless of metacognition levels, performance remained high for those individuals with higher math anxiety that were also highly metacognitive. Furthermore, higher metacognition also was related to higher overall levels of confidence in performance.

In regard to the relationship between metacognition and anxiety, the results would suggest that individuals with higher anxiety benefit from higher levels of metacognition. Replicating prior research, higher math anxiety was associated with poorer performance. However, greater use of metacognition actually seems to counter the negative effects of anxiety. These results would not support the notion that metacognition necessarily contributes to more deleterious effects of anxiety (e.g., such as leading to a dual-task type situation or greater rumination of anxious thoughts). It is possible that the nature of metacognition and anxiety are heavily state-dependent relative to the potential consequences of the outcome, the nature of the math problems presented and the general context. Note that, similar to prior studies a modular math task used to avoid practice effects relative to math backgrounds as well as be computationally within the abilities of the participants without a calculator. Thus, the task was not designed to necessarily *exceed* the capabilities of the participants. Furthermore, given that it was an experimental situation, the consequences of failure to perform were relatively minimal (e.g., as opposed to high pressure tests such as the GRE or SAT). It is therefore likely that participants perceived the math task as not being beyond their capabilities and the cost of not performing at peak was not as threatening. However, the task did lead to some degree of stress or pressure to perform as math anxiety was related to accuracy. Presumably, no relationship of math anxiety to accuracy would have been observed had the task been viewed as completely benign by the participants. Therefore, it could be argued that although the task did lead to some stress in terms of performance, task difficulty was not so excessive that it precluded those individuals that were also high in metacognition to effectively utilize the beneficial aspects of metacognition such as checking behaviors and strategic use of problem solving. By allocating mental attention to metacognition processes, attention was diverted from anxiety-related thoughts. Importantly, the metacognitive processing would appear to have been utilizing productive strategies rather than being utilized to ruminate upon anxious thoughts about the context or negative perceptions of ability. It has been argued that highly anxious individuals might have been able to process the situation in this way because of the nature of the modular arithmetic task and context (relatively non-threatening). However, had the context been more analogous to a high-stress testing situation such as an SAT or a final exam, the highly anxious individuals might have utilized metacognitions in a negative fashion by ruminating on the situation or potential outcome rather than checking behaviors or problems solving. This current study taken in tandem with other research suggests that the nature of math anxiety and metacognition may be highly context dependent.

The notion that highly metacognition individuals were utilizing these processes in a positive fashion is also supported by the relationship between metacognition and judgments of performance. Overall, higher metacognition was associated with perceptions of better performance, regardless of anxiety level. Notably, a secondary analysis indicated that confidence in accuracy was positively correlated with actual performance on the task ($R^2 = .43$, $p = .001$). Thus, it would appear that these participants were devoting mental resources to the task in an efficient manner and were very aware of this fact. Indeed, it might have been this very awareness that countered the effects of anxiety. Again, this may be true in a situation in which, although stress provoking, is not judged by the participant to be beyond their math capabilities. As noted above, if the judgment were that the situation exceeded abilities, the opposite may have been observed as in prior studies examining working memory (e.g., Beilock & Carr, 2005).

Educational Implications

One educational implication of this finding would be to advocate metacognitive training. As noted previously, Kruger and Dunning (1999) found evidence that addressing metacognitive processes such as strategy use and checking behaviors increase college students' ability to perform well on varying tasks. Much of the educational literature suggests that metacognitive training is also useful in helping individuals in elementary, middle and high school (Cardell-Elawar, 1995; Kramarski & Mevarech, 2003; Teong, 2003).

Metacognitive training has been shown to be a very effective method in which to overcome mathematics problem-solving difficulties. Metacognitive training is usually based on the principals set forth by Polya (1945) and involves directing student and participant attention to metacognitive thinking such as strategy use, problem solving, and time and accuracy monitoring. It also involves encouraging participants to monitor their confidence in their abilities or lack of confidence. Some metacognitive training occurs mainly in groups or dyads (primarily teacher-student), or individually (Kramarski & Mevarech, 2003). Schoenfeld (1992) indicated that metacognitions, as they relate to mathematics, involves the awareness of one's thought processes (such as how to solve a problem and strategies that could be chosen to solve any given problem, regulation and monitoring, and personally held thoughts and beliefs toward math, such as how good a person thinks he or she is at math). Thus, some metacognitive training procedures focus on different aspects of these domains (all of which align with Schraw and Moshman's (1995) model of metacognition as well). Because metacognitive training improves performance overall, as the present finding suggest it may be a worthwhile way in which to overcome the deleterious effects of math anxiety in highly math anxious individuals.

Kramarski and Mevarech (2003), for example, provided some students with metacognitive training while others received traditional teaching and then were tested on their performance interpreting a linear graph unit. Students were also either placed into groups or received the training or teaching individually. Individuals receiving the metacognitive training performed significantly better than the students receiving only the traditional teaching method, regardless of whether they received the metacognitive training in groups of individually.

Furthermore, even if students are split into high and low achieving groups, metacognitive training does have positive benefits, although most benefits seem to occur within low achieving groups (Kruger & Dunning, 1999). Researchers found that high achievers benefit most from viewing other individuals' responses to problems so that they better apprehend the superiority of their own answers. However, at low achieving levels, individuals must be instructed in regard to the skills necessary to correctly evaluate themselves as well as how to positively use metacognitive strategies. Cardelle-Elawar (1995) found evidence for this supposition as well. This researcher examined elementary and middle school age children who were considered low-achievers in mathematics. In this study, individuals were randomly assigned to either receive traditional teaching or metacognitive training. The metacognitive training, again, directed students to answer certain questions throughout the problem-solving process that related to metacognitive functioning such as, “Do I understand the words in this problem?” and “With what operations needed to solve this problem do I typically have difficulty completing?” Students receiving the metacognitive training significantly improved their performance compared to students in the control condition. Interestingly, and especially relevant to the current study, the students in the metacognitive training group also exhibited improved attitudes toward mathematics. These findings support the results of the current study in that students who demonstrated greater confidence in their problem-solving abilities also showed higher performance overall. Creating a climate in which self-efficacy promotes improved performance may be a critical by which metacognition benefits mathematical performance.

The present results also support the idea metacognition can counter the negative or stressful perceptions of math, although I have cautioned that this may be context dependent. However, this study lends credence to the notion that by increasing the effective use of metacognitive skills, individuals with math anxiety in particular may be able benefit and increase performance to levels similar to those individuals with low anxiety.

Furthermore, in testing situations, first providing students with problems that they perceive are within their capacity to solve may increase confidence and consequently lead to overall higher levels of performance. That is, if individuals feel greater confidence in their overall ability to correctly solve the problems a self-fulfilling prophecy may occur. In other words, those who are reinforced with feelings of confidence may solve problems more accurately in the future compared to individuals who do not feel confident in their abilities and might “give up.” This suggests that an effective teaching strategy would be to create, in an initial phase of a math assessment, a portion promoting confidence in responding, such that students might metacognitively generalize this to the situation in general and thereby increase overall performance.. Future research should be aimed at an investigation of this approach in various settings, particularly those that lead to high anxiety such SAT or GRE testing.

Neuropsychological Correlates

The research on math performance and math anxiety is growing as researchers continue to explore the numerous characteristics affecting math problem solving execution (Ashcraft, 2002; Beilock & Carr, 2005; Beilock, Kulp, Holt, & Carr, 2004). Neuropsychological and psychophysiological evidence may also be critical in terms of better understanding math anxiety as well as its relationship to internal cognitive variables such as metacognition. It is interesting to note that the same areas in the brain (frontal and midfrontal regions) responsible for working memory, particularly the central executive, are also the same regions associated with anxiety monitoring and metacognition (Shimamura, 2000). This evidence is especially interesting when considering the previously mentioned research providing evidence that metacognition, stereotype threat, and math anxiety all tax the working memory components and decrease performance. As in many areas of cognitive science, neuroscience can aid cognitive psychologists in their endeavors to provide evidence and support for their psychological models. This is true regarding the area of metacognition and math performance as well.

Until more reliable and conclusive neuropsychological evidence is revealed, however, cognitive experimentation can continue to yield further insight into the problems or benefits arising from math anxiety and metacognition.

Limitations

In terms of limitations of the current study, it should be noted that the design was quasi-experimental as metacognition and math anxiety were not manipulated factors. Future research should attempt to explore means by which to experimentally manipulate both metacognition and anxiety in order to make more robust claims regarding possible causal relationships among these variables. One way by which to manipulate math anxiety would be to use the methodology set forth by Beilock and Carr (2005) in which participants are videotaped, told that they have a partner who is relying on them to improve their performance, and that professors will be evaluating the videotapes in the future. Metacognition could experimentally be manipulated by providing some participants with metacognitive training prior to the task. Another way in which to obtain stronger control over metacognition would be to present some participants with metacognitive analysis questions throughout a problem solving task. For instance, if a participant is solving a math problem, at random times throughout the process, different questions might appear on the screen asking the participants to respond to various items such as, “How much time is remaining to complete this task?” or “Are there any other ways to solve this problem that might be more efficient?”

For this study, examining a college population was appropriate due to the nature of the topic of math anxiety. However, generalizability may be limited to college students. Thus, another possible limitation of this study is that the results may not generalize to other populations such as younger students, adults in the workplace, or individuals who suffer from anxiety disorders. Further research should examine the extent to which the patterns obtained in the current study are also observed in other populations. For example, research might examine at what age metacognition begins moderating anxiety. Additionally, adult populations from both math-intensive fields such as computer science as well as non-math-intensive fields such as English education might be examined to if there are differences among these groups in how metacognition relates to math performance or anxiety.

A final limitation of the current study that warrants mention is the difficulty of the math task. As noted above, the moderation relationship observed in this study may only extend to situations in which the math task is actually within an individual's range of ability. There are many different types of math tasks including those that can be computed without a calculator, some required advanced mathematical software such as SPSS, while others have more real world applications such as when a person needs to figure out the amount of change to give to back to a customer making a purchase at a store.

Additionally, the current study found no moderating relationship between metacognition and math anxiety when reaction time was analyzed. However, the results revealed a slight trend indicating that individuals at high anxiety levels spent more time attempting to solve the problems. At low anxiety levels, alternatively, individuals with high metacognitions spent the most time (but less than highly anxious individuals). However, Beilock and Carr (2005) found that highly math anxious individuals oftentimes have lower reaction time values which are attributed mainly to avoidance behaviors (i.e. "I just want to get this over with"). These two differing patterns may again be related to task difficulty. In a relatively easy task, such as the one used in the current study, highly anxious participants may spend more time focusing on either positive or negative metacognitive strategies (checking behaviors or anxiety rumination). On more difficult math tasks, participants may then switch to the avoidance behavior usage once they determine they are not capable of solving the problem or do not want to put forth the effort in order to compute the problem. Future research needs to evaluate in what contexts these differing reaction time patterns occur.

Conclusion

Research on math anxiety is still in its infancy as the interacting variables, mechanisms, and outcomes are established. Metacognition's relationship to math anxiety is also a new topic and requires additional future research. The implications of math anxiety are well known, far-reaching and possibly contribute to the learning gap between Western and Eastern cultures. As basic research explores the components related to this issue, applicable interventions can be identified that mitigate the negative impact of math related stress or anxiety.

REFERENCES

Aiken, L. S. & West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions.* London: Sage Publications.

Aronson, J., Lustina, M. J., Good, C., Keough, K., Steele, C. M., & Brown, J. (1999). When white men can't do math: Necessary and sufficient factors in stereotype threat. *Journal of Experimental Social Psychology, 35,* 29-46.

Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*, 181-185.

Ashcraft, M. H. & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130*, 224-237.

Ashcraft, M. H. & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin and Review, 14*, 243-248.

Ashcraft, M. H. & Ridley, K. S. (2005). Math anxiety and its cognitive consequences. In J. I. D. Campbell (Ed.), *Handbook of Mathematical Cognition* (pp. 315-327). New York: Psychology Press.

Baddeley, A. D. (1992). Working memory. *Science, 255,* 556-559.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4,* 417–423.

Baron, R. M. & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51,* 1173-1182.

Baumeister, R. F. (1984). Choking under pressure: self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology, 46,* 610-620.

Beilock, S. L. & Carr, T. H. (2005). When high-powered people fail: Working memory and "choking under pressure" in math. *Psychological Science, 16*, 101-105.

Beilock, S. L., Carr, T. H., MacMahon, C., & Starkes, J. L. (2002). When paying attention becomes counterproductive: Impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experimental Psychology: Applied, 8,* 6-16.

Beilock, S. L., Kulp, C. A., Holt, L. E., & Carr, T. H. (2004). More on the fragility of performance: Choking under pressure in mathematical problem solving. *Journal of Experimental Psychology: General, 133*, 584-600.

Beilock, S. L., Rydell, R. J., & McConnell, A. R. (2007). Stereotype threat and working memory: Mechanisms, alleviation, and spillover. *Journal of Experimental Psychology: General, 136*, 256-276.

Burson, K. A., Larrick, R. P. & Klayman, J. (2006). Skilled or unskilled, but still unaware of it: How perceptions of difficulty drive miscalibration in relative comparisons. *Journal of Personality and Social Psychology, 90,* 60-77.

Cardell-Elawar, M. (1995). Effects of metacognitive instruction on low achievers in mathematics problems. *Teaching and Teacher Education, 11,* 81-95.

Chambers, J. R. & Windschitl, P. D. (2004). Biases in social comparative judgments: The role of nonmotivated factors in above-average and comparative-optimism effects. *Psychological Bulletin, 130,* 813-838.

Clayson, D. E. (2005). Performance overconfidence: Metacognitive effects or misplaced student expectations? *Journal of Marketing Education, 27,* 122-129.

Conway, A. R. A., Kane, M. J., & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Science, 7,* 547-552.

Coutinho, S. A. (2007). The relationship between goals, metacognition, and academic success. *Educate, 7*, 39-47.

Daneman, M. & Carpenter, P. A. (1980). Individual-differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence, and function of the prefrontal cortex. In A. Miyake & P. Shah (Eds.), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control (*pp. 102-134). New York: Cambridge University Press.

Dunning, D., Johnson, K., Ehrlinger, J. & Kruger, J. (2003). Why people fail to recognize their own incompetence. *Current Directions in Psychological Science, 12,* 83-87.

Everson, H. T., Smodlaka, I., & Tobias, S. (1994). Exploring the relationship of test anxiety and metacognition on reading test performance: A cognitive analysis. *Anxiety, Stress, and Coping, 7,* 85-96.

Eysenck, M. W. & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition and Emotion, 6,* 409-434.

Georghiades, P. (2003). From the general to the situated: Three decades of metacognition. *International Journal of Science Education, 26*, 365-383.

Ginsburg, H. C., Choi, Y. E., Lopez, L. S., Netley, R., & Chi, C. Y. (1997). Happy birthday to you: Early mathematical thinking of Asian, South American and U.S. children. In T. Nunes & P. Bryant (Ed.), *Learning and teaching mathematics: An international perspective* (pp. 163–207). Hove, England: Psychology Press.

Hamann, M. S. & Ashcraft, M. H. (1985). Simple and complex mental addition across development. *Journal of Experimental Child Psychology, 40,* 49-72.

Hannula, M. S. (2002). Attitudes toward mathematics: Emotions, expectations, and values. *Educational Studies in Mathematics, 49,* 25-46.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21,* 33-46.

Kennedy, E. J., Lawton, L., & Plumlee, E. L. (2002). Blissful ignorance: The problem of unrecognized incompetence and academic performance. *Journal of Marketing Education, 24*, 243-252.

Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal, 40,* 281-310.

Kruger, J. (1999). Lake Woebegon be gone! The "below-average effect" and the egocentric nature of comparative ability judgments. *Journal of Personality and Social Psychology, 77,* 221-232.

Kruger, J. & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology, 77*(6)*,* 1121-1134.

Lee, S. J. (1994). Behind the model-minority stereotype: Voices of high- and low-achieving Asian American students. *Anthropology and Education Quarterly, 25,* 413-429.

LeFevre, J. A., DeStafano, D., Coleman, B., & Shanahan, T. (2005). Mathematical cognition and working memory. In J. I. D. Campbell (Ed.), *Handbook of Mathematical Cognition* (pp. 361-378). New York: Psychology Press.

Lewis, B. & Linder, D. (1997). Thinking about choking? Attentional processes and paradoxical performance. *Personality and Social Psychology Bulletin, 37,* 2014-2024.

Lucangeli, D., Coi, G., & Bosco, P. (1997). Metacognitive awareness in good and poor math problem solvers. *Learning Disabilities Research and Practice, 12,* 209-212.

Miller, G. A. (1956). The magical number seven, plus or minus two. *Psychological Review, 63,* 81-97.

Miller, H. & Bichsel, J. (2003). Anxiety, working memory, gender, and math performance. *Personality and Individual Differences, 37,* 591-606.

National Center of Educational Statistics (1988). *Trends in Minority Enrollment in Higher Education, Fall 1986-Fall 1988.* Washington, DC: U.S. Department of Education.

National Research Council (1990). *A Challenge of Numbers.* Washington, DC: National Academy Press.

O'Neil, H. F. Jr. & Abedi, J. (1996). Reliability and validity of a state metacognitive inventory: Potential for alternative assessment. *The Journal of Educational Research, 89,* 234-245.

Plake, B. S. & Parker, C. S. (1982). The development and validation of a revised version of the mathematics anxiety rating scale. *Educational and Psychological Measurement, 42,* 551-557.

Polya, G. (1945). *How to solve it?* Garden City, NY: Doubleday.

Ryan, K. E. & Ryan, A. M. (2005). Psychological processes underlying stereotype threat and standardized math test performance. *Educational Psychologist, 40*, 53-63.

Schneider, W. Eschman, A., & Zuccolotto, A. (2002). E-Prime User's Guide. Pittsburgh: Psychology Software Tools, Inc.

Schmader, T. & Johns, M. (2003). Converging evidence that stereotype threat reduces working memory capacity. *Journal of Personality and Social Psychology, 85,* 440-452.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. Grouws (Ed.), *Handbook for Research on Mathematics Teaching and Learning* (pp. 334-370). New York: MacMillan.

Schraw, G. & Dennison, R.S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19,* 460-475.

Schraw, G. & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7,* 351-371.

Shimamura, A. P. (2000). Toward a cognitive neuroscience of metacognition. *Consciousness and Cognition, 9, 313-323.*

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology, 35,* 4-28.

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist, 52,* 613-629.

Seigler, R. S., & Mu, Y. (2008). Chinese children excel on novel mathematics problems even before elementary school. *Psychological Science, 19,* 759-763.

Stevenson, H.W., & Stigler, J.W. (1992). The learning gap. New York: Free Press.

Sundstrom, A. (2005). Self-assessment of driving knowledge and abilities. *Transportation Research Part F: Psychology and Behaviour, 11,* 1-36.

Teong, S. K. (2003). The effect of metacognitive training on mathematical word-problem solving. *Journal of Computer Assisted Learning, 19,* 46-55.

Turner, M. L. & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language, 28*, 127-154.

Vallacher, R. R., Wegner, D. M. (1987). What do people think they're doing? Action identification and human behavior. *Psychological Review, 94,* 3-15.

Vallacher, R. R., Wegner, D. M., & Somoza, M. P. (1989). That's easy for you to say: action identification and speech fluency. *Journal of Personality and Social Psychology, 56,* 199-208.

Veenman, M. V. J., Kerseboom, L., & Imthorn, C. (2000). Test anxiety and metacognitive skillfulness: Availability versus production deficiencies. *Anxiety, Stress, and Coping, 13*, 391-412.

Yenilmez, K., Girginer, N., & Uzun, O. (2007). Mathematics anxiety and attitude level of students of the faculty of economics and business administration; the Turkey model. *International Mathematics Forum, 2,* 1997-2021.

Appendix A

Demographics Survey

Age: ________ Major: ______________________

Please circle the appropriate answer.

Gender: Male Female

Ethnicity

Caucasian African American Asian Native American Hispanic

Other: _______________

Year in school:

First Year Sophomore Junior Senior Other: ___________

Please list the math courses you have taken in high school and the grade you received in them:

Course	Grade
____	___________
____	___________
____	___________
____	___________

Please list the math courses you have taken in college and the grade you received in them:

Course	Grade
____	___________
____	___________
____	___________
____	___________

Appendix B

Revised Mathematics Anxiety Rating Scale

Revised Mathematics Anxiety Rating Scale

Please rate your anxiety level for each of the following examples. Think about the anxiety you would have in that actual situation.

0 = No Anxiety at All 1 = Low Anxiety 2 = Moderate Anxiety 3 = High Anxiety 4 = Extreme Anxiety

	No Anxiety	Low	Moderate	High	Extreme
Looking through the pages in a math text	0	1	2	3	4
Walking into a math class	0	1	2	3	4
Having to use the tables in the back of a math book	0	1	2	3	4
Reading a formula in chemistry	0	1	2	3	4
Buying a math textbook	0	1	2	3	4
Thinking about an upcoming math test one day before	0	1	2	3	4
Watching a teacher work an algebraic equation on the blackboard	0	1	2	3	4
Being told how to interpret probability statements	0	1	2	3	4
Picking up a math textbook to begin working on a homework assignment	0	1	2	3	4
Taking an examination (quiz) in a math course	0	1	2	3	4
Reading and interpreting graphs or charts	0	1	2	3	4
Solving a square root problem	0	1	2	3	4
Signing up for a course in statistics	0	1	2	3	4
Getting ready to study for a math test	0	1	2	3	4
Reading the word "statistics"	0	1	2	3	4
Being given a homework assignment of many difficult problems which is due the next class meeting	0	1	2	3	4
Listening to a lecture in math class	0	1	2	3	4
Waiting to get a math test returned in which you expected to do well	0	1	2	3	4
Working on an abstract mathematical problem	0	1	2	3	4
Being given a "pop" quiz in math class	0	1	2	3	4
Taking an examination (final) in math class	0	1	2	3	4
Starting a new chapter in a math book	0	1	2	3	4
Listening to another student explain a math formula	0	1	2	3	4
Walking on campus and thinking about a math course	0	1	2	3	4
	No Anxiety	Low	Moderate	High	Extreme

Plake, B. S. & Parker, C. S. (1982). The development and validation of a revised version of the mathematics anxiety rating scale. *Educational and Psychological Measurement, 42,* 551-557.

Appendix C

State Metacognitive Inventory

Direction: Read each statement below and indicate how you thought DURING the math task.

	Not At All	Somewhat	Moderately So	Very Much So
1. I was aware of my own thinking.	1	2	3	4
2. I checked my work while I was doing it.	1	2	3	4
3. I attempted to discover the main strategies/ideas in the task problems.	1	2	3	4
4. I tried to understand the goals of the task problems before I attempted to answer.	1	2	3	4
5. I was aware of which thinking technique or strategy to use and when to use it.	1	2	3	4
6. I corrected my errors.	1	2	3	4
7. I asked myself how the task problems related to what I already knew.	1	2	3	4
8. I tried to determine what the task required.	1	2	3	4
9. I was aware of the need to plan my course of action.	1	2	3	4
10. I almost always knew how much of the task I had left to complete.	1	2	3	4
11. I thought through the meaning of the task questions before I began to solve them.	1	2	3	4
12. I made sure I understood just what had to be done and how to do it.	1	2	3	4
13. I was aware of my ongoing thinking processes.	1	2	3	4
14. I kept track of my progress and, if necessary, I changed my techniques/strategies.	1	2	3	4
15. I used multiple thinking techniques of strategies to solve the task problems.	1	2	3	4
16. I determined how to solve the task problems.	1	2	3	4
17. I was aware of my trying to understand the task problems before I attempted solving them.	1	2	3	4
18. I checked my accuracy as I progressed through the task.	1	2	3	4
19. I selected and organized relevant information to solve the task problems.	1	2	3	4
20. I tried to understand the task problems before I attempted to solve them.	1	2	3	4

O'Neil, H. F. Jr. & Abedi, J. (1996). Reliability and validity of a state metacognitive inventory: Potential for alternative assessment. *The Journal of Educational Research, 89,* 234-245.

Appendix D

Metacognitive Awareness Inventory

Check True or False as appropriate.

	True	False
1. I ask myself periodically if I am meeting my goals.		
2. I consider several alternatives to a problem before I answer.		
3. I try to use strategies that have worked in the past.		
4. I pace myself while learning in order to have enough time.		
5. I understand my intellectual strengths and weaknesses.		
6. I think about what I really need to learn before I begin a task		
7. I know how well I did once I finish a test.		
8. I set specific goals before I begin a task.		
9. I slow down when I encounter important information.		
10. I know what kind of information is most important to learn.		
11. I ask myself if I have considered all options when solving a problem.		
12. I am good at organizing information.		
13. I consciously focus my attention on important information.		
14. I have a specific purpose for each strategy I use.		
15. I learn best when I know something about the topic.		
16. I know what the teacher expects me to learn.		
17. I am good at remembering information.		
18. I use different learning strategies depending on the situation.		
19. I ask myself if there was an easier way to do things after I finish a task.		
20. I have control over how well I learn.		
21. I periodically review to help me understand important relationships.		
22. I ask myself questions about the material before I begin.		
23. I think of several ways to solve a problem and choose the best one.		
24. I summarize what I’ve learned after I finish.		
25. I ask others for help when I don’t understand something.		
26. I can motivate myself to learn when I need to		
27. I am aware of what strategies I use when I study.		
28. I find myself analyzing the usefulness of strategies while I study.		
29. I use my intellectual strengths to compensate for my weaknesses.		
30. I focus on the meaning and significance of new information.		
31. I create my own examples to make information more meaningful.		

	True	False
	True	False
32. I find myself using helpful learning strategies automatically.		
33. I find myself pausing regularly to check my comprehension.		
34. I know when each strategy I use will be most effective.		
35. I ask myself how well I accomplish my goals once I'm finished.		
36. I draw pictures or diagrams to help me understand while learning.		
37. I ask myself if I have considered all options after I solve a problem.		
38. I try to translate new information into my own words.		
39. I change strategies when I fail to understand.		
40. I use the organizational structure of the text to help me learn.		
41. I read instructions carefully before I begin a task.		
42. I ask myself if what I'm reading is related to what I already know.		
43. I reevaluate my assumptions when I get confused.		
44. I organize my time to best accomplish my goals.		
45. I learn more when I am interested in the topic.		
46. I try to break studying down into smaller steps.		
47. I focus on overall meaning rather than specifics.		
48. I ask myself questions about how well I am doing while I am learning something new.		
49. I ask myself if I learned as much as I could have once I finish a task.		
50. I stop and go back over new information that is not clear.		
51. I stop and reread when I get confused.		

Schraw, G. & Dennison, R.S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19,* 460-475.

Appendix E

Post-Math Task Questionnaire

1. Overall, how difficult do you think this math task was for you personally? (circle one)

Extremely Easy	Sort of Easy	Sort of Difficult	Extremely Difficult

2. Overall, how difficult do you think this math task is for other college students? (circle one)

Extremely Easy	Sort of Easy	Sort of Difficult	Extremely Difficult

3. Please complete this sentence as it relates to you.
Compared to other people who take this task, I think my performance/score on this task:
______ is much worse/lower
______ is somewhat worse/lower
______ is about the same/average
______ is somewhat better/higher
______ is much better/higher

4. Please complete this sentence as it relates to you.
Compared to other people who take this task, I think I finished the task:
______ much slower than others
______ somewhat slower than others
______ in about the same time as others
______ somewhat faster than others
______ much faster than others

Appendix F

Debriefing Form

Thank you for your participation in this study! In order to protect the results of this study, please do not give details about this experiment to other potential participants. ☺

What are your thoughts regarding the math task (i.e. it was too hard, it was too easy, etc.)

____

____

What percentage of the math problems do you think you guessed on (i.e. made little to no attempt to calculate the problem in your head)? ____________ %

<u>Purpose of This Study:</u> This study is looking at the effects of math anxiety and how aware people are of their actual thought processes on people's math performance. Some research suggests that tests such as the SAT and the GRE do not adequately capture some people's true intellectual abilities because thought processes can interfere with a person's ability to score well on a standardized test. This experiment is furthering this line of research.

<u>Gift Card:</u> The top scores will be contacted 2 weeks before the end of the semester (Fall 2008).

Please provide an email address that can be used to contact you if you win a gift card. Only the primary investigator of this experiment, Angela Legg, will contact you and your email address will not be shared. However, if you do not wish to provide an email address then one can be assigned to you for the purposes of this study.

Email address: ____

Do you have any other thoughts about this study that you would like to share?

____

____

____

Thank you for your participation!

Angela M. Legg, M.S.

605 Elvina Court
Dacula, GA 30019

Phone: 404-735-1202
Email: angelalegg@gmail.com

EDUCATION

Ph.D. in Psychology – Social/Health Psychology Emphasis (2009 – Present)
- University of California, Riverside

M.S. in Experimental Psychology (2009)
- Georgia Southern University

B.A. in Psychology (2006)
- Georgia State University

PUBLICATIONS AND MANUSCRIPTS

Legg, A. M. & Wilson, J. H. (in press). Email from professor enhances student perceptions and motivation. *Teaching of Psychology.*

Stoinski, T. S., Perdue, B. M. & Legg, A. M. (in press). Sexual behavior in captive female western lowland gorillas (*Gorilla gorilla gorilla*): Evidence for sexual competition. *American Journal of Primatology.*

Wilson, J. H. & Legg, A. M. (under review). Instructor touch enhanced college students' evaluations.

Legg, A. M. & Locker, L. (under review). Math performance and its relationship to math anxiety and metacognition.

Legg, A. M. & Naufel, K. Z. (in preparation). Relationship-seeking behaviors of HIV positive and non-positive individuals on internet dating service websites.

Legg, A. M. & Wilson, J. H. (in preparation). Comparing ratemyprofessors.com and in-class evaluations.

CONFERENCE TALKS AND POSTER PRESENTATIONS

Legg, A. M. & Locker, L. (April 2009). Metacognition moderates math anxiety and impacts math performance.
- Talk given at the Georgia Psychological Society's Annual Conference, Macon

Legg, A. M. & Wilson, J. H. (February 2009). Ratemyprofessors.com and In-Class Evaluations.
- Poster presented at the Southeastern Teaching of Psychology Conference, Atlanta, GA

POSTERS CONTINUED

Legg, A. M., Scott, L., & Naufel, K. Z. (February 2009). Relationship-seeking behaviors of HIV positive and non-positive individuals on internet dating service websites.

- Poster presented at the Society for Personality and Social Psychology conference, Tampa, FL

Legg, A. M. & Wilson, J. H. (April 2008). Instructor touch: Students' perceptions of immediacy.

- Talk given at the Georgia Psychological Society's Annual Conference, Macon
- Poster presented at Georgia Southern's Graduate Research Symposium, Statesboro, GA

Legg, A. M. & Wilson, J. H. (February 2008). Email enhanced student rapport before the semester began.

- **Winner** of the poster session at the Southeastern Teaching of Psychology Conference, Atlanta, GA
- Talk given at the Phi Kappa Phi Research Symposium, Statesboro, GA (March 2008)

Stoinski, T. S., Legg, A. M., Price, E., & Antworth, B. A. (June 2007). Sexual behavior in western lowland gorillas [Abstract]. *American Journal of Primatology, 69*(Supp. 1), 56.

- Poster presented at the American Primatological Society's Annual Conference, Winston-Salem, NC

Legg, A. M., Mumaw, M. A., King, T. Z., & Morris, R. D. (April 2006). Serial position effects in cerebellar and third ventricle tumor patients.

- Poster presented at the Georgia Psychological Association's Annual Student Poster Session, Atlanta, GA
- Poster presented at the Psychology Undergraduate Research Conference at Georgia State University, Atlanta, GA

RESEARCH AND TEACHING EXPERIENCE

Graduate Assistant (August 2007 – Present) – 20 hours per week

Department of Psychology, Georgia Southern University, Statesboro, GA

- Responsibilities include presenting guest lectures in undergraduate courses, tutoring undergraduates, grading class work and maintaining grade databases, writing and editing manuscripts intended for publication, data analysis, running participants for experiments
- Assisted with the following courses: Psychological Statistics, Advanced Psychological Statistics, Research Methods, Introduction to Psychology, Physiological Psychology

Research Intern (August 2005 – June 2007) – 40 hours per week

Zoo Atlanta Research Department, Atlanta, GA

- Responsibilities included daily collection of behavioral and experimental data, presenting research lectures to zoo guests, assisting in the training of undergraduate interns, preparing and editing research articles for publication, and data entry, summarization, and analysis
- Studies included social learning, memory, group dynamics, and general cognitive and behavioral assessment of gorillas, orangutans, other non-human primates and pandas

Research Assistant (August 2005 – May 2006) – 10-15 hours per week

Clinical Neuropsychology Laboratory, Georgia State University, Atlanta, GA

- Responsibilities included directing and assisting participants during experiments, utilizing ECG, SCR, and EMG technology to collect data, reviewing and summarizing medical records of patients, and creating and maintaining databases in Excel and SPSS
- Research involved a longitudinal investigation of developmental and cognitive outcomes of pediatric brain tumor patients and examination of the psychophysiology of emotional responses during visual and memory tasks.

Research Assistant (October 2005)

Georgia Health Access Research Project, Atlanta, GA

- Responsibilities included data collection, database organization and maintenance

INVITED LECTURES

- Optimizing Your Chances of Getting Into Graduate School – April 18, 2009 – Presented at the Psi Chi Undergraduate Research Conference at Georgia Southern University, Statesboro, GA
- Comparing ratemyprofessors.com and in-class evaluations. – April 14, 2009 – Presented for the Research Colloquium Series at Georgia Southern University, Statesboro, GA
- Navigating Through and Surviving the First Year of Graduate School – April 26, 2008 – Presented at the Psi Chi Undergraduate Research Conference at Georgia Southern University, Statesboro, GA
- Primate Research in a Zoo Setting – April 15, 2007 – Presented to the psychology department at Southern Catholic College, Dawsonville, GA

SOFTWARE KNOWLEDGE AND SKILLS

• SPSS	• Microsoft Word	• The Observer	• E-Prime
• Windows	• Microsoft Excel	• Adobe Photoshop	• Microsoft PowerPoint

- Neurobehavioral Systems Presentation Programming Software – Workshop taken on June 1-14, 2007 at Emory University

GRANTS

- Graduate Student Travel Grant awarded by Georgia Southern University's College of Graduate Studies (February 2009) - $450

SERVICE

• Ad-hoc reviewer for the *North American Journal of Psychology* - 2009

• Judge of poster and oral presentations at the 2009 Psi Chi Undergraduate Research Conference, Georgia Southern University, Statesboro, GA – April 18, 2009

• Reviewer of symposia and posters for the 2009 Society for the Teaching of Psychology Annual Conference – December 2008

• Created a database and organized files for the faculty search committee – Georgia Southern University – 2007

ACCOMPLISHMENTS

Georgelle Thomas Award Scholarship (Spring 2009)

- Awarded to one graduate student who demonstrates a significant contribution to the science of psychology during his or her time at Georgia Southern

Outstanding Poster Award (2008), $100 prize, Southeastern Teaching of Psychology Conference

Faculty Scholar (2005-2006), Georgia State University

- Earned by achieving a semester GPA of 4.0

Computer Club President (2002), Georgia Perimeter College

- Directed weekly meetings, scheduled computer workshops for students, recruited members

PROFESSIONAL AFFILIATIONS AND MEMBERSHIPS

American Psychology Association (2008-Present)
APA Division 2 – Society for the Teaching of Psychology (2007-Present)
Comparative Cognition Society (2008-2009)
Georgia Psychological Society (2008-2010)
Georgia Southern Graduate Student Organization (2007-2009)
Society for Personality and Social Psychology (2008-Present)

GUEST LECTURES FOR UNDERGRADUATE AND GRADUATE COURSES

TOPIC TAUGHT	DATE	COURSE
Correlations, Linear and Multiple Regression	April 22-30, 2009	Advanced Statistics
Introduction to SPSS	March 10, 2009	Research Methods
Independent Samples *t*-tests	February 23, 2009	Advanced Statistics
Math Anxiety and Metacognition	November 19, 2008	Research Seminar (Graduate)
Primate Cognition/Development	October 13, 2008	Research Methods
Becoming Involved in Research	October 1, 2008	Research Seminar (Graduate)
Schedules of Reinforcement	October 1, 2008	Animal Learning
Sampling Distribution of the Mean	September 17, 2008	Advanced Statistics
HIV Research on the Internet	September 10, 2008	Health Psychology
Developmental Theories	July 15, 2008	Introduction to Psychology
T-tests in SPSS	March 25, 2008	Research Methods
Correlations in SPSS	March 18, 2008	Research Methods
False Memories/Eyewitness Testimony	March 5, 2008	Introduction to Psychology
Naturalistic Observation Research	March 4, 2008	Research Design (Graduate)
Introduction to SPSS	March 4, 2008	Research Methods
Memory	March 3, 2008	Introduction to Psychology
Writing the Introduction to a Research Paper	February 5, 2008	Research Methods
Naturalistic Observation Research	February 4, 2008	Research Methods
Naturalistic Observation Research	September 7, 2007	Research Methods
Measures of Central Tendency	September 5, 2007	Psychological Statistics
Samples, Populations, and Variables	August 17, 2007	Psychological Statistics