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# Math anxiety and performance following observational learning and performance pressure

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# MATH ANXIETY AND PERFORMANCE FOLLOWING OBSERVATIONAL LEARNING AND PERFORMANCE PRESSURE

**by**

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We, the undersigned members of the Graduate Faculty of the University of Alabama in Huntsville, certify that we have advised and/or supervised the candidate on the work described in this thesis. We further certify that we have reviewed the thesis manuscript and approve it in partial fulfillment of the requirements for the degree of Master of Arts in Psychology.

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**ABSTRACT**

The School of Graduate Studies
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Title Math Anxiety and Performance Following Observational Learning and Performance Pressure

Past research demonstrated that a variety of factors contribute to the severity of math anxiety and its detriments on math performance. The present study examined the influence of performance pressure, sex, second-hand success or failure of a male or female, and problem difficulty on math anxiety and performance. The design included a 2 (Participant sex: male, female) x 2 (Student actor sex: male, female) x 2 (Video outcome: success, failure) x 2 (Problem difficulty: easy, difficult) x 2 (Pressure: low, high) mixed design. Participants (UAH students, *n* = 232) were recruited from introductory psychology courses and completed the study via Qualtrics. The pressure manipulation was found to be ineffective. Participants' math anxiety and performance were most influenced when watching a male fail at solving problems. These results could be used to mitigate the influence of stereotypes on math anxiety and performance in education.

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## TABLE OF CONTENTS

## LIST OF FIGURES

Figure Page

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| Abbreviation | Definition |
|---|---|
| ANOVA | Analysis of Variance |
| BIS | Behavioral Inhibition System |
| LST | Listening Span Task |
| MAS | Mathematics Anxiety Scale |
| MME | Modular Math Exercise |
| MTMCE | Most troublesome mathematics classroom experience |
| PDS | Personal Data Sheet |
| PTQ | Post-Task Questionnaire |
| SIMA | Single-Item Math Anxiety Scale |
| WM | Working Memory |
| WMC | Working Memory Capacity |
| WME | Worst mathematics experience |

## LIST OF SYMBOLS

| Symbol | Definition |
|---|---|
| $F$ | Analysis of Variance statistic |
| $M$ | Sample mean |
| $N$ | Total sample size |
| $n$ | Sample size |
| $\eta_p^2$ | Partial eta squared |
| $p$ | Significance value |
| $r$ | Correlation coefficient |
| $SD$ | Standard deviation |
| $SE$ | Standard error |
| $X^2$ | Chi-square statistic |

# CHAPTER 1. INTRODUCTION

## 1.1 General Introduction

Math anxiety is a densely studied construct in the field of psychology and has many problematic consequences for people who struggle with it. Ashcraft (2002) defined math anxiety as feelings of fear and apprehension that obstruct one's efficiency at math. Previous research concerning math anxiety has identified a myriad of other variables that reciprocally influence math anxiety, such as one's self-concept and self-efficacy in relation to math (Ahmed, Minnaert, Kuyper, & van der Werf; Galla, & Wood, 2012; Jansen *et al.*, 2013; Krinzinger, Kaufmann, & Willmes, 2009; Yang, Zhao, Zhang, & Pruessner, 2013), observation of significant role models and stereotype threats targeting gender (Beilock, Gunderson, Ramirez, & Levine, 2010; Bekdemir, 2010; Gunderson, Ramirez, Levine, & Beilock, 2012; Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015), WMC (Ashcraft & Krause, 2007; Beilock & DeCaro, 2007; Ramirez, Gunderson, Levine, & Beilock, 2013; Trezise & Reeve, 2014), and evaluative threat (Beilock, 2008; Beilock & DeCaro, 2007; DeCaro, Rotar, Kendra, & Beilock, 2010; Liew, Lench, Kao, Yeh, & Kwok, 2014). In addition, math anxiety has a neurological basis in that more math anxious individuals demonstrate more activity in right amygdala regions as well as other areas of the brain (Maloney & Beilock, 2012; Yang *et al.*, 2013). Further, math anxiety has an environmental basis in that exposure to negative attitudes about math from caregivers and teachers tends to increase children's math anxiety (Lyons & Beilock, 2011), in addition to economic factors placing some students at higher risk of experiencing math anxiety (Radišić, Videnović, & Baucal,2014). Math anxiety has also been found to be stable over time in low pressure conditions, while unstable in high pressure conditions (Trezise & Reeve, 2014). Math anxiety poses a threat to the development of children's math skills, as well as their eventual academic and career choices. Current research regarding math anxiety is focused on parsing the influence of one's self-efficacy and self-concept towards math, stereotype threat, and evaluative threat on problem solving performance.

### 1.2 Math Performance, Self-Concept, and Self-Efficacy

The dynamics between math performance, self-concept, and math anxiety have been studied in young participants. Krinzinger *et al.* (2009) sought to understand if math anxiety predicts future math performance, if math performance predicts future math anxiety, and if these associations are mediated by one's attitude toward math. The literature indicates that math anxiety affects individuals via physiological reactions such as sweating, cognitive effects such as worrisome thoughts, and avoidance behavior surrounding number processing and calculation. The avoidance of math may lead to a cycle of not having enough practice with math performance which may lead to more disappointment and emotional issues (Ashcraft, 2002). Further, Krinzinger and colleagues also addressed the inhibition theory and the processing efficiency theory. The inhibition theory states that cognitive performance decreases when distracting stimuli are present while the processing efficiency theory states that anxiety draws on working memory resources, thus negatively affecting cognitive performance. The literature also suggests that poorer math performance may occur because those with high math anxiety are unable to withdraw attention from their worrisome thoughts, rather than poor math performance being a direct outcome of these thoughts.

Another evidential link in the literature was the connection between math ability and math anxiety in adults. Krinzinger *et al.* (2009) identified that a lack of developmentally-based studies that could illuminate more about this link. Thus, Krinzinger and colleagues tested child participants at four different time periods, once at the end of first grade (T1), again in the middle of second grade (T2), once more at the end of second grade (T3), and finally in the middle of third grade (T4). The participants orally completed calculation tasks that included small and large addition and subtraction problems. Following this, participants completed the Math Anxiety Questionnaire which includes questions concerning their self-efficacy and attitudes towards math generally, written calculations, mental calculations, easy calculations, difficult calculations, math homework, and listening to lectures about math. Krinzinger and colleagues found that math performance and evaluation of math were correlated at T1 and mutually affected each other until T2. After T2, only math performance predicted evaluation of math. No significant correlations were found between math ability and math anxiety, and evaluation of mathematics was not found to be a mediator. Krinzinger *et al.* postulated that this observed phenomenon that is opposite of the established findings in adults could entail methodological issues or because this link might not be prominent until older age. The results indicated that utilizing physiological reactions might be a better fit for children rather than self-report questionnaires as the cognitive aspect of anxiety may be difficult for young children to communicate in a self-report.

The relationship between math self-concept and math anxiety has also been studied extensively. Math self-concept refers to the ideas and beliefs one holds about oneself in regard to math and math ability. Ahmed *et al.* (2012) specifically analyzed whether established math self-concept predicts future math anxiety negatively, as well as the reverse relationship. Prior models have suggested that low self-concept in math results in feelings of incompetence, thereby increasing anxiety surrounding math. Other models indicated that high levels of math anxiety results in a distorted self-image, and that distorted cognition leads to a negative self-concept. More recently, many socio-cognitive models demonstrated a reciprocal relationship between math anxiety and math self-concept. Ahmed and colleagues sought to parse the temporal order of this reciprocal relationship by assessing math self-concept with a 4-item measure adapted from past research. Following this, math anxiety was measured using several items slightly modified from the Academics Emotions Questionnaire – Mathematics, with questions addressing participants' anxiety while in math class, studying or doing math homework, and taking math tests. Additionally, prior cognitive ability with mathematics was assessed based on participants' scores on a national test. Upon utilizing cross-temporal correlations, Ahmed and colleagues found significant relationships between math anxiety and math self-concept. They also analyzed the reciprocal effects of these two constructs by utilizing structural equation modeling. This analysis indicated that a lower math self-concept predicts higher levels of math anxiety, and vice versa. Interestingly, although this effect is reciprocal, Ahmed and colleagues noted that the influence of self-concept on anxiety appears to be stronger than the influence of anxiety on self-concept.

In a similar vein, research has been conducted regarding how emotional self-efficacy, or one's surety in ability to manage negative emotions, can protect against the impairments of math anxiety. Galla and Wood (2012) examined whether emotional self-efficacy moderates the relationship between math anxiety and math performance during a standardized math test. The literature regarding emotional self-efficacy demonstrates that high levels of emotional self-efficacy generally indicate lower levels of anxiety and depression, mediate associations of attentional control as well as emotional and behavioral problems, and influence educational outcomes positively for students with low verbal IQ. Galla and Wood, in trying to expand the literature, had children answer the Multidimensional Anxiety Scale for Children and the emotional self-efficacy subscale of the Self-Efficacy Questionnaire. Upon performing a moderated regression analysis, Galla and Wood identified support for anxiety being negatively correlated with performance on math portions of the SAT-9 in line with previous research, but also that children reporting high levels of anxiety and low levels of emotional self-efficacy demonstrated lower math performance. Conversely, children reporting high anxiety and high emotional self-efficacy did not exhibit the same impairments in their math performance. These results provide support that high emotional self-efficacy can ward against the negative performance impairments that have repeatedly been found in the literature.

Research has been conducted regarding experiencing success in math and the influence this has on math self-efficacy and math anxiety. Jansen *et al.* (2013) hypothesized that the increasing success rate induced by a computer-adaptive program would be associated with a decrease in math anxiety, an increase in math self-efficacy, and an increase in math performance. Jansen and colleagues examined the literature demonstrating the seemingly reciprocal relationship between math performance and math anxiety, perceived competence, and test anxiety, as well as perceived competence and academic performance. The apparent link between these constructs is that actual performance negatively correlates with test anxiety, but positively correlates with perceived competence, and perceived competence negatively correlates with test anxiety. Thus, Jansen and colleagues attempted to disentangle these connections in the domain of math by having children complete pretests and posttests concerning their math self-efficacy, math anxiety, and math performance. In the interim, the children completed practice math problems in a computer program that contained an adaptive algorithm. This algorithm estimated the skill of each individual child and adjusted the problems presented to be more feasible for the child to complete. Success rates were also manipulated in that participants experienced success either 60%, 75%, or 95% of the time. Upon doing well on problems, children would be awarded with virtual flowers for a virtual garden. The results indicated that math anxiety was reduced from the pretest to the posttest for students in all conditions. Additionally, math self-efficacy only improved slightly in comparison to math anxiety, and this was only found in students in the 75% success rate condition. Math performance also improved, but only slightly and most notably in the higher success conditions, mediated by the number of problems the students attempted in the computer program. Logically, this implies that higher success rates increased practice, and increased practice increased math performance.

### 1.3 Gender Socialization and Observation

Stereotypical beliefs and observation of role models of math ability have been found to influence the development of math anxiety. Beilock *et al.* (2010) investigated three research questions surrounding this relationship. First, they suggested that the higher math anxiety that a female teacher had, the lower math performance would be in her students. Second, this relationship would only be present for girls. Lastly, they posited that this relationship could be accounted for by girls who subscribed to the traditional academic stereotype that girls are worse at math than boys. The literature surrounding this topic has indicated that most teachers are women, but also that elementary education majors have the highest levels of math anxiety among college majors. Further, Beilock and colleagues cite many of the previously mentioned tendencies of math anxiety, such as avoidance of math and math courses, worrisome thought compromising reasoning, reduction in self-efficacy, and impairments to math achievement. An additional fact found in the literature for stereotype threat is that children are more likely to copy and internalize behavior and attitudes of same-gender adults. Collectively, these facts suggest that girls are likely more vulnerable to develop math anxiety than boys. To parse these relationships, Beilock and colleagues evaluated students' math achievement in the first and last few months of first- and second-grade students' school year. Similarly, the students' teachers' math anxiety and knowledge were also assessed. For their third hypothesis specifically, they had the children engage in a task at the beginning and end of the school year in which they were read a story about a student who was good at math and a student who was bad at math. After listening to the story, they were asked to draw the students in the story as a way of assessing the students' subscription to stereotypical academic gender roles. The results of this study demonstrated that there were no gender differences present at the beginning of the school year, but at the end of the school year, girls who subscribed to stereotypical gender roles in school (based on their drawings of the students in the math stories) exhibited worse math performance than girls who did not and boys in general. The researchers found that this effect was because of their female teachers' math anxiety.

More research has been conducted in relation to math anxiety and teachers of elementary students. Bekdemir (2010) aimed to answer whether or not worst mathematics experience (WME) and most troublesome mathematics classroom experience (MTMCE) influence math anxiety in pre-service elementary school teachers. Additionally, they sought to understand the precursors of anxiety in relation to subjective, negative experience. Bekdemir noted research concerning specific, highly negative experiences with math has found that some participants with high math anxiety relate their feelings back to a very imprinting experience in which a deep hatred for math was formed, thus leading to lowered confidence in math ability, avoidance of math, and impaired math achievement. Bekdemir also noted several pieces of literature in which these negative experiences may be the major source of mathematics anxiety. To extend upon this area of the literature, Bekdemir distributed self-report surveys to pre-service elementary teachers to gather information regarding math anxiety levels, WMEs, and MTMCEs. The measures used for this were the Mathematics Anxiety Scale (MAS) and the Worst Experience and Most Troublesome Mathematics Classroom Experience Reflection Test, respectively. Following these, the participants also completed interviews in which math anxiety, WME, and MTMCE were further evaluated. These interviews were coded based on negative experiences surrounding teacher instruction, teacher attitude, peer pressure, and school and surrounding context. The results corroborated past research in that 59% of the 167 participants exhibited moderate to severe math anxiety. Further, Bekdemir found that math anxiety levels were notably higher in those who reported WME and MTMCE than those who did not report those types of experiences. This indicates a direct relation between math anxiety and WME and MTMCE.

Further research has also incorporated the role of both parents and teachers in the development of gender-related math views. Gunderson *et al.* (2012) reviewed past research revolving around the impact of adults' gender stereotypes and expectancies on children's math views, the influence of adults' math anxieties and implicit theories of intelligence on children's math views, the developmental perspectives of children's math anxiety, and the mechanisms by which adults' gendered views get passed on to children. Some striking findings regarding adults' attitudes indicated that parents generally believe that their male child has more math ability, and they expect higher math achievement from him than parents of female children. Additionally, parents indicated that they anticipated boys to have more success in math-based careers, that math comes easier to boys than girls, and that math is more important for boys than girls. Parents' beliefs of their child's math ability also more strongly predict the child's self-perception of math than the child's own math accomplishment. Similar results have been found for teachers as well in all these regards. In addition, the attributions adults make for the math success of children vary by gender. For example, mothers are more likely to attribute boys' success in math to inherent skill and girls' success in math to effort. Parents often believe that girls must expend more effort to be successful in math than boys do.

Interestingly, Gunderson *et al.* found results from prior research that teachers with low math self-concepts more often reported that they endorsed stereotypical academic gender roles during interviews. Furthermore, teachers with lower math teaching self-efficacy had a noticeable influence for lower-achieving math students, *i.e.*, students who observed math anxious teachers displayed lower math achievement. Overall, these findings demonstrate the extent to which children's math attitudes are influenced by the attitudes of the significant adults in their lives.

Research has found intergenerational effects of math anxiety that appear to have an environmental basis rather than genetic basis. Maloney *et al.* (2015) analyzed the relationship between parent help with math homework on children's math achievement and anxiety. Adjacent research on this topic indicated parents play an important part in children's early academic development, and that parents of young children believe they play a lesser role in their math achievement than they do in other subjects, such as reading and writing. Additionally, research has found that positive effects of parent assistance are more prevalent for verbal-oriented subject matter than for math-oriented subject matter. Other research has in fact found that parents' assistance on math homework is negatively related to students' math achievement. Maloney and colleagues believed that this noticeable effect could be influenced by how math anxious a parent is. To test this hypothesis, they had a large number of children complete measures of math achievement, reading achievement, and math anxiety within the first and last weeks of the school year. Maloney and colleagues also had the children's parents complete questionnaire packets that included the short Math Anxiety Rating scale as well as an assessment of how they assist their children with homework. The children's teachers were also evaluated based on math anxiety and math knowledge. The results exhibited a negative relationship between parents' math anxiety symptoms and children's math learning over the course of the school year. This dynamic was only present when parents helped their children with their math homework often, but not when parents helped with children's reading assignments. Thus, the results indicated that math anxiety may be the influential factor in the relationship between parents' help and children's math achievement, and that these influences are still present even after controlling for variables surrounding the children's teachers.

### 1.4 Working Memory Capacity and Performance Pressure

Another striking dynamic is the relationship between math performance, WMC, and the ability to perform under pressure. Beilock and DeCaro (2007) analyzed this dynamic extensively. Prior literature on WMC has stated that performance on tasks is severely reliant on maintaining focus on task-relevant information, and this level of attentional control consumes working memory resources. WMC, because it is an individual difference, is high in some people and low in others. Beilock and DeCaro looked to dual-process theory to explain some of the performance differences found in people with high and low WMC. This theory states that, when problem solving, people use associative processing and rule-based processing. Associative processing utilizes resemblance-based associations that are accumulated over time and typically do not consume a large amount of WM resources. Rule-based processing, in contrast, relies on explicit knowledge as a means for navigating processing and consumes a larger amount of WM resources. Further, Beilock and DeCaro noted that research has shown those with low WMC tend to rely on associative processing while those with high WMC tend to rely on rule-based processing when engaging in problem solving.

Additionally, pressure can be defined in this context as a situation that elicits expectation of performance from an individual. Beilock and DeCaro (2007) consulted prior literature in which participants with high and low WMC completed a difficult math task including a low-pressure and high-pressure condition. The researchers for those studies found that those with high WMC outperformed those with low WMC in the low-pressure condition, but in the high-pressure condition the high WMC participants' performance was reduced to the level of the lower WMC participants while the lower WMC participants were unaffected between the two conditions. With all this information in mind, Beilock and DeCaro sought to expand these areas of the literature with an experiment in which participants completed modular arithmetic problems under low-pressure or high-pressure with participants randomly asked to explain their problem-solving strategy after completing problems. Participants also completed measures regarding their state anxiety and perception of personal performance under pressure. The results of the experiment corroborated past research in that those with higher WMC performed better in the low-pressure situation and relied on rule-based processing in this instance. Further, they found high WMC participants performed the same as low WMC participants in the high-pressure condition, but also that they began to utilize more associative processing as well. These results indicate that the WM resources sequestered by worry in the high-pressure situation do not leave enough resources for using more accurate strategies.

Elaborating on previous findings, more research has been conducted concerning the effects of performance pressure on math performance as well as its underpinnings. DeCaro *et al.* (2010) investigated whether a problem's spatial orientation could lead to differential consumption of verbal or visuospatial WM. The literature surrounding WM indicates that pressure recruits WM resources that are required for other executive functioning, such as problem solving and categorization, and that the assumed mechanism behind this is worrisome and distracting thoughts. To provide more explicit evidence for this, DeCaro and colleagues looked to the multicomponent model of WM that separates WM into the central executive that controls the flow of information in WM, the phonological loop and the visual-spatial sketchpad that process auditory and visual-spatial information respectively, and the episodic buffer which binds information in the prior two mechanisms and long-term memory together to create a single representation. Additionally, other research has demonstrated that the orientation of math problems appears to recruit verbal and visual-spatial WM differentially, and that math performance was impaired when a WM incongruent task was completed alongside calculations. An example of this would be completing a visual-spatial horizontal math problem while maintaining a series of nonwords in memory.

The multicomponent model of WM could entail solutions for mitigating math anxiety. DeCaro *et al.* (2010) predicted that verbal WM is recruited by anxiety's distracting thoughts, and that by focusing verbal WM on the task at hand, performance impairments could be alleviated. DeCaro and colleagues had participants complete a modular arithmetic task that consisted of low- and high-demand problems, half of which were oriented horizontally while the other half were oriented vertically. Further, participants were separated into talk and no-talk groups with the instructions to either talk through their problem solving or to remain silent for the task. Participants were also placed into low- and high-pressure conditions in which low-pressure participants were told to work through problems accurately and quickly while high-pressure participants were told they and a partner had to improve by a required amount from the practice block to receive a monetary reward and that their partner had already done so. The results indicated that verbal WM resources are drained in important examination scenarios because of worrisome thoughts caused by performance pressure and its associated anxiety. These factors impeded accuracy on problems that were horizontal (intensive on verbal WM) rather than those that were vertical (intensive on spatial WM).

The relationship between math anxiety and math performance has been established across adults but has also recently been observed in children. The literature regarding math anxiety and math performance favors young adults, thus Ramirez *et al.* (2013) sought to find more evidence for the emergence of this dynamic in young children. They investigated the literature concerning middle school and high school students and found that math anxiety is negatively associated with math scores on the SAT. Ramirez and colleagues also looked to the literature concerning WM and math anxiety and noted that WM needed for problem solving is compromised by the distracting and ruminative thoughts caused by math anxiety. Those with a higher WMC are more vulnerable to poor performance from math anxiety because they have developed problem solving strategies that incorporate their larger reservoir of resources, and when math anxiety depletes those resources, they suffer a more severe reduction in performance than those with low WMC. In their current study, Ramirez and colleagues hypothesized that first- and second-grade children with a high WMC may be more prone to performing poorly in math, with self-reported math anxiety as the mechanism for this. The researchers measured children's WMC, math performance, and reading performance as a control comparison, as well as their math anxiety. Ramirez and colleagues found results that corroborated past research. The children who were higher in WMC suffered impairments to math performance as a function of their math anxiety. Reading performance was unaffected; thus, math anxiety can be deduced as the problem rather than general academic anxiety.

The avoidance temperament discussed in past research has been assessed in its relation to math performance and math anxiety. Liew *et al.* (2014) examined the influence of avoidance temperament and evaluative threat on college students' standardized math test scores and math course grades. Temperament has been described as a subdivision of personality in which emotional, attentional, and behavioral tendencies toward acting and reacting are specified. Liew and colleagues noted the temperament dimension of fearfulness in that it has displayed impeding effects on test performance in past research. This fearfulness is related to self-focus of attention and personal distress, and the behavioral inhibition system (BIS) is a facet of Gray's temperament model that anticipates distress when presented with threat or imminent punishment (Heponiemi, Keltikangas-Jarvinen, Puttonen, & Ravaja, 2003). Further, these adult temperaments align well with the Big Five model of personality in which fearfulness maps very strongly to the neuroticism facet. Research has also indicated that the BIS is highly related to neuroticism, and that those with high neuroticism generally perform worse on yearly examinations.

The temperamental aspects of personality can influence math performance. Liew *et al.* (2014) hypothesized that temperamental fear and behavioral inhibition would be positively correlated, and both traits would have a negative relation with standardized math scores and math course grades. The researchers measured participants' temperamental fear with the Adult Temperament Questionnaire and participants' evaluative threat by asking them how threatened by the upcoming test they were and how much they felt like they would fail. The indices of math were 7 items taken from the SAT Reasoning Test and self-reported average grade that participants received in their college math courses. Liew and colleagues found that the trait anxiety of avoidance temperament and the state anxiety of evaluative threat are positively related to each other. Gender differences were also found in that women exhibited higher avoidance temperament than men, but there were no gender differences in math performance. Further, avoidance temperament and evaluative threat were related to low standardized math scores, while only low math course grades were related to evaluative threat but not avoidance temperament. Liew *et al.* proposed that a mediational model may be at work here in which high temperamental fear and BIS sensitivity may prime individuals to have poor coping skills or avoidance of coping altogether. Individuals high on these two traits may also have attention and information processing impediments. Thus, avoidance temperament may influence people to experience evaluative threat through emotional, cognitive, or attentional mechanisms. In this experience, hypervigilance expends attentional resources to threat related stimuli rather than problem solving. This reflects many of the models of math anxiety consuming WM resources.

### 1.5 Hypotheses

Prior research detailed some of the variables that can influence math anxiety and math performance. Research has demonstrated that math anxiety and math performance of students can be severely impacted by interacting with math anxious parents (Beilock *et al.*, 2010; Gunderson *et al.*, 2012) or math anxious teachers (Maloney *et al.*, 2015) whereas experiencing success with math can reduce anxiety and improve performance (Jansen *et al.*, 2013); however, it is currently unknown how watching others succeed or fail at math problems affects one's own math performance and math anxiety. Thus, for the present study, we asked participants to view videos of male or female students who successfully or unsuccessfully solve math problems. Following this, we adapted the modular math problems and pressure conditions utilized by Beilock and DeCaro (2008) and DeCaro *et al.* (2010) to identify if these additional manipulations exacerbate or change math anxiety after watching others succeed or fail at math. Further, the observational effects of gender socialization and evaluative threat discussed by Beilock *et al.* (2010), Gunderson *et al.* (2012), and Liew *et al.* (2014) were explored in consequence to math performance and math anxiety.

**H1:** I expected an interaction between participant sex, student actor sex, and video outcome such that male participants viewing a male student actor would be uninfluenced in terms of math performance by the male student actor succeeding or failing. I expected female participants viewing the female student actor successfully completing math would experience an increase in math performance, relative to females watching a female student actor fail (Beilock *et al.*, 2010; Gunderson *et al.*, 2012; Jansen *et al.*, 2013).

**H2**: I predicted an interaction between pressure condition and problem difficulty such that the high-pressure manipulation would yield similar performance to the low-pressure condition for easy problems but would yield worse performance for the difficult problems (Beilock & DeCaro, 2007; DeCaro *et al.*, 2010).

**H3**: I anticipated an interaction between participants' WMC and pressure condition in which individuals with high WMC would demonstrate higher math performance than those with low WMC in the low-pressure condition, but high WMC individuals' math performance would level to the math performance of individuals with low WMC (Beilock & DeCaro, 2007; DeCaro *et al.*, 2010).

**H4**: I predicted that participants would have higher math performance on easy problems than on difficult problems (Ashcraft & Krause, 2007; Beilock & DeCaro, 2007; DeCaro *et al.*, 2010).

**H5:** Based on previous research (Beilock & DeCaro, 2007; DeCaro *et al.*, 2010), I anticipated participants would have higher math performance in the low-pressure condition than in the high-pressure condition.

**H6**: I expected an interaction in which male participants would demonstrate lower math anxiety while watching a male actor succeed in solving math problems than when watching him fail. Similarly, I anticipated female participants would demonstrate lower math anxiety watching a female actor succeed in solving math problems than when watching her fail (Beilock *et al.*, 2010; Gunderson *et al.*, 2012; Jansen *et al.*, 2013).

**H7**: Overall, I anticipated that male participants would demonstrate lower math anxiety than female participants (Beilock *et al.*, 2010).

**H8**: Overall, I predicted that math anxiety would be lower in the low-pressure condition than in the high-pressure condition (Beilock & DeCaro, 2007; DeCaro *et al.*, 2010).

# CHAPTER 2. METHOD

## 2.1 Participants

Participants were undergraduate students from UAH ($N$ = 232) in introductory psychology courses who were at least 18 years of age. The mean age of students was 20.21 with a standard deviation of 3.79. Of this sample, 126 (54%) were female and 106 were male. Furthermore, 163 participants (70%) were White, 27 participants (12%) were Black or African American, 20 participants (9%) were Asian, 12 participants (5%) were Hispanic or Latino, 8 participants (3%) were American Indian or Alaskan Native, and 2 participants (1%) were Native Hawaiian or other Pacific Islander. Participants were randomly assigned to one of four conditions based on the sex of the student actor in the video they were to watch and the outcome of the video. Female Actor—Succeeds entailed the female student actor succeeding, Female Actor—Fails involved the female student actor failing, Male Actor—Succeeds depicted the male student actor succeeding, and Male Actor—Fails showed the male student actor failing to solve the math problems. Table 2.1 describes how participants were spread throughout the conditions by the end of the experiment.

**Table 2.1**

*Number of Male and Female Participants in Each Video Condition*

| Video Condition | Males | Females | Total |
|---|---|---|---|
| Female Actor—Succeeds | 22 | 45 | 67 |
| Female Actor—Fails | 24 | 31 | 55 |
| Male Actor—Succeeds | 26 | 31 | 57 |
| Male Actor—Fails | 34 | 19 | 53 |
| Total | 106 | 126 | 232 |

Additionally, the participants demonstrated a mean score of 55.36 with a standard deviation of 11.27 for their WMC. Participants with math solving disabilities, such as dyscalculia, were advised to seek another study as this one includes solving several math problems in succession. The study was approved by the IRB (See Appendix A for approval letter and Appendix B for the approved consent form) and all APA ethical guidelines were followed.

## 2.2 Design

The present experiment consisted of a 2 (Participant sex: male, female) x 2 (Student actor sex: male, female) x 2 (Video outcome: success, failure) x 2 (Problem difficulty: easy, difficult) x 2 (Pressure: low, high) mixed design. Student actor sex, Participant sex, and Video outcome were manipulated between participants; Pressure and

Problem difficulty were manipulated within participants. Student actor sex was determined by whether the actor in the math problem solving videos presents as traditionally masculine or feminine. Participant sex was acquired from the personal data sheet (PDS) and was controlled for with separate sign-up boards for males and females on SONA Systems. In the student success condition, the student in the video correctly and confidently completed the math problems they were presented in front of a class. In the student failure condition, the student actor incorrectly and timidly completed the math problems in front of the class. Problem difficulty was based on whether problems consisted of single digit numbers without requiring a borrowing operation during subtraction (low difficulty; low WM load) or double-digit numbers with a borrow operation during subtraction (high difficulty; high WM load). For example, $(9 \equiv 6) \bmod 3$ would be a low difficulty problem while $(67 \equiv 48) \bmod 4$ would be a high difficulty problem. Lastly, in the high-pressure condition participants experienced performance pressure by being told they were being recorded on a webcam attached to their computer, and that their performance on the math problem solving task would be evaluated by researchers studying math problem solving. When participants experienced the low-pressure condition, they solved the problems without this preface.

The dependent variables consisted of math anxiety and math performance. Math anxiety was measured according to participants' responses to the Single Item Math Anxiety (SIMA) scale (Núñez-Peña, Guilera, & Suárez-Pellicioni, 2014) collected at the beginning of the experiment, after watching the math video, after the instructions for the Modular Math Task were read, after completing the first set of 20 modular math problems (under low pressure conditions), and again after completing the second set of modular math problems (under high pressure conditions). Math performance was measured in terms of the number of problems participants got correct on a series of modular math problems.

## 2.3 Materials and Procedure

The study occurred in the Lifelong Learning Lab located on the UAH campus. Participants were seated at one of 6 computer stations, and upon checking identifications and obtaining informed consent, the experiment began. External measures consisted of the PDS and the Listening Span Task (LST; Salthouse & Babcock, 1991). Participants first answered questions regarding their demographic information with the PDS. Next, participants completed the LST over a period of approximately 25 min to evaluate their working memory capacity. The LST consists of 7 sections of increasing difficulty with three trials per section. The first trial includes listening to a sentence, answering a question about the sentence, and waiting a moment before trying to recall the last word of the sentence. With each section, an additional sentence, question, and required word to recall are added to a maximum of seven of each in the final section. Participants' WMC score were based on how many final words of the sentences they could correctly recall, with a maximum possible of 81.

After completing the external measures, participants completed the SIMA scale (Núñez-Peña *et al.*, 2014), an abbreviated version of the Math Anxiety Rating Scale, to assess their self-reported math anxiety. The SIMA and the lengthier Shortened Math Anxiety Rating Scale have been found to have correlation of $r = .77$ and a Cronbach's alpha of .94, thus the SIMA can be used as a fast and valid method of obtaining participants' math anxiety scores.  Following this, participants watched an approximately 3 min prerecorded video in which they observed a male or female student solve math problems in front of a class.  The student actor either succeeded or failed to solve the problems presented to them.  Upon finishing the video, participants completed the SIMA scale once more, thus providing an indicator of the video's impact on math anxiety.

Participants then were asked to mentally complete 20 modular arithmetic problems in the low-pressure condition (Beilock, 2008; DeCaro *et al.*, 2010).  In this task, participants were presented with math problems on the screen and asked if they were true or false.  To determine if a problem is true or false, they subtract the first number by the second number and then divide that resulting number by the "mod" number outside of the parentheses.  If the number resulting from this division is a whole number, the statement is true.  If it is not, then it is false.  The participants were presented with these math problems horizontally in order to control for the verbal and visuo-spatial effects on math performance and math anxiety found in DeCaro *et al.* (2010).  An example of these problems can be observed in Table 2.2.

**Table 2.*2***

*Examples of Modular Math Problems*

| Difficulty | Problem | Answer |
|---|---|---|
| Easy | $(8 \equiv 4) \bmod 2$ | True |
| Easy | $(8 \equiv 3) \bmod 2$ | False |
| Difficult | $(62 \equiv 14) \bmod 6$ | True |
| Difficult | $(57 \equiv 34)$ Mod 7 | False |

Participants were given 7 min and 30 s to complete these problems. Following, participants completed the SIMA a fourth time. Upon beginning the high-pressure condition, participants were primed with a preface stating that their performance on the math problems would be recorded and observed by researchers studying math problem solving. They were also given 7 min and 30 s to complete the problems in the high-pressure condition. Following this, participants completed the SIMA scale a final time to assess the impact of solving math problems on math anxiety. After completing the final SIMA, participants completed the post-task questionnaire, read the debriefing form, and were released. The post-task questionnaire included questions such how participants interpreted the pressure manipulation, how anxious they felt, and how they approached solving the math problem (See Appendix C for full list of questions).

# CHAPTER 3. STATISTICAL ANALYSES AND RESULTS

## 3.1 Statistics

Participant sex was coded as man (1) or woman (2). Student actor sex and video outcome were combined as four separate conditions and were coded as Female—Succeeds (1), Female—Fails (2), Male—Succeeds (3), and Male—Fails (4). Math performance was calculated as the number of problems participants answered correctly in the modular math task. I calculated how many easy and difficult problems participants correctly answered of 20 possible in the low-pressure and high-pressure blocks respectively. The scores of the LST demonstrated a bimodal distribution. Furthermore, a median split was performed on participants' LST scores to indicate that participants who scored 56 or less were regarded as low WMC (0) and those who scored 57 or more were regarded as high WMC (1). Data were analyzed using two repeated measures ANOVAs utilizing participants' raw scores on the LST to use WMC as a covariate to determine which of these factors influenced math performance and math anxiety, with significance set as $p < .05$.

## 3.2 Results for Math Performance

The results of the ANOVA demonstrated that pressure was an ineffective manipulation, thus results for hypotheses regarding pressure were not reported, $p > .05$. A main effect was found for participant sex on math performance, $F(1, 223) = 17.682$, $p < .0001$, $\eta_p^2 = .073$. Female participants demonstrated lower math performance

($M$ = 8.978, $SE$ = 0.058) than did male participants ($M$ = 9.334, $SE$ = 0.062). The analyses also illuminated a main effect for difficulty on math performance, $F(1, 223) = 28.927$, $p < .0001$, $\eta_p^2 = .115$. Math performance was overall higher for easier math problems ($M$ = 9.756, $SE$ = 0.030) than for difficult math problems ($M$ = 8.555, $SE$ = 0.074). An additional finding was that WMC had a main effect on math performance, $F(1, 223) = 20.377$, $p < .0001$, $\eta_p^2 = .084$. Math performance overall was higher for high WMC individuals ($M$ = 9.363, $SE$ = 0.066) than for low WMC individuals ($M$ = 9.002, $SE$ = 0.058).

The ANOVA revealed a main effect for video condition on math performance as well, $F(3, 223) = 4.646$, $p = .004$, $\eta_p^2 = .059$. Pairwise comparisons revealed that math performance was significantly lower after watching the Male—Fails video than the Male—succeeds video, $p = .001$. The Male—Fails video condition also yielded lower performance than the Female—Succeeds video condition, $p = .002$. The remaining comparisons of the video conditions were not significant, $p > .05$. Figure 3.1 shows that math performance was highest when participants watched a female actor succeed and lowest when a male actor failed.

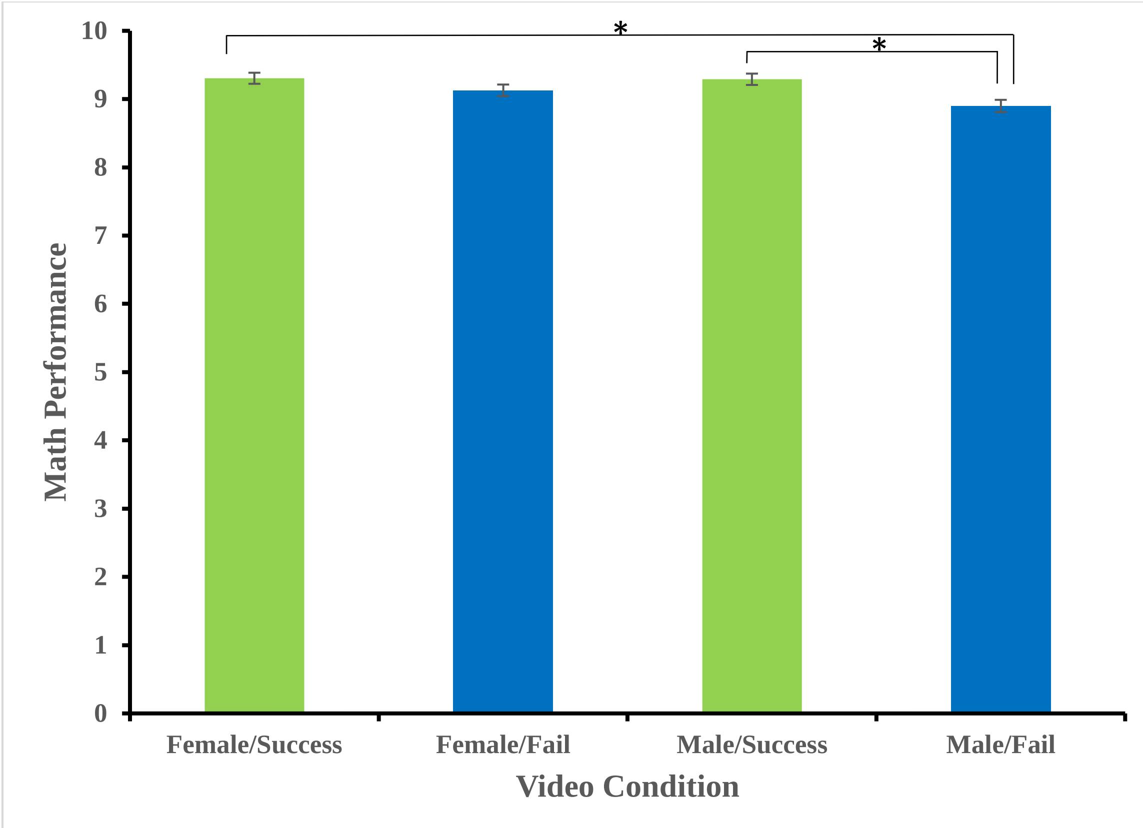


**Figure 3.1**

*Math Performance for each Video Condition*

### 3.3 Exploratory Analyses for Math Performance

Although not hypothesized, analyses revealed an interaction between problem difficulty and WMC, $F(1, 223) = 5.021$, $p < .0001$, $\eta_p^2 = .022$. A series of univariate ANOVAs were used to understand the relationships among problem difficulty and WMC. It was found that low WMC individuals performed better on easy than difficult problems, $F(1, 122) = 165.401$, $p < .0001$. High WMC individuals performed better on easy than on difficult problems, $F(1, 108) = 83.875$, $p < .0001$. High WMC individuals outperformed low WMC individuals on easy problems, $F(1, 230) = 7.343$, $p = .007$. Lastly, high WMC individuals outperformed low WMC individuals on difficult problems, $F(1, 230) = 16.415$, $p < .0001$. Figure 3.2 depicts that high WMC individuals outperformed low WMC individuals on difficult problems, but high WMC and low WMC individuals performed more similarly on easy problems.

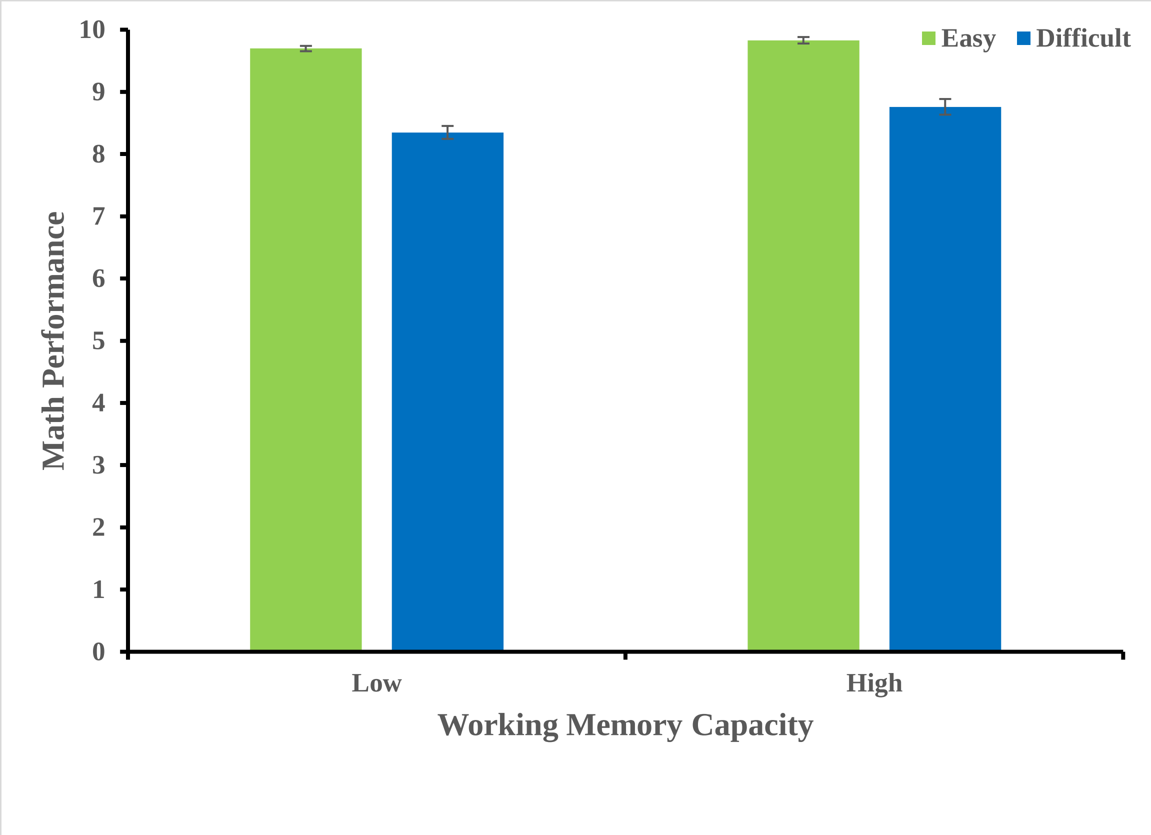


**Figure 3.2**

*Math Performance for Problem Difficulty by WMC*

Further, an interaction was found between difficulty and participant sex in relation to math performance, $F(1, 223) = 17.794$, $p < .0001$, $\eta_p^2 = .74$. The interaction between problem difficulty and sex was further examined using a series of univariate ANOVA. These unveiled that male participants performed better on easy problems than on difficult problems, $F(1, 102) = 67.208$, $p < .0001$. Female participants performed better on easy than difficult problems, $F(1, 122) = 196.520$, $p < .0001$. Male and female participants performed similarly on easy problems, $F(1, 230) = .208$, $p = .649$. Male participants performed better on difficult problems than female participants, $F(1, 230) = 16.668$, $p < .0001$. Figure 3.3 demonstrates that female and male participants performed about the same on easy problems, but female participants did notably worse on difficult problems.

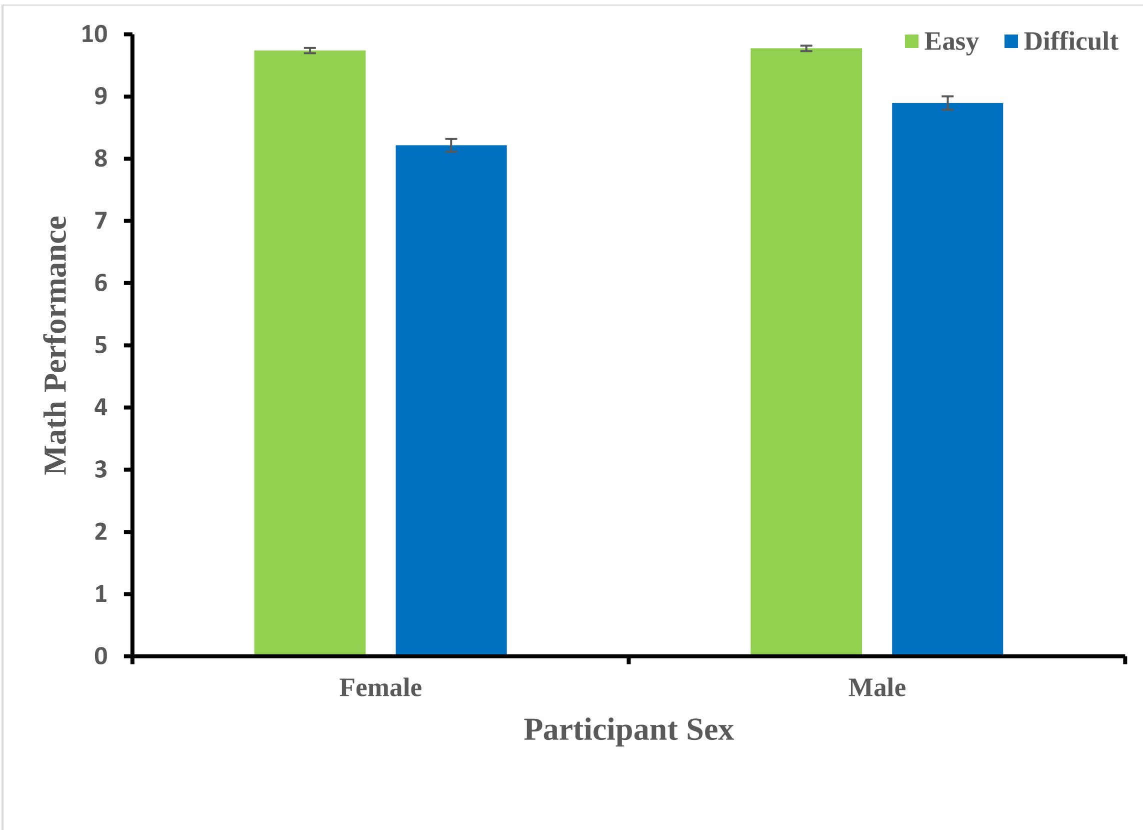


**Figure 3.3**

*Math Performance for Participant Sex by Problem Difficulty*

### 3.4 Results for Math Anxiety

In a similar vein to the analysis conducted for math performance, pressure was an ineffective manipulation and further results regarding it will not be reported, $p > .05$. There was however a main effect for participant sex on math anxiety, $F(1, 223) = 47.668$, $p < .0001$, $\eta_p^2 = .176$. Math anxiety was higher for female participants ($M = 5.472$, $SE = 0.184$) than it was for male participants ($M = 3.622$, $SE = 0.194$).

Additionally, there was a main effect for the video condition on math anxiety, $F(3, 223) = 4.468$, $p = .005$, $\eta_p^2 = .057$. Pairwise comparisons were conducted on video condition in respect with math anxiety, $F(3, 223) = 4.468$, $p = .005$. It was found that the Male—Fails condition yielded more math anxiety than the Female—Fail condition, $p = .004$. Additionally, the Male—Fails condition yielded more math anxiety than the Male—Succeeds condition, $p = .001$. The remaining comparisons did not manifest as significantly different, $p > .05$. Figure 3.4 indicates that math anxiety was highest when participants watched a male actor fail to solve math problems and lowest when a male actor succeeded in solving math problems.

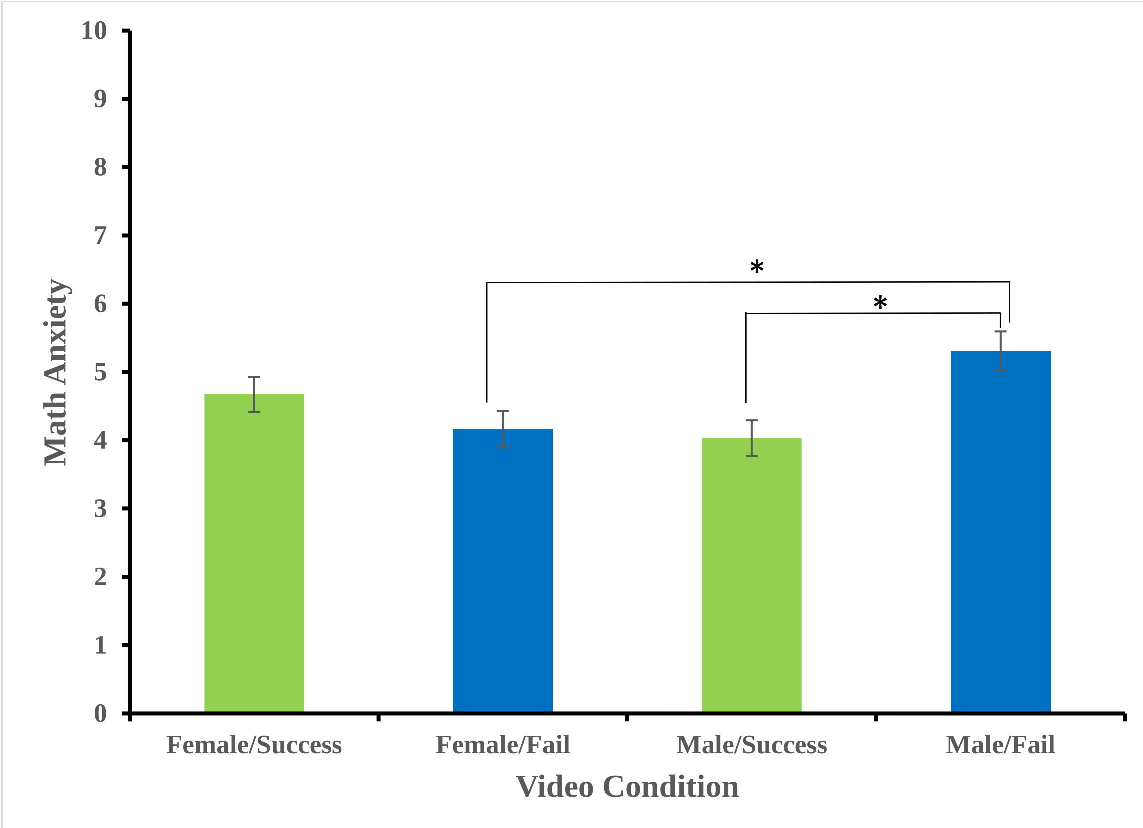


**Figure 3.4**

*Math Anxiety for each Video Condition*

### 3.5 Exploratory Analyses for Math Anxiety

A main effect was also found WMC on math anxiety, $F(1, 223) = 8.586$, $p = .004$, $\eta_p^2 = .037$. Math anxiety was higher overall for low WMC individuals ($M$ = 4.851, $SE$ = 0.184) than it was for high WMC individuals ($M$ = 4.081, $SE$ = 0.222). There was also a significant difference between math anxiety ratings at different points within the experiment, $F(4, 220) = 3.504$, $p = .009$, $\eta_p^2 = .060$. A pairwise comparison identified there were significant differences in anxiety reports on the SIMA throughout the course of the experiment. All SIMA ratings were significantly different from each other, $p < .0001$, with the exception of the baseline and right after being explained the instructions of the MME, $p = .080$. Figure 3.5 exhibits that math anxiety was the highest immediately following the video and lowest immediately after finishing the high-pressure condition of solving math problems.

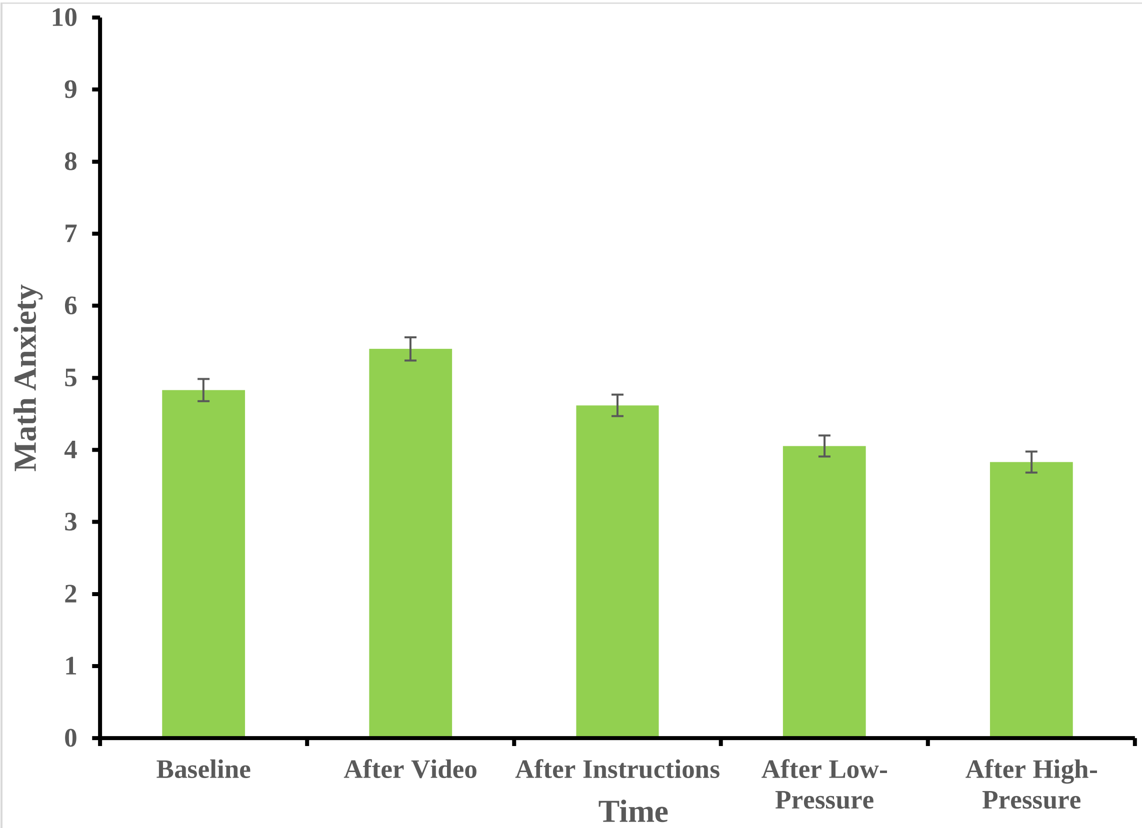


**Figure 3.5**

*Math Anxiety Across Experiment*

WMC was also found to be a significant covariate for math anxiety across the different periods of the experiment, $F(4, 223) = 4.394$, $p = .008$, $\eta_p^2 = .031$. A series of univariate ANOVA were used to assess the relationships between all five SIMA ratings and WMC. At baseline, high WMC individuals had lower math anxiety than low WMC individuals, $F(1,230) = 6.318$, $p = .013$. This pattern was found again after the video had been watched, $F(1, 230) = 10.806$, $p = .001$. It was found after participants had been explained how to complete the MME, $F(1, 230) = 8.929$, $p = .003$. It also held after participants had completed solving problems in the low-pressure condition, $F(1, 230) = 19.792$, $p < .0001$, and after they completed solving problems in the high-pressure condition, $F(1, 230) = 16.654$, $p < .0001$. Figure 3.6 illustrates that low WMC individuals had consistently higher math anxiety during all 5 instances the SIMA was delivered during the experiment.

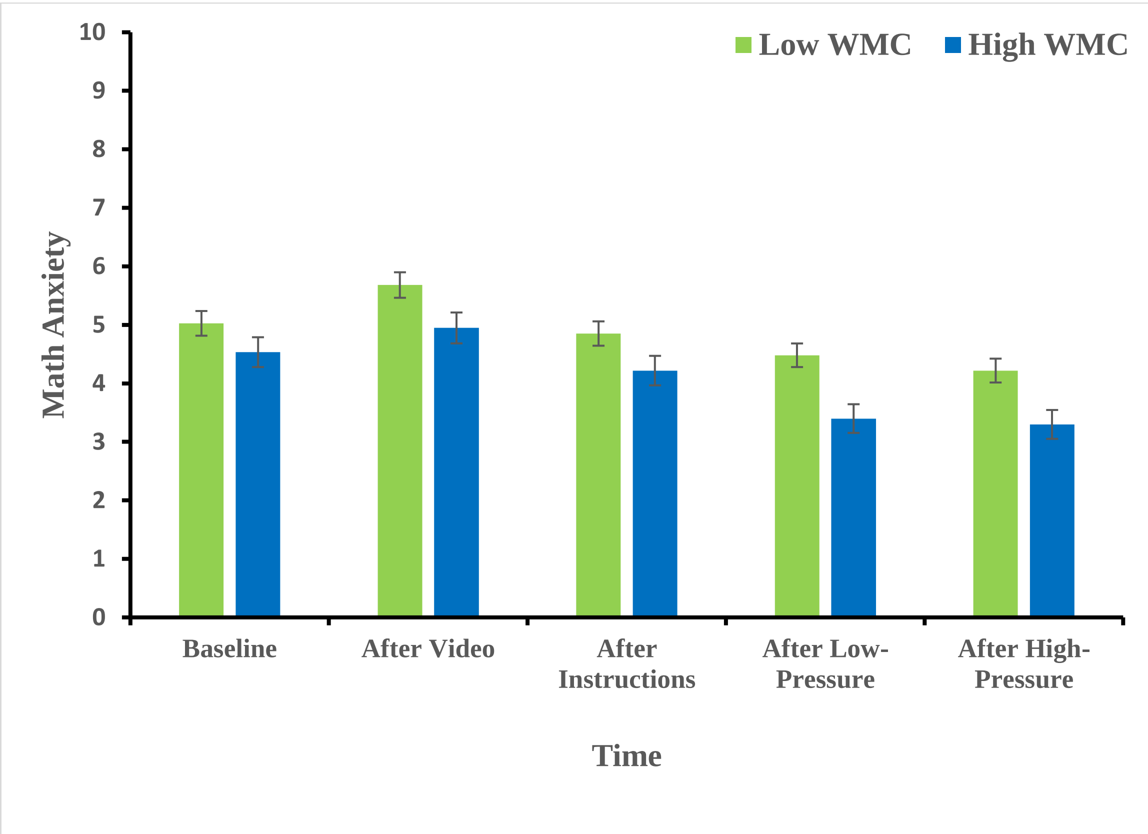


**Figure 3.6**

*Math Anxiety Across Experiment for Low and High WMC*

### 3.6 Post-task Questionnaire Responses

The responses received from the PTQ can assist in identifying how participants interpreted the experiment and potentially help to fix problems for future research. When asked if their confidence was affected following the video, the majority of participants across all four conditions answered either that it did not affect their confidence (40%) or that it made them feel less confident (40%) while the minority answered that it made them feel more confident (20%), $X^2(6, N = 232) = 15.286, p = .018$. Interestingly, in both conditions in which the student actor failed, most of the participants who thought the video affected their confidence answered that it lowered their confidence rather than increased it. When asked whether or not the sex of the student actor influenced expectations of their own math performance, the vast majority across all four conditions answered that it did not (88%), $X^2(3, N = 232) = 4.673, p = .197$. When participants were asked if the video caused any anxiety about completing the MME, a weak majority answered that it made them more anxious (55%), $X^2(6, N = 232) = 8.185, p = .225$. This trend was present for all four video conditions. For those who answered that the video made them more anxious, they were prompted with a follow-up question asking how anxious it made them on a *7*-pt Likert scale (1 – no anxiety, 7 = extreme anxiety). There were no significant differences of general anxiety between conditions for participants who answered that they felt more anxiety, $F(3, 125) =1.725, p = .165$. However, the average anxiety across all conditions was 4.243 ($SD = 1.542$). This indicates that the videos only made participants who answered that it made them more anxious experience moderate anxiety about the upcoming MME. This subsection of participants was also asked what about the video made them more anxious. One participant's response was removed as it was redundant with the previously asked question regarding the sex of the student actor. The remaining respondents cited anxiety being evoked from the speed in which the student actor solved the problems or the fact that they were timed (36%), a lack of confidence in their own math abilities or a lack of familiarity with the math being performed by the student actor (28%), or reasons with no common themes (36%), $X^2(6, N = 125) = 34.747, p < .0001$.

Understanding how participants viewed the pressure conditions was another important piece of insight that we had hoped to glean. When asked if being taped made them feel anxious on a *7*-pt Likert scale (1 – no anxiety, 7 = extreme anxiety), most of the participants across all four conditions reported no to moderate anxiety ($M = 2.906$, $SD = 1.975$), $X^2(18, N = 213) = 17.922, p = .461$. It was also important to understand how participants viewed the math problems themselves. They were given the options of viewing them as either a challenge, a threat, or neither. The majority (67%) reported that they viewed them as a challenge while (26%) viewed them as neither, and (7%) viewed them as a threat, $X^2(6, N = 232) = 5.369, p = .497$. Lastly, participants were asked if their performance on the MME was reflective of their own math ability. The participants' responses as a whole did mark a notable trend with 129 answering yes (56%) and 103 answering no (44%), $X^2(3, N = 232) = 3.768, p = .288$. Approximately half of the participants across all conditions answered that it was reflective of their math ability while the other half answered that it was not.

# CHAPTER 4. DISCUSSION

## 4.1 Secondhand Math Experiences on Math Performance

The influence of sex, performance pressure, and problem difficulty on math performance and math anxiety have been widely studied in the field of psychology. The present study sought to address a gap in the literature concerning how these constructs are affected by viewing another person completing math problems successfully or unsuccessfully. The pressure manipulation was overall ineffective, and this had an impact on several of my hypotheses. For my first hypothesis, I anticipated that an interaction would occur in which male participants viewing a male actor solving math problems would not have their math performance influenced regardless of if he succeeded or failed. In contrast, I anticipated that a female participant viewing a female actor succeed in completing math problems would experience an increase in math performance relative to viewing a female actor fail to complete math problems. This hypothesis was not supported. Interestingly, however, there was an overall influence of video condition on math performance. Participants demonstrated the highest math performance after watching a female actor succeed at solving problems and the lowest when watching a male actor fail at solving math problems. Further, participants exhibited higher math performance in the Male—Succeeds condition than in the Male—Fails condition. A possibility is that participants were making implicit judgements of the student actor based on the student actor's sex and ability to perform in relation to stereotypical beliefs without taking their own sex deeply into account. Beilock *et al.*

(2010) covered these stereotypical beliefs and how they develop and internalize from an early age. In this stereotypical belief system, women are viewed as being poor at math while men are viewed as being good at math. With that in mind, it makes sense why overall math performance would be highest when a female actor succeeds and lowest when a male actor fails. If someone who is viewed as bad at math does well, then that entails the math must be easy. In contrast, if someone who is considered good at math fails, then that would lead one to belief the math at hand is very hard.

### 4.2 Pressure, WMC, & Problem Difficulty on Math Performance

Performance pressure, WMC, and problem difficulty and their influence on math performance were additionally important. For my second hypothesis, I anticipated that there would be an interaction between pressure and problem difficulty in that math performance would be similar in the high- and low-pressure conditions for easy problems, but math performance would drop for difficult problems in the high-pressure condition. This trend commonly observed in the literature (Beilock & DeCaro, 2007; DeCaro *et al.*, 2010); however, this exact interaction was not present in this study. Similarly, my third hypothesis regarding an interaction between performance pressure and WMC was not confirmed. The most likely explanation for this was the lack of effectiveness of the pressure manipulation, as there was an observed difference overall in that math performance was stronger on easy problems than on difficult problems. Although the interaction between pressure and problem difficulty was not present, there was an interaction between problem difficulty and WMC. It was found that high WMC individuals performed better overall on the modular math problems than low WMC individuals. This aligns with patterns observed by Beilock and DeCaro as the modular problems are designed to require more WM resources, especially the difficult problems. Disappointingly yet logically, my fifth hypothesis stating that the pressure conditions would have varying math performance was also unconfirmed. In contrast, my fourth hypothesis stating that easy problems would yield higher math performance than difficult problems was supported. Higher performance on the easier versions of modular math problems corroborates with Beilock and DeCaro (2007) as well as DeCaro *et al.* (2010). Essentially, the easier modular math problems require less WM resources and general effort to complete than the difficult problems as they use smaller numbers with less carrying operations. Because of those inherent qualities of the easy problems, they generally yield higher math performance.

### 4.3 Secondhand Math Experiences on Math Anxiety

Math anxiety was an additional construct being examined in this study. My sixth hypothesis stated that an interaction would occur in which male participants would be less math anxious when watching the male actor succeed than when watching him fail. Additionally, I anticipated a similar interaction for female participants such that they would experience lower math anxiety when watching a female actor succeed in completing math problems than when watching her fail. This exact dynamic did not occur; however, an interaction did occur with actor sex and video outcome. Participants had the highest anxiety when the male actor failed to solve problems, the second highest anxiety when the female actor failed, the second lowest anxiety when the female actor succeeded, and the least anxiety when the male actor succeeded. It appears that watching a male fail to solve math problems elicits anxiety such that it establishes a context in which math problems are perceived to be incredibly difficult. If a male, who stereotypically is assumed to be good at math by default, cannot solve math problems properly, then his math ability is not in question, rather the difficulty of the problems is (Beilock *et al.*, 2010; Gunderson *et al.*, 2012). This is troublesome when considering that the second highest anxiety was when the female actor failed. The missing link here is likely regarding one's self-efficacy in relation to math. Ahmed *et al.* (2012) established that self-efficacy is important in relation to math anxiety in that low self-efficacy regarding math can lead to high math anxiety. If a male, who is stereotypically thought to be good at math, happens to timidly fail in completing math problems, it might evoke worry and insecurity from the viewer if they did not completely understand the problems when first observing in the video. Harking back to the responses of the PTQ, those who felt anxiety often reported that they felt intimidated with how effortlessly the actor completed the task. With that logic in mind, it would make sense for a timid man completing unfamiliar math problems to elicit some insecurity about one's self-efficacy, thus increasing anxiety.

### 4.4 Pressure and Participant Sex on Math Anxiety

Math anxiety overall in regard to participant sex and performance pressure was also examined. The seventh hypothesis suggested that male participants would have lower math anxiety than female participants; the data confirmed this. The trends in the literature suggest that math anxiety is formed at an early age and can be influenced by role-models in a child's life, particularly those role models who are of the same sex as the child (Beilock *et al.*, 2010; Bekdemir, 2010; Gunderson *et al.*, 2012; Maloney *et al.*, 2015). The outdated idea that women are inherently bad at math and men are inherently good at it is perpetuated in a cycle from adults to children via formation of self-concept and self-efficacy surrounding math. The children observe how math anxious an adult is and internalize that anxiety. The data of the present study suggest that this trend of women being more math anxious persists into adulthood. Consistently in the literature it is found that math anxiety and math performance have an inverted, reciprocal relationship. With this in mind, it makes sense that overall males outperformed females while also exhibiting less anxiety than females. Furthermore, an interaction occurred in which difficulty and participant sex influenced math performance, providing additional proof of the link between gendered stereotypes, math anxiety, and math performance. Although not something I predicted as a hypothesis, an interesting and logical finding did occur between participant sex and math problem difficulty in which male and female participants performed similarly on easy problems, but male participants performed better on difficult problems. Lastly, I predicted in my final hypothesis that math anxiety would be higher in the high-pressure condition than in the low-pressure condition. Beilock and DeCaro (2007) and DeCaro *et al.* (2010) found this exact pattern; however, as previously stated, the pressure condition was overall ineffective. This will be discussed further in the limitations section.

### 4.5 Math Anxiety Across the Experiment

How math anxiety changed across different points of the study was also of interest. Math anxiety reported right after watching the video was found to be the highest. This suggests that the video did have an effective influence on participants' math anxiety. Curiously, participants' math anxiety at baseline and after being read the instructions on how to complete the MME were not significantly different. Another interesting finding concerning math anxiety ratings over time was how they interacted with participants' WMC. Across all five administrations of the SIMA, high WMC individuals had lower math anxiety than low WMC individuals. This corroborates patterns noted in the literature in that individuals who have lower WMC likely have lower math performance, thus leading to more math anxiety and further poorer math performance (Ashcraft, 2002; Ashcraft & Krause, 2007). An additional piece to note in this cycle is the influence of self-efficacy on math anxiety. The cyclical nature depicted here has been found to be induced by negative math experiences influencing one's self-efficacy regarding math, which in turn increases math anxiety (Ahmed *et al.*, 2012). Thus, the pattern observed in which high WMC individuals exhibit lower math anxiety across all points of the experiment is a logical pattern.

### 4.6 Limitations & Future Directions

Understanding the limitations of a study can assist in recognizing what needs to be addressed and adjusted for future research endeavors. One obvious limitation for the present study was that the pressure manipulation was ineffective. With it being established in past research that performance pressure can influence math performance, the issue appears to be more methodologically based rather than pressure not relating to lower math performance. Based on responses from the PTQ as well as general inference, participants did not seem all that convinced or concerned with being taped or told that their performance would be evaluated by math researchers. This could be for a number of reasons. The University of Alabama in Huntsville is a university with a focus on math-intensive degrees such as various domains of engineering and computer science. The sample of participants gathered may simply be used to being evaluated on their math skills. The younger generation are also very knowledgeable about how technology functions and may not have been convinced that professors would be able to glean much from just a video of a student's face as they solve math. Another limitation of the present study was relying only on self-reports for anxiety. This limitation presents a number of problems, the most poignant being that anxiety can only be determined before or after a task and not during. This is particularly a problem for the high-pressure condition as most participants are likely to stop feeling as anxious once they have completed the task at hand. Furthermore, many participants noted in the PTQ that the disparity between how much time the student actor was given in the video and how much time they were given to solve problems made them feel less anxious. This is further reflected in the fact that participants had lower anxiety overall at baseline, then higher anxiety after watching the video, and then a return to baseline levels after being explained the instructions of the MME.

Solutions to the aforementioned limitations could prospect interesting new research. Regarding performance pressure, the manipulation should be much more salient and convincing. Perhaps the experimenter could walk in with a camera and ask the participant to verbally solve the math problems in order to induce more anxiety. The issue of self-reports could be mitigated by using physiological measures separate or in conjunction with self-report questionnaires. This would allow an analysis of anxiety during, before, and after tasks. Additionally, how much time is allotted to participants during the MME should be reduced to be more in line with that of the videos. This could even be a manipulation to ascertain how much time restrictions affect math anxiety and performance.

## 4.7 Conclusion

The present study extended research on math anxiety and performance in relation to secondhand math experience and gender socialization effects. The current findings implicate that, in adults, almost exclusively external judgments are made when watching another complete math problems. These judgments appear to primarily take the observed individual's sex into account when anticipating the difficulty of a novel math task. The results of this study could potentially aid in identifying combined factors that produce harmful environments for academic achievement. Once these variables are identified, future research can take them into account and provide measures to mitigate them in real life scenarios. If math anxiety can be better understood and alleviated, future individuals will be able to thrive in vital math-oriented fields which they might have been too afraid to even approach beforehand.

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APPENDICES

APPENDIX A

*Institutional Review Board Approval Form*

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

| |
|---|
| X_Expedited (see pg 2) |
| __ Exempted (see pg 3) |
| __ Full Review |
| __ Extension of Approval |

Date: 25 August 2021

PI: Jodi Price
PI Department: Psychology
The University of Alabama in Huntsville

Dear Jodi,

The UAH Institutional Review Board of Human Subjects Committee has reviewed your proposal titled: *The Effects of Pressure and Secondhand Math Experiences on Math Anxiety and Math Performance* and found it meets the necessary criteria for approval. Your proposal seems to be in compliance with these institutions Federal Wide Assurance (FWA) 00019998 and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).
Please note that this approval is good for one year from the date on this letter. If data collection continues past this period, you are responsible for processing a renewal application a minimum of 60 days prior to the expiration date.

No changes are to be made to the approved protocol without prior review and approval from the UAH IRB. All changes (e.g. a change in procedure, number of subjects, personnel, study locations, new recruitment materials, study instruments, etc) must be prospectively reviewed and approved by the IRB before they are implemented. You should report any unanticipated problems involving risks to the participants or others to the IRB Chair.

If you have any questions regarding the IRB's decision, please contact me.

Sincerely,

Ann L. Bianchi

Ann L. Bianchi
IRB Chair
Associate Professor, College of Nursing

# APPENDIX B

## *Consent Form*

Consent Form: Solving Math Problems

You are invited to participate in a research study about solving math problems. This study is designed to help us better understand how watching someone else solve math problems affects math performance.

The primary investigator is Dr. Jodi Price, from the Lifelong Learning Lab located in Morton Hall. You can contact the Lifelong Learning Lab at 256-824-4950.

PROCEDURE TO BE FOLLOWED IN THE STUDY: Participation in this study is completely voluntary. Once consent is given you will be asked to complete a demographics questionnaire and a task in which you will try to remember words spoken at the end of sentences. Afterward, you will watch a math video of another student solving math problems before being asked to complete modular math problems yourself. Modular math problems require the participant to compute basic subtraction and division mentally without the assistance of a calculator, scratch paper, or writing utensil. Following the math exercise, you will complete a post task questionnaire in which you will be asked how you approached the task. Afterward, you will receive a debriefing form and then the study will conclude. This session will take 90 minutes.

DISCOMFORTS AND RISKS FROM PARTICIPATING IN THIS STUDY: There are no expected risks associated with your participation. You might feel worry and stress from the math exercise and sensitivity to the computer screen, but no more than you would experience in a basic math class or viewing other material on a computer screen. Should you need a break, feel free to take one.

EXPECTED BENEFITS: Results from his study can benefit society by looking at a potential method to improve math learning. Please see the section below for incentives and compensation for participation in this study.

INCENTIVES AND COMPENSATION FOR PARTICIPATION: The subjects that participate in the current study will receive 3 research credits to be used in their Introductory Psychology course.

CONFIDENTIALITY OF RESULTS: Participant numbers will be used to record your data, and these numbers will be made available only to those researchers directly involved with this study, thereby ensuring strict confidentiality. This consent form will be destroyed after 3 years. The data from your session will only be released to those individuals who are directly involved in the research and only using your participant number.

FREEDOM TO WITHDRAW: You are free to withdraw from the study at any time. You will not be penalized because of withdrawal in any form. Investigators reserve the right to remove any participant from the session without regard to the participant's consent.

CONTACT INFORMATION: If you have any questions, please contact the principal investigator, Dr. Jodi Price, in Morton Hall at 256-824-3321 or at jodi.price@uah.edu. If you have questions about your rights as a research participant, or concerns or complaints about the research, you may contact the Office of the IRB (IRB) at 256.824.6992 or email the IRB chair Dr. Ann Bianchi at irb.@uah.edu.

APPENDIX C

*Post-task Questionnaire*

Q1 - How important is it to you to perform well in math courses (1 = not important at all, 7 = very important)?

- ○ (1) Not important at all
- ○ (2)
- ○ (3)
- ○ (4)
- ○ (5)
- ○ (6)
- ○ (7) Very important

Q2 - How important was it for you to perform well in this task (1 = not important at all, 7 = very important)?

- ○ (1) Not important at all
- ○ (2)
- ○ (3)
- ○ (4)
- ○ (5)
- ○ (6)
- ○ (7) Very important

Q3 - How anxious were you while completing the Modular Math Exercise (1 = no anxiety, 7 = extreme anxiety)?

- ○ (1) No anxiety
- ○ (2)
- ○ (3)
- ○ (4)
- ○ (5)

- (6)
- (7) Extreme anxiety

Q4 - In the video you watched, did the student successfully or unsuccessfully solve the math problems?

- Successfully solved math problems
- Unsuccessfully solved math problems

Q5 – Were you told that you would be taped while completing the Modular Math Exercise?

- Yes
- No

Q6 – Did being watched make you feel anxious at all (1 = no anxiety, 7 = extreme anxiety)?

- (1) No anxiety
- (2)
- (3)
- (4)
- (5)
- (6)
- (7) Extreme anxiety

Q7 - How do you think watching another fail at math affected your confidence in your performance on the Modular Math Exercise?

- This video did not affect my confidence.
- This video made me feel *more* confident in my performance.
- The video made me feel *less* confident in my performance.

Q8 – Do you feel as if the sex of the student actor in the video impacted your expectations for your own math performance?

- The sex of the student actor *did not* impact my expectations for myself.

- ◯ The sex of the student actor *did* impact my expectations for myself.

Q9 – How much did the sex of the student actor impact your expectations for your own math performance (1 = no impact, 7 = very high impact)?

- ◯ (1) No impact
- ◯ (2)
- ◯ (3)
- ◯ (4)
- ◯ (5)
- ◯ (6)
- ◯ (7) Very high impact

Q10 - Did viewing the math video cause you to experience ***any*** feelings of anxiety about the Modular Math Exercise?

- ◯ The video did not cause me to feel anxiety.
- ◯ The video caused me to feel *more* anxious about the math exercise.
- ◯ The video caused me to feel *less* anxious about the math exercise.

Q11 - How anxious did you feel (1 = minimal anxiety, 7 = extreme anxiety)?

- ◯ (1) Minimal anxiety
- ◯ (2)
- ◯ (3)
- ◯ (4)
- ◯ (5)
- ◯ (6)
- ◯ (7) Extreme anxiety

Q12 - What about the video caused you to feel anxiety?
[Text box for written response]

Q13 - How did you view the math problems?

- ◯ A threat

- A challenge
- Neither

Q14 - Did some of the math problems appear easier to you than others?

- Yes
- No

Q15 - What characteristics of the math problems made them appear easier?
[Text box for written response]

Q16 - What strategies did you use to solve the math problems?
[Text box for written response]

Q17 - Do you believe your performance on this task is reflective of your math ability?

- Yes
- No

Q18 - Had you previously been exposed to this type of modular math problem before?

- Yes
- No

Q19 - Think back to a time when you were in math class and viewed a peer incorrectly answering a math question. How did this affect your perception of your own math ability?

- It did not affect my perception because I knew the answer.
- It made me doubt my math ability because I did not know the answer either.
- It did not affect my perception regardless of if I knew the answer or not.
- It depends on how the teacher responded.

Q20 - In your experience, how have teachers typically responded to students when they get a math problem wrong?

- With patience and understanding
- With impatience and a demeaning attitude
- I don’t remember