Relations Between Choking Under Pressure and Sleep on a Cognitive Task in College Students

by

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Abstract

The current study intended to explore how three sleep-related variables predicted the phenomenon of choking under pressure by utilizing a task that required the use of working memory abilities to solve problems as quickly and accurately as possible.

Participants were recruited through SONA and all participants were undergraduate students from Auburn University. Questionnaires were utilized to assess demographic information, caffeine intake, measure state anxiety (CSAI-2R; Cox, Martens, & Russell, 2003), performance pressure (Beilock et al., 2004), sleep disturbance and variations in the wake cycle (STQ; Monk et al., 2003), and subjective sleep disturbance (PROMIS Short Form v1.0 – Sleep Disturbance 8b, 2018). Working memory capacity was measured by averaging the scores between two working memory tasks (OSPAN; Turner & Engle, 1989; ARSPAN; Conway et al., 2005). Modular arithmetic as demonstrated in Beilock (2008), Beilock and DeCaro (2007), Beilock et al. (2004), and Mattarella-Micke et al. (2011), was used in this study because the task requires WM capabilities to mentally hold information (e.g., storage), while solving (e.g., processing) the entire problem. The dependent variables accuracy and reaction time were measured based upon participants responses to correctly solved high demand problems.

A data collection error resulted in only the initial half of the Sleep Timing Questionnaire being administered to all participants. Thus, the variables sleep duration and variations in the wake cycle were unable to be analyzed and the confirmatory analyses for sleep duration and the exploratory analyses for variations in the wake cycle were not run.

The Statistical Package for the Social Sciences (SPSS) was used to conduct all analyses. Two hierarchical linear regressions were used to test the exploratory analysis for sleep disturbance. There were limited significant findings. This could be because results indicate that

the high pressure scenario did not produce the desired effect of creating a high pressure environment. Significant findings were found for the dependent variable, reaction time, which was not anticipated. Results indicated that lower sleep disturbance statistically predicted faster reaction times where reaction times were calculated by subtracting the change in reaction time between the two experimental blocks. Lower sleep disturbance moderated the relationship between working memory capacity and reaction time. Specifically, reaction times were faster among students who reported low sleep disturbance and demonstrated higher working memory capacities. For students with high sleep disturbance, working memory capacity did not significantly predict reaction time. These results provide information to those that work with students or employees in settings that require high-order cognitive abilities and consider the positive benefits of obtaining quality sleep.

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CHAPTER I

Introduction

The day-to-day life for college students is multifaceted and can be stressful. In varying degrees, students are balancing priorities of maintaining personal space, striving for scholastic achievement, developing social relationships, participating in organizations, working, and managing their personal and physical well-being. For many individuals, college is the first step in their transition to independence, and students must learn how to balance their responsibilities. College students, or emerging adults, are in a unique developmental period as they transition and continue to further cultivate their social, learning, and independence skills. It is not surprising that college students report feeling anxious, overwhelmed, stressed, and worried (American College Health Association [ACHA], 2017; Iarovici, 2014; McGrath, 2006; Putwain 2007). Managing these responsibilities and the subsequent stress and anxiety reported by many students is enough to warrant the attention of researchers; and, the impact that stress and anxiety have on those students' academic performance deserves further exploration.

Stress and Anxiety

College students experience a multitude of stressors as they strive to balance their responsibilities throughout their academic career (Beiter et al., 2015; McGrath, 2006). Financially, the cost to attend college for a four-year degree can be a financial burden, costing as much as a luxury car, and continues to increase (McFarland et al., 2019). As a result, many students rely on loans and scholarships (McFarland et al., 2019) and over two-thirds of college students hold a job to assist with the costs associated with college expenses (Ross et al., 2012). Additionally, students may have difficulty navigating interpersonal relationship changes, such as separating from friends and family, developing new relationships, and maintaining relationships

(Hurst, Baranik, & Daniel, 2013). Balancing social needs amongst other responsibilities can be challenging and distressing for students. Individuals who perceive less social support have been found to have increased health risks and stress, with social supports helping to moderate life stressors (Zaleski, Levey-Thors, & Schiaffino, 1998). Furthermore, there are many dimensions of personal well-being that increase stress: sleep, body image, self-esteem, health behaviors, adjustment, and identity exploration (Hamaideh, 2011; Hudd et al., 2000; Klasner & Pistole, 2003; Koff & Sangani, 1997; Ross, Niebling, & Heckert, 1999). Students may feel overwhelmed when they do not attend, or feel unable to attend, to their personal needs. In addition to these stressors, staying on top of their coursework and studies can understandably be a challenge for many students. The academic rigor required of students in a postsecondary program is substantial. Student underperformance, or the fear of underperformance, is a significant cause of stress (Ducey, 2006). Students experience pressure to succeed from internal factors, such as competition and work overload (Hamaideh, 2011), and external factors, such as family and teachers' expectations (Hurst, Baranik, & Daniel, 2013; Pariat, Rynjah, Joplin, & Kharjana, 2014), and are required to manage both personal and academic responsibilities. Ultimately, the stressors that college students experience vary and at times are interrelated. Thus, it is not surprising that college students experience stress and anxiety, becoming worried and overwhelmed.

Given the responsibilities that college students must balance, only a small minority of college students complete their collegiate studies without experiencing stress and anxiety. According to the 2017 National College Health Assessment, within the last year over 85% of students reported feeling overwhelmed (ACHA, 2017) and more than half of the students reported experiencing overwhelming anxiety, "more than average stress" or "tremendous stress" within the past year (ACHA, 2017). These numbers are alarming. Students often visit counseling centers and academic support departments to seek help managing their concerns. In 2001, 63% of students who sought out a counseling center endorsed their presenting concern as anxiety or stress, which is a significant increase from 38% in 1988 (Iarovici, 2014). In fact, both anxiety and stress surpass depression as the most common presenting concerns among counseling students (LeViness, Bershad, & Gorman, 2017). College counseling centers often offer a limited number of therapy sessions to students due to the high demand that many college counseling centers experience (Iarovici, 2014). Therefore, it is important to identify distinctive incidents that increase stress in an academic environment and consider a variety of interventions to help mitigate the effects of such stressors. This study will further explore the effects of stress in a college student population by exploring their performance on a challenging cognitive task.

Academic performance. The stress and anxiety experienced by college students tends to have an effect on academic performance. Out of over 30 questions identifying different factors that could presumably affect academic performance, stress and anxiety were rated the highest (ACHA, 2017). According to 2017 National College Health Assessment, almost one-third of college students reported that both stress and anxiety affected their academic performance by lowering an exam or course grade (ACHA, 2017). Furthermore, the Survey of College Mental Health Services found that 84% of colleges reported that academic performance anxiety is “often a problem” or “a serious problem here” (Primary Research Group Staff, 2015, p. 27). As such, it appears that both stress and anxiety are perceived to interfere with academic functioning, which is concerning for students and other university members given its ubiquity on college campuses.

Anxiety related to academic demands and evaluations is believed to impede academic performance (Ducey, 2006). However, it appears that there are conflicting findings regarding the exact nature of the relationship between stress/anxiety and academic performance. There is some research suggesting that academic performance is not significantly related to or affected by stress and anxiety with regard to grade point average (GPA) and cumulative examination grades (Andrews & Wilding, 2004; Hahn, Kropp, Kirschstei, Rucker, & Müller-Hilke, 2017; Zajacova, Lynch, & Espenshade, 2005), whereas other studies have shown that severe stress and generalized anxiety disorder are associated with failing exams or general academic impairment (Keyes et al., 2012; Sohail, 2013). Conversely, other studies have suggested that low levels of anxiety might actually increase performance over situations where individuals experience no anxiety (Khan, Ahmed, & Khan, 2015; Pfeiffer, 2001). As can be seen, there are many ways to measure academic performance and define stress and anxiety; and the differences in methodology may in part be responsible for contradictory findings. However, it is possible that these contradictory results are due to the use of broad measure of academic performance. When using different measures of academic performance, there is cause for concern when interpreting the relationship between anxiety and academic performance. Many studies reviewed GPA (Curcio, Ferrara, & De Gennaro, 2006; Eliasson, Eliasson, King, Gould, and Eliasson, 2002; Önder, Beşoluk, İskender, Masal, & Demirhan, 2014; Singleton & Wolfson, 2009; Zajacova et al., 2005) or cumulative exams (Andrews & Wilding, 2004; Hahn et al., 2017). One disadvantage with these studies is that none were conducted as controlled experimental studies. Additionally, some studies used grouped variables (e.g., pass or fail) in their correlations, which does not adequately examine the moment at which anxiety begins to have an impact on performance.

Yerkes-Dodson's inverted-U model (1908), and later termed Yerkes-Dodson law (as cited in McMorris, 2014), provides useful insight into the effect of arousal on performance. When arousal becomes too intense, anxiety interferes with performance. Whereas when there is a moderate amount of arousal, performance levels are improved. Therefore, students may be motivated to perform better and the resulting mild to moderate amount of stress aids superior performance. Therefore, stress is not inherently bad; however, too much stress or stress resulting in anxiety related to the task at hand may lead to poor performance.

There is an important distinction between exam failure and poor exam performance that may also contribute to the aforementioned contradictory findings on the relationship between anxiety and academic performance. As discussed, too much stress or anxiety (e.g., worries, stereotype threat) during a testing situation can result in suboptimal performance that does not capture true scholastic ability (Ashcraft & Kirk, 2001; Beilock, 2010); however, it may not always result in failure to the extent of a failing grade. Therefore, below optimal performance is not always an accurate representation of skill mastery and/or knowledge attainment, if stress or anxiety interfered with their performance (Ashcraft & Kirk, 2001; Beilock, 2010). Thus, nuanced measures of suboptimal performance may better reflect college students' reports of stress and anxiety interfering with their overall academic achievement. Therefore, the researcher examines test anxiety to better explain the relationship between stress and academic performance.

Test anxiety. Since the 1980s, researchers have studied the relationship between anxiety and standardized testing (Liew, Lench, Kao, Yeh, & Kwok, 2014). Zeidner (1998) defined test anxiety as "the set of phenomenological, physiological and behavioral responses that accompany concern about possible negative consequences or failure in the examination or similar evaluative situation" (p. 17). Additionally, test anxiety is a "situation-specific trait accounting for individual differences in the extent to which people find examinations threatening" (Sindhu, 2015, p. 88). There are cognitive, affective, and behavioral components of test anxiety (Zeidner, 1998). The cognitive and affective components of test anxiety refer to the worries about being evaluated and the physiological and emotional reactions during the test (Numan & Hasan, 2017). For instance, a student reading through an exam may begin to question their ability to successfully complete the test and worry about their grade and become apprehensive. Less effective learning methods and techniques can also lead to problems with cognitive processing, and anxiety can lead to distractibility and difficulty concentrating on the exam (Numan & Hasan, 2017). In this case, test anxiety can result in problems with encoding and storing information as well as cause divided attention. Negative and self-deprecating thoughts can additionally lead to test anxiety (Putwain, 2008). In a study on college students' math performance as predicted by test anxiety, high-test anxiety was found to be negatively related to student performance on a standardized math exam resulting in a low-test score (Liew et al., 2014). Among elementary students, math anxiety was found to predict lower scores on a math achievement test (Ramirez, Gunderson, Levine, & Beilock, 2013). Fear and distress related to the prospect of testing as well as being evaluated or meeting expectations of the self or other were found to contribute to poor performance (Ashcraft & Kirk, 2001; Beilock, 2010).

Stress and anxiety are clearly experienced by college students (ACHA, 2017; Iarovici, 2014; LeViness et al., 2017); however, the ways in which they affect academic performance remain to be completely understood. It appears that the factors related to test anxiety such as worries and apprehension about a test are what lead to performance decrements rather than general stressors or anxiety that a college student may face from day to day. Perhaps instead of explaining academic performance decrements as the result of overarching stress and anxiety, performance decrements can best be described by examining the relationship between high-pressure situations and performance. Researchers (Baumeister, 1984; Bielock and Carr, 2005) introduced the term, "choking," to further explain the mechanisms underlying the relationship between stress and performance. Frequently, this term is part of the phrase – choking under pressure.

Choking Under Pressure

From the championship game, where the kick goes wide or the ball hits air rather than net, to the academic arena, when a student panics during an exam, “choking under pressure,” is a phrase that has been used to describe types of suboptimal performance experiences under psychological pressure. The phenomenon was originally discussed in the psychological research literature by Baumeister (1984) and defined by breaking down the phrase into its two components – pressure and choking. He defined pressure as “any factor or combination of factors that increases the importance of performing well on a particular occasion” and choking as “performance decrements under pressure circumstance” (p. 610). Baumeister and Showers (1986) expanded on the definition of choking to include that an individual must be capable of successfully executing a skillset in a non-pressure situation and desire to perform better in a high-pressure situation to earn an incentive. Therefore, in order to choke, the individual must perceive the situation as important with impending consequences and be capable of successfully performing the task (Hill, Hanton, Matthews, & Fleming, 2010). In other words, the individual must perceive that superior performance is necessary and possess the required skillset to be able to perform at a high standard, yet have performed worse than expected based upon their capabilities. Importantly, choking can occur in any performance situation and is not limited to athletics. Beilock (2010) extended this line of thinking related to pressure when studying stereotype threat. With stereotype threat – “introducing a negative stereotype about a social group in a particular domain can reduce the quality of task performance exhibited by group members” (Beilock, Rydell, & McConnell, 2007) – choking under pressure can happen during a practice test. For example, if a racial minority student believes that they will perform worse on an exam or a White athlete performs worse on an athletic task at practice, this can be due solely to awareness of racial stereotypes (Beilock, 2010; Beilock et al., 2007). This further illustrates how suboptimal performance can be influenced by perceived psychological pressure. Choking under pressure is moderated by a variety of factors to include stereotype threat, self-consciousness, trait anxiety, and audience presence that impact the mechanism of choking, such as attention and its relationship with automaticity and the working memory system (Hill et al., 2010).

Two theories of choking under pressure have been established – self-focus theories, also referred to as explicit monitoring theories, and distraction theories. Research has linked self-focus theories to sensorimotor skills (Beilock & Carr, 2001). Self-focused theories propose that performance pressure raises anxiety and self-consciousness about performing well. Decrements in performance are the result of attentional shifts from the task at hand to skill execution in an attempt to maintain optimal performance (Bausmesiter, 1984; Beilock & Carr, 2001; Beilock, Kulp, Holt, & Carr, 2004). When a golfer at the US Open becomes anxious about holding their lead, they may try to exert control by self-consciously focusing on the step-by-step execution of their swing. In doing this, they forgo executing their usual automatic motion, also referred to as procedural memory or the “know how” of a task which is developed through repetition (Lafleche & Palombo, 2017). They will likely “choke” because the pressure elicited a desire to control the situation instead of relying on autonomous processes. Researchers (Beilock et al., 2004; Gucciardi & Dimmock, 2008; Hill et al., 2010) later found evidence to support distraction theories when studying tasks that rely on cognition, working memory, and attention. In distraction theories, performance plummets when physiological arousal and worry cognitions are high because working memory resources become overloaded trying to sustain the competition between worry about performance and the task at hand (Beilock et al., 2004; Beilock, 2010; Hill et al., 2010). One can imagine a student heading into a testing environment prepared for a math examination only to begin worrying about their test performance, which would consume attentional resources necessary to complete the test. Whereas test anxiety itself leads to a variety of perceived negative responses within an evaluative environment, similar to choking, working memory also plays a vital role in determining performance decrements in a pressure scenario.

Working memory. Working memory is an integral component of cognitive abilities. Working memory is a workspace that temporarily stores and processes information while maintaining attention on a specific task and avoiding distraction from outside stimuli (Beilock, 2010; Engle, 2018). Complex cognitive tasks rely heavily on working memory. Thus, it is more likely that individuals with a greater working memory capacity will correctly solve mental math problems, which has been demonstrated in numerous studies (Beilock & Carr; 2005; Beilock & DeCaro, 2007; Beilock, 2008; Gimmig, Huguet, Caverni, & Cury, 2006; Mattarella-Micke, Mateo, Kozak, Foster, & Beilock, 2011). Individuals with a greater working memory capacity are able to hold more information and actively attend to or process relevant stimuli while ignoring other distractors (Beilock, 2010). It would seem that having a higher working memory capacity would result in better performance overall; however, research findings suggest that individuals with high working memory capacity are more susceptible to performance decrements in stress conditions than those with low working memory capacity (Beilock & Carr; 2005; Beilock & DeCaro, 2007). Individuals with high working memory capacities are believed to rely on “short cuts,” which in part is why these individuals can successfully solve complex problems that rely heavily on working memory. However, under pressure, working memory resources are being allocated toward both worry and the task at hand. As a result, when completing demanding tasks, individuals with high working memory capacities experience the greatest performance decrements because their strategies fail with diminished working memory resources, while individuals with low working memory capacities do not experience a significant drop in performance (Beilock & Carr, 2005).

Choking impacts individuals differently. Much like an individual who encounters a stressful environment, the way an individual interprets physiological stress reactions can result in either thriving or failing (Mattarella-Micke et al., 2011). As with test anxiety, some arousal is needed to excel, but too much arousal results in performance decrements. However, this appears to vary once working memory capacity is taken into account due to the relationship between working memory and anxiety. Working memory has a limited supply of resources. Anxiety taxes working memory reducing the ability of the working memory to maintain attention on and control of a specific task, particularly among individuals with high working memory capacities as noted above. Therefore, this study aims to expand the literature on choking under pressure among college students because research demonstrates that stress and anxiety affect academic performance. Sleep is another concern that has been found to disrupt performance and affect college student functioning (ACHA, 2009; ACHA, 2017; Lockley & Foster, 2012). Therefore, choking under pressure and sleep will be examined together.

Sleep

Sleep is one of the most vital, routine necessities for humans and is a contributing factor in overall health and well-being (Mendelson, 2017). Research has established that sleep contributes to neurocognitive functioning, performance, learning, physiology, physical and mental health, and disease prevention (Mendelson, 2017; Watson et al., 2015). In fact, it affects working memory (Durmer & Dinges, 2005). In addition, when people experience sleep disturbances, a multitude of other problems can occur such as drowsiness, decreased performance, impairments in cognitive functioning, illness, and decreased psychological well-being (Buboltz et al., 2006; Mendelson, 2017).

Sleep deprivation, in particular, has been shown to have a significant negative effect on cognitive performance (Durmer & Dinges 2005; Lim & Dinges, 2010; Lowe, Safati, & Hall, 2017; McCoy & Strecker 2011; Pilcher & Huffcutt 1996; Pilcher & Walters, 1997; Wesensten, Hughes, & Balkin, 2011). When an individual undergoes total sleep deprivation or is partially sleep deprived over the span of a few days, working memory abilities decline, sustained attention rapidly diminishes, attention-related errors increase, pressure to respond quickly increases errors, and it becomes difficult to learn new cognitive tasks (Durmer & Dinges 2005). In two meta-analyses, sleep deprivation was found to impair cognitive tasks requiring the use of attention and vigilance, working memory, and processing speed (Lim & Dinges, 2010; Lowe et al., 2017). Neuroimaging suggests that decreased activation in the prefrontal cortex when an individual is sleep deprived corresponds with cognitive deficits and are comparable brain imaging seen in individuals with prefrontal cortex damage (Lowe et al., 2017; Wesensten et al., 2011). However, these results do not present a straightforward conclusion on the effects of sleep deprivation on cognitive functioning. Cognitive deficits vary depending on the amount of time spent sleeping, how long sleep deprivation occurs, and individual differences in the amount of sleep required to sustain performance (Durmer & Dinges 2005; Wesensten et al., 2011). Furthermore, individuals may be unable to accurately report decrements in performance when they experience sleep deprivation or fatigue.

College student sleep and performance. Despite the importance of sleep for college students' functioning as they manage new responsibilities and endeavor to maintain balance, sleep duration continues to decrease while sleep-related problems increase among college students. Between 1969 and 2001, the median sleep duration of college students decreased from 7.75 hours to 6.65 hours (Hicks, Fernandez, & Pellegrini, 2001b), while their dissatisfaction with sleep increased from 24% in 1978 to 71% in 2000 (Hicks, Fernandez, & Pellegrini, 2001a). Becker et al. (2018) found that among college students over one-third receive less than seven hours of sleep and almost two-thirds experience poor sleep. Research suggests that upwards of one-third of all college students experience regular sleep problems, while only a tenth of college students meet criteria for good sleep quality (Iarovici, 2014). Other studies have found that two-thirds to three-quarters of college students experience a variety of sleep difficulties, including sleep deprivation or delayed sleep phase disorder (DSPD), also referred to as delayed sleep phase syndrome (DSPS; Lund, Reider, Whiting, & Prichard, 2010; Sadigh, Himmanen, & Scepansky, 2014; Wolfson, 2010).

ACHA (2017) found that 76.6% of college students reported that they felt rested zero to four days over the past seven days while 64.5% felt tired or sleepy during the day four or more days a week. Additionally, 45.8% of students reported that sleepiness impacted their daytime activities and described it as "more than a little problem", "a big problem", and "a very big problem", while 30.7% of students perceived sleep difficulties to be "very difficult" to manage. Fewer students attributed their problems to sleep difficulties suggesting that college students either managed their sleep-related symptoms or attributed them to other factors, such as stress-related problems. Even though sleep problems are very frequently reported, LeViness et al. (2017) found that only 15.8% of college students are treated for sleep problems across university populations of <1,500 students to >35,000 students, indicating a gap between the prevalence of sleep problems and treatment. The prevalence of sleep problems among college students necessitates a closer look into the relationship between college student sleep and academic performance.

College student academic performance relies, in part, on obtaining a good night's sleep. According to the National College Health Assessment, college students reported that while stress is the first problem that negatively affected academic performance, sleep difficulties are second (ACHA, 2009). When asked to reflect on the impact of sleep difficulties across the past 12 months, college students reported sleep difficulties impacted their academic performance in the following ways: 29% of students received a lower exam grade, 9% received a lower course grade, 2% received an incomplete or dropout, and 2% experienced a significant disruption of their thesis as a result of sleep difficulties (ACHA, 2017). This is understandable because when people do not obtain quality sleep, they are likely to notice decrements in their levels of alertness, performance, cognition, memory, attention, metabolism, and health (Lockley & Foster, 2012). However, as with stress and anxiety, it is unclear how much sleep disturbance relates to academic decrements.

Studies have yielded conflicting results with regard to the impact of sleep on academic performance. In some studies, sleep quality and amount of sleep correlated with or were the largest predictors of performance (Ahrberg, Dresler, Niedermaier, Steiger, & Genzel 2012; Baert, Omey, Verhaest, & Vermeir, 2015; Gomes, Tavares, & de Azevedo, 2011; Lowry, Dean, & Manders, 2010; Paavonen et al., 2000; Trockel, Barnes, & Eggnet, 2000). Yet, in other studies, no relationship was found between total amount of sleep and academic performance, as measured by cumulative GPA (Eliasson et al., 2002; Önder et al., 2014; Singleton & Wolfson, 2009). However, when examining cognitive performance among college students in laboratory settings, Pilcher and Walters (1997) found sleep deprivation impaired college student performance on a critical thinking cognitive task. Sleep reduction was also found to diminish performance on cognitive tasks assessing vigilance, inhibition, and impulsivity (Rossa, Smith, Allan, & Sullivan, 2014). Research using cumulative markers of performance, like GPA or course grades, to measure performance may overlook the impact of sleep deprivation, which may be captured by more discrete measures of performance, such as cognitive performance. Therefore, it is important to continue controlled experimental studies in order to better understand the relationship between performance and sleep among college students.

Present Study

To date, there are several studies examining choking under pressure and a multitude of studies examining sleep; however, to the knowledge of the researcher, no prior studies have examined the relationship between these two variables. This study will further expand the literature on choking under pressure, a subset of stress and anxiety, and sleep among college students by providing insight into how two common problems experienced by college students – stress/anxiety and sleep – lead to performance decrements. Specifically, this study will examine the relationship between working memory and pressure condition (as supported by distraction theories of choking under pressure) and sleep duration on performance accuracy and performance time. Additionally, exploratory analyses will examine the relationships between working memory and pressure condition as moderated by sleep duration, subjective sleep quality, and delayed sleep-wake cycles, separately.

Conceptual and Operational Definitions

Choking under pressure: “The occurrence of inferior performance despite striving and incentives for superior performance” (Baumeister & Showers, 1986, p. 361). For the purposes of this study, choking under pressure will be operationalized by participants’ total accuracy scores and reaction times on modular arithmetic problems on correctly solved high demand problems when in a high-pressure condition. The low-pressure condition will ask participants to simply solve the problems. The high-pressure condition will be manipulated. The high-pressure condition will ask participants to solve the problems with three sources of pressure applied to induce anxiety and performance pressure.

Choking: “Performance decrements under pressure circumstance” (Baumeister, 1984, p. 610).

Pressure: “Any factor or combination of factors that increases the importance of performing well on a particular occasion” (Baumeister, 1984, p. 610).

Working memory: The workspace that temporarily stores and processes information while maintaining attention on a specific task and avoiding distraction from outside stimuli (Beilock, 2010; Engle, 2018). Participants’ total scores on two complex working memory tasks, the RSPAN and OSPAN, will be averaged.

Sleep duration: “The total amount of sleep obtained per 24 hours” (Buysse, 2014, p. 10) and “the actual time during which an individual is asleep” (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010, p. 180). Participants’ average number of hours they sleep at night as recorded on the Sleep Timing Questionnaire, during an average week.

Subjective sleep quality: “The subjective indices of how sleep is experienced including the feeling of being rested when waking up and satisfaction with sleep” (Dewald et al., 2010, p.

180). Participants' total scores on the PROMIS Sleep Disturbance Short Form when responding to questions about the quality of their sleep.

Variations in sleep-wake cycles: "Significantly later sleep and awakening times during the weekend than during the week" (Brown, Soper, & Buboltz, 2001, p. 474). Participants' variation in their wake times from weekdays to the weekends as recorded on the Sleep Timing Questionnaire, during an average week.

Research Questions

Q1: After controlling for caffeine intake and accounting for the other main effects of working memory capacity and sleep duration, to what extent does a high-pressure scenario predict performance (i.e., accuracy and reaction time) on high demand problems?

Q2: After controlling for caffeine intake and accounting for the other main effects of working memory capacity and pressure condition, to what extent does sleep duration predict performance on high demand problems?

Q3: After controlling for caffeine intake and accounting for the other main effects of pressure condition and sleep duration, to what extent does working memory capacity predict performance on high demand problems?

Q4: To what extent does working memory capacity predict performance in a high-pressure scenario on high demand problems, as compared to those in a low-pressure scenario?

Q5: After accounting for the above main effects and relevant two-way interactions, do sleep duration, working memory capacity, and pressure interact to predict performance on high demand problems?

Chapter II

Literature Review

This chapter will present research relevant to the current study. Literature pertaining to stress and anxiety, choking under pressure, cognitive performance, and sleep, primarily within the college student population, will be reviewed. This study will focus on the sleep patterns of college students with particular interest in their sleep duration as it declines and lingers below the seven-hour threshold. Studies have examined the relationships between test anxiety and academic performance (Hahn et al., 2017; Tempel & Neumann, 2016) and sleep deprivation and cognitive performance (Durmer and Dinges, 2005; Lim & Dinges, 2010). Through research on choking under pressure and Processing Efficiency Theory researchers have learned that working memory, specifically, cannot manage pressure-induced anxiety and the processing of information, which leads to choking under pressure (Hill et al., 2010). Both performance anxiety and sleep-related problems have been found to negatively impact performance on academic measures and cognitive tasks. Research and students' self-reports suggest that stress and poor sleep contribute to academic difficulties (ACHA, 2017; Ashcraft & Kirk, 2001; Beilock, 2010). As college students strive to effectively balance their collegiate and personal responsibilities, it is important to understand how college students manage the multiple high-pressure situations they encounter. It is important to understand the underlying mechanisms that impact their performance, as they will continue to be expected to perform well under pressure in their careers and personal responsibilities beyond graduation.

Stress and Anxiety Among College Students

A review of the literature found that researchers and college students often use the definitions of anxiety, stress, and worry interchangeably; and therefore, they are not uniformly operationalized (Iarovici, 2014; Putwain, 2007), while some researchers have attempted to develop distinctive differences among these concepts (American Psychological Association, 2013; Kremer, Moran, Walker, & Craig, 2012). Researchers often discuss academic distress by presenting events and factors that lead to distress among students without providing a clear definition of academic stress. Putwain (2009) offers three ways in which stress may be best conceptualized: “as a property of an event/situation, as a person’s perception of an event/situation or as the person’s reaction” (p. 394). Similarly, Kremer et al. (2012) defined stress as “a pattern of physiological, behavioural, emotional and cognitive responses to real or imagined stimuli that are perceived as endangering us or harming our well-being in some way” (p. 32). Simplified, an individual can experience stress in response to an event or situation if they have a physical, affective, cognitive reaction. For example, if a professor informs their class that their exam is moved up to the next week, students may experience stress reactions such as making changes to their schedule, becoming irritated, or noticing their heart rate increase. Kremer et al. (2012) separately described anxiety as “negatively interpreted arousal – an emotional state characterized by worry, feelings of apprehension and bodily tension that tend to occur in the absence of real or obvious danger” (p. 32). With the same example, students may become worried or feel apprehensive about having enough time to study and fear they will not perform as well. Students have numerous concerns related to their collegiate experience, which may result in stress or anxiety (Beiter et al., 2015; Pfeiffer, 2001). While students may react to stress in a variety of ways, negatively interpreting an external situation like that described above is likely to result in anxious responses such as worrisome thoughts, feelings of fear, tension, restlessness, and fatigue. Unfortunately, research indicates that this is a common experience among college students.

The prevalence of stress and anxiety among college students is alarmingly high. Anxiety has been found to be more prevalent among college students (Boehm, Lei, Lloyd, & Prichard, 2016; Farrer, Gulliver, Bennett, Fassnacht, & Griffiths, 2016; Keyes et al., 2012; Lipson, Gaddis, Heinze, Beck, & Eisenberg, 2015; Weigold & Robitschek, 2011), than in same-aged individuals not in college (Farrer et al., 2016). Managing stress and anxiety is difficult as a college student, as many students are learning how to live independently and balance their responsibilities for the first time. To complicate matters further, individuals with anxiety disorders are more likely to have ineffective coping strategies (Weigold & Robitschek, 2011) and report having diminished quality of life (Beiter et al., 2015). While not all adults who experience anxiety symptoms will meet criteria for an anxiety disorder, they can still find themselves being significantly impacted by stress. Unfortunately, research indicates that mental health problems continue to increase over time among the college student population (CCMH, 2017), which suggests that not enough is being done to help students successfully navigate this important, and all too often stressful, part of their lives. While experiencing stress and anxiety is inherently unpleasant, also concerning is the fact that stress and anxiety can have a detrimental effect on a student's academic performance.

Academic performance. One way that stress manifests itself among college students is through academic performance (Pfeiffer, 2001). Many students undergo considerable amount of stress related to their coursework. ACHA (2017) found that during a 12-month period college students reported that anxiety impacted their academic performance in the following ways: 29% of students received a lower exam grade, 10% received a lower course grade, 4% received an incomplete or dropped out, and 3% experienced a significant disruption of their thesis as a result of anxiety. Students who were administered mental health screeners for depression and anxiety were found to be at a greater risk for academic impairment, which was defined as six or more days across four weeks where problems with emotional or mental health hindered academic performance (Keyes et al., 2012). Managing multiple courses, taking challenging or demanding courses, and external and internal pressures to succeed can all lead to academic distress.

As a result, colleges and universities are finding that more and more students are seeking treatment for a variety of disorders. For example, the Franciscan University Counseling Center saw their number of clients double, and their total number of sessions more than double in a one-year period (Beiter et al., 2015). Additionally, two-thirds of students who seek counseling services report that counseling helped their academic performance (LeViness et al., 2017). However, taken together, these statistics should raise concerns for students seeking postsecondary education, as well as universities' concerns about the success and well-being of their students. These findings alone indicate the need for further research on how anxiety and stress impact academic performance and well-being and what can be done to help students minimize their impact.

Test anxiety. Studies are beginning to analyze how stress reduces performance within academic settings, often by examining test anxiety (Hahn et al., 2017; Tempel & Neumann, 2016). As discussed in chapter I, studies have often examined broad markers of academic achievement and performance by measuring the relationship between anxiety and course grades or GPA (Andrews & Wilding, 2004; Hahn et al., 2017; Zajacova et al., 2005). These broad markers do not take into account the nuances of performance decrements across the smaller facets of academic success measures. Studying test anxiety allows researchers to capture a more in-depth understanding of how stress can be associated with performance.

Recent studies indicate that the cognitive effects of stress, and worry, rather than the emotional and physiological components of stress, more significantly and directly contribute to academic distress and inferior performance (Brady, Hard, & Gross, 2018; Tempel & Neumann, 2016). Therefore, as previously discussed, the most detrimental effects of stress on academic performance seem to result from cognitive responses to stress, such as worry. Interestingly, students with high-test anxiety prior to taking their exam had lower levels of mental concentration and selective attention when measuring cognitive performance (Fernández-Castillo & Caurcel, 2015). Furthermore, when students were provided with a reappraisal message informing students of the benefits of arousal the night before an exam, first-year students performed better on the exam than their same-grade peers who did not receive this message and earned higher course grades (Brady et al., 2018). These studies lend further evidence to support that cognitive anxiety impedes academic performance. Thus, to better understand a more precise mechanism by which anxiety can impede academic performance, the phenomenon of choking under pressure and the theories that support it provide a useful framework to understand the relationship between desired outcomes and inferior performance.

Choking Under Pressure

As discussed in the previous chapter, a model of "choking under pressure" was first introduced in academic literature by Baumeister in 1984. Baumeister and Showers (1986) define choking as the "occurrence of suboptimal performance under pressure conditions" and pressure as the "presence of situational incentives for optimal, maximal, or superior performance" (p. 362). They further refine the conceptual understanding of "paradoxical performance effects", more commonly referred to as choking under pressure, as "the occurrence of inferior performance despite striving and incentives for superior performance" (Baumeister & Showers, 1986, p. 361). To choke under pressure, an individual must be intrinsically and/or extrinsically motivated to perform well and possess enough proficiency in a skillset that their performance can be significantly and perceptibly hindered by these “paradoxical performance effects” in a high-pressure situation.

Arousal and motivation have been understood to be important factors in any performance setting since the introduction of the Yerkes-Dodson law in 1908 (cited in McMorris, 2014), as previously referenced. Since then, the Yerkes-Dodson law has been cited to examine the relationship between arousal and behavior by many researchers and professionals sometimes missing an important component. The Hebbian version of the Yerkes-Dodson law updated the inverted-U shaped curve demonstrating that arousal alone does not impair performance, but that when a cognitive task becomes quite difficult, anxiety then hinders performance (Diamond, Campbell, Park, Halonen, & Zoldaz, 2007). Therefore, when a task is simple, performance is not impeded (Diamond et al., 2007). Aligning with sports psychology and choking under pressure, moderate levels of arousal are needed for optimal performance to reduce distractibility and maintain a subjective level of motivation (Baumeister & Showers, 1986; McMorris, 2014). To illustrate, the low end of this effect is comparable to a low stakes sporting event, when a high-ranked football team might underperform against an unranked team because they were unmotivated. The other end of this effect is more likely to be seen in high stakes sporting events, for instance in NFL playoff games when veteran players, such as Peyton Manning, might perform poorly, or choke, after having consistent, incredible regular season statistics against elite teams. Though according to Baumeister and Showers (1986), this model of the relationship between arousal or ‘drive’ and performance may not exemplify choking under pressure as it does not provide an explanation for performance decrements.

Baumeister and Showers (1986) postulate another theory that may be more relevant than the Yerkes-Dodson law, as the law does not account for why some individuals' performance is not hindered during championships. Easterbrook's hypothesis (1959) explores cue utilization theory, as cited in Baumeister and Showers (1986), Eysenck (1992), and Hanoch and Vitouch (2004), which incorporates cognitive processes, such as attentional focus on task-relevant/irrelevant cues, to describe the relationship between emotional arousal and performance. Therefore, it would seem that factors beyond motivation, or drive, could result in performance deterioration during moments when optimal performance is desired. When a person experiences high arousal, they may instead narrow their attention toward a primary task. This may be beneficial until it narrows their attention to the point of adversely affecting their performance on a secondary task, leading to worse performance. Therefore, the exclusion of too many task-relevant cues can lead to a subsequent decline in performance. For example, a quarterback becomes so narrowly focused on throwing the football to the wide receiver that they are unaware of the safety charging them and get sacked. Conversely, when the individual is moderately aroused, they are able to attend to all of the task-relevant cues and perform optimally. This theory lends itself to identifying how cognitive processes, such as attention, and arousal are integral components of choking under pressure.

In order to choke, a person must experience arousal in a perceived, high-demand environment and must be capable of performing a skillset under nonstressful circumstances. Since Baumeister (1984) proposed a model for "choking under pressure", two theories have been put forward to explain why people fail in high-pressure situations (Beilock & Carr, 2001; Beilock et al., 2004; Lewis & Linder, 1997). Before exploring the two theories, an important distinction needs to be addressed. Arent and Landers (2003), citing Sage (1984), define *arousal,* synonymous with activation, as “an energizing function responsible for harnessing the body’s resources for intense and vigorous activity” (p. 437). As previously stated, *stress* is a physiological, behavioral, emotional, or cognitive state or response to a real or perceived threat (Kremer et al., 2012). This distinction is important because the mechanisms that lead to a “choke” vary for both theories of choking under pressure (Hill et al., 2010). *Arousal* leads to performance decrements in self-focused theories as attentional shifts lead to choking, while for distraction theories, cognitive worry, a component of *stress*, results in divided attention and leads to choking (Hill et al., 2010). Below is a review of self-focused theories and distraction theories to describe the phenomenon of choking under pressure.

Self-focus theories. In the first study using the phrase “choking under pressure,” Baumeister’s (1984) research demonstrated a model of choking that suggests that performance decrements are mediated by attentional shifts. These attentional shifts are the result of increased self-consciousness. As an individual’s attention shifts from completing the task at hand to the specific mechanisms required to complete the task, they inadvertently hinder their performance. This is similar to Easterbrook’s hypothesis in that when arousal significantly increases, an individual narrows their focus to the extent that their performance is likely to suffer. This happens in situations where an individual perceives optimal performance as important, due to a variety of motivators, such as to earn money or for another incentive. This is comparable to the above scenario where a football player in a high-stakes event tries to maintain control of the situation and ensure optimal performance by self-focusing on their step-by-step execution.

There has been substantial evidence to support self-focused theories’ conception of performance decrements under pressure. Kimble and Perlmuter’s (1970) research found that when automatic processes (responses that no longer require voluntary control) are disrupted, attention shifts back to what was once involuntary leading to less attention being devoted to the task performance. This was supported by Masters' (1992) study in which one group of novices who were taught the skill of golf-putting explicitly and then tested under stress conditions performed worse than another group that learned how to putt implicitly (Masters, 1992). An attentional shift causes individuals to focus on step-by-step execution, rather than rely on their automatic processes, leading to detrimental performance. Lewis and Linder (1997) also argued that self-focus theories, rather than distraction theories, account for performance deficits under pressure while completing a putting task. They found that individuals who were distracted in fact performed better than those whose attention was on their performance under a high-pressure situation, while individuals in low pressure scenarios instead performed worse when distracted. Again, these findings support the notion that an optimal level of arousal may narrow focus enough to improve performance, while too much attention leads to performance decrements. For a long time, researchers were only finding evidence to support self-focus theories, also called explicit monitoring theories, such as in Beilock and Carr (2001) and Beilock, Carr, MacMahon, & Starkes (2002).

Research had only examined "choking under pressure" by studying sensorimotor skill performance, such as in sports. Complex motor skills, such as those required for putting or dribbling, use procedural knowledge (Beilock, 2010). These skill sets are stored as motor programs within the brain, and once a sensorimotor skill becomes automatic, it no longer requires a large neuropsychological demand (McMorris, 2014). If a skill is rehearsed and becomes procedural knowledge, focusing on skill execution results in poor performance. Deikman (1969) termed this breakdown of skilled performance as deautomatization, which he defined as the "undoing of automatization, presumably by *reinvesting actions and percepts with* *attention*" (as cited in Masters, 1992, p. 344). In sensorimotor-based performance, it is not the arousal and stress of the environment alone that causes an individual to choke. Rather, it is the disruption of automatic motor programs by instead consciously focusing on skill execution to maintain optimal performance in a high-pressure environment. This disruption impedes performance because the individual is no longer relying on their automatic processes. When automatic control structures no longer operate as a whole, and are instead activated as independent units, the chance for error increases (Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007). As a result, the athlete chokes. Yerkes-Dodson law and Easterbrook's hypothesis lend themselves to explore the relationship between arousal and performance in a manner that fits with the explicit monitoring theories' discussion of task-relevant/-irrelevant attention. As arousal and task difficulty increase, attention narrows, and in this case, shifts to skill execution, which conversely results in inferior performance in skilled individuals. Therefore, researchers began to examine other methods to search for evidence to support distraction theories (Beilock et al., 2004).

Building on the recognition of differences between working memory and procedural knowledge, Beilock et al. (2004) suggested that while explicit monitoring theories explain performance decrements for sensorimotor skills, cognitive skills might be better explained by distraction theories. Beilock et al. (2004) recognized that automatic sensorimotor skills do not rely on working memory. As a result, self-focused theories do not anticipate instances of "choking under pressure" related to cognitive performance because sensorimotor and cognitive skills rely on different brain processes. Easterbrook's (1959) hypothesis takes into account the importance of task-relevant narrowing of attention for performance, wherein attentional narrowing is the result of arousal suggesting that there is an increased capability to reduce distractions but focusing too narrowly can lead to performance decrements (Eysenck, 1992). However, it does not take into account a deeper understanding of cognitive processes and anxiety's effect on them. Shapiro and Lim (1989) found evidence to suggest that highly anxious participants instead broaden their attentional field, detecting peripheral stimuli in addition to task-relevant information. Eysenck (1992) concludes that both theoretical possibilities are worthy of consideration, suggesting that anxious individuals may initially broaden their visual scope rapidly for best stimulus detection and then narrow their focus. Furthermore, it is understood that individuals with high-trait anxiety will experience performance decrements; however, Eysenck (1992) addresses the fact that performance and anxiety appear to be frequently studied at high levels of anxiety, rather than also considering conditions where anxiety and stress are much lower, in order to examine the components of information processing that may be susceptible under conditions of heightened anxiety and stress. Therefore, distraction theories had not been appropriately tested because researchers were not studying the appropriate cognitive process. Thus far, attention and arousal have demonstrated having a negative effect on performance by disrupting automaticity in task completion within a high-pressure environment. The present study aims to apply distraction theories of choking under pressure to college students' performance on cognitive tasks in a high-pressure environment, to further contribute to the understanding of college student performance in an academic-related setting.

Distraction theories. Attention and cognitive functioning have been studied for over a century (James, 1890). As James (1890) states, attention "implies withdrawal from some things in order to deal effectively with others" (p. 404). James (1890) continues to discuss that attending to stimuli is what allows individuals to have an "experience". In other words, when people selectively attend to something in their environment, they have a conscious awareness that can shape their own experience. Therefore, for an individual to choke under pressure, they must perceive the situation or environment as competitive; and therefore, must call their attention to the pressures at hand.

Wine’s (1971) review of the literature found that individuals with high test anxiety often perform poorly on tasks because they are distracted by their increased arousal, shifting their attention from the task they are to perform toward worries about the situation or their own intrusive thoughts. Similar to explicit monitoring theories, when pressure or anxiety to perform well becomes too great, it disrupts performance by shifting attentional focus. However, unlike explicit monitoring theories where a person focuses on their skill execution, distraction theories explore the effects of divided attention. Attentional capacity is thought to be divided in dual-task situations because focus is placed on both the task and one’s worries about their performance (Beilock et al., 2004). To better understand the relationship between anxiety and divided attention, working memory is reviewed.

Working memory. As previously discussed, attention is a key component of choking, and it is also theorized that extensive burdens placed on working memory in performance settings lead to choking due to worries related to the consequences of poor performance. While attention and arousal, and additionally stress, have been shown to affect performance, attention and working memory are intimately connected. Working memory “stands at the crossroads between memory, attention, and perception” (Baddeley, 1992, p. 559). Working memory (WM) is involved in executive functioning and spatial tasks, memory, language, and problem solving (Beilock, 2010; Unsworth, Redick, Heitz, Broadway, & Engle, 2009). Therefore, a main purpose of WM is to process and attend to information. Beilock (2010) describes WM as being “more than just storage; it also reflects your ability to hold information in memory while doing something else at the same time", and it "involves being able to attend to some things and ignore others so that you can keep the information you want to remember in mind" (p. 80). This is captured by the proposal of distraction theories because within cognitive choking scenarios, an individual's WM is being taxed by both anxiety-driven worries and the task at hand. When an individual perceives stress or anxiety, it reduces their working memory capability. This is because WM is striving to attend to the information being presented and process it efficiently. When there is an impairment or burden placed on executive functioning, individuals are more sensitive to stimuli, with greater difficulty discriminating and reducing distractors, and thereby have more difficulty processing information.

The support for distraction theories drew from the notion that WM is taxed because both worries and cognitive tasks rely on working memory capacity (WMC; Beilock, 2010). Through Beilock's research collaborations, various researchers have studied choking under pressure as proposed by distraction theories in different contexts: individuals with high WMC, learning strategies, math-anxiety, and stereotype threat (Beilock, 2008; Beilock et al., 2004; Beilock & Carr, 2005; Beilock & DeCaro, 2007; Beilock et al., 2007; Mattarella-Micke et al., 2011). The thread that connects these studies is the focus on how WMC is instrumental for cognitive performance. The underlying theory that accounts for these decrements stems from various research exploring the relationships between attention, arousal, and anxiety, eventually reaching WM (Eysenck, 1992).

This chapter has reviewed Easterbrook's hypothesis as an example of attention narrowing leading to performance decrements (Eysenck, 1992). However, researchers found that his theory did not always hold merit (Eysenck, 1992). Shapiro and Lim (1989) demonstrated that anxious mood states lead to an individual broadening their attention toward periphery cues, such as secondary tasks or distractors, dependent upon their level of anxiety. Some theorists (e.g., Sarason 1984, 1988) have further hypothesized that worry and self-preoccupation interfere with task performance, resulting in impaired performance (Eysenck, 1992). However, evidence suggests that high-anxious participants performed equally well as low anxious participants on difficult tasks (Eysenck, 1992, p. 126-127). Therefore, it would appear that there are additional cognitive elements, beyond worry, that further address the relationship between anxiety and task performance. Processing Efficiency Theory (PET) is the theory that addresses inefficient processing when anxiety is elevated and will be the foundation for this study as applied to the distraction theories of choking under pressure (Eysenck, 1992).

Processing Efficiency Theory. Theoretically, Eysenck (1992) and Beilock et al. (2004) recognized that something beyond worry and arousal better articulated the relationship between anxiety and performance. Their inclusion of WM in their theoretical and practical applications suggests that working memory is a central component in demonstrating and explaining performance decrements. Sarason's Cognitive Interference Theory (1984, 1988), as cited in Eysenck (1992) and Eysenck and Calvo (1992), argues that cognitive anxiety, such as worry, consumes short-term memory resources or impairs tasks with high attentional demands. For example, those with high test anxiety will perform worse because their worry interferes with their ability to attend to the task. However, studies found that this is not consistent across all cases. Instead, high- and low-test anxious participants did not differ in their performance (Eysenck, 1992). It appears that anxiety causes worry which tends to affect performance (Eysenck & Calvo, 1992), but Sarason's theory alone does not account for all scenarios. Instead, an argument has been made that inefficient processing accounts for performance decrements (Eysenck, 1992).

Processing Efficiency Theory (PET) has been studied extensively and was found to explain anxiety's effect on central execution within WM (Eysenck, 1992). PET addresses the relationship between WM and worry on task performance (Eysenck, 1992). Two assumptions of PET include: 1) worries impact WM, in that anxiety and task demands both compete for its resources, and 2) worry has a greater influence on processing efficiency than on performance effectiveness (Eysenck, 1992, p. 133). Performance effectiveness, or the quality of performance, is not as impaired as processing efficiency, defined as performance effectiveness divided by the processing resources or amount of effort being utilized for task completion (Derakshan & Eysenck, 2007). In other words, more WM resources are attending to worries instead of WM processing and storage to attend to the task at hand. Stress requires the perception of an external or internal threat. In order to choke, a person must feel pressure to perform well to avoid failure or consequence(s) if they do not perform their best, or rephrased in a positive light, they strive to perform their best to earn a particular marker of success. These pressure situations can induce worry. The worries of failing or not maintaining a certain level of performance are the result of internal and/or external influences. Furthermore, as discussed previously, WM is largely involved in dual-task conditions, which are now associated with distraction theories (Mattarella-Micke et al., 2011). When worries and task performance compete for the resources of WM, the individual is likely to become distracted from the task at hand and results in insufficient processing. Concentration moves from the task and becomes divided by the worries associated with either stressors of competition or pressure to be successful. Two studies demonstrate the relationship between attention, WM, and stress in a performance setting, providing support for distraction theories (Beilock & Carr, 2005; Mattarella-Micke et al., 2011).

Pressure condition and problem demand. As previously discussed, pressure is defined as "any factor or combination of factors that increases the importance of performing well on a particular occasion" (Baumeister, 1984, p. 610). The significance of a high-pressure condition can be measured by comparing scores between those in low- and high-pressure conditions on measures of stress/anxiety, performance pressure, performance success, and importance. Common experimental pressure conditions include monetary incentives, an audience or social evaluation, being filmed on camera to be evaluated by others, peer pressure, or any combination of these pressures (Beilock & Carr, 2005; Beilock et al., 2004; Carr, 2014). High-demand problems refer to tasks, such as borrowing while subtracting, that place heavy demands on working memory (Ashcraft & Kirk, 2001). Additionally, demand is referenced in research on dual-task performance in that both the primary and secondary task will compete for working memory resources for successful performance (Ashcraft & Kirk, 2001). Therefore, demand, in the context of performance, refers to the extent to which WM resources are required to complete the task(s) at hand.

In the first study to provide strong evidence for distraction theories in understanding choking und pressure, Beilock et al. (2004) studied the impact of low- and high-pressure environments on performance by examining the differences in performance when completing low- and high-demand problems. In their first experiment, the researchers sought non-mathematic major students to determine if they could teach an unfamiliar math task (modular arithmetic) and see performance decrease as a product of stress. All participants completed low- and high-demand problems in order to see if pressure-induced performance decrements are linked to WM demands because high-demand problems require more resources of WMC. After the task was introduced (pre-test) in a low-pressure condition and then further practiced in an additional low-pressure condition, the researchers manipulated pressure by incentivizing superior performance through monetary consequences and social evaluation (post-test; high-pressure). The results indicated that performance (i.e., accuracy) in a low-pressure situation with low- and high-demand problems improved from pre- to post-test. Performance also improved from pre- to post-test when individuals completed low-demand problems in a low-pressure situation. However, when completing high-demand problems in a high-pressure environment, individuals choked and solved significantly more problems incorrectly than the other groups. The increased feelings of perceived pressure and anxiety individuals experienced resulted in greater performance decrements when solving high-demand problems. Regarding performance as measured by reaction time, reaction times were faster when solving low- rather than high-demand problems. Reaction times were also faster from pre- to post-test for both low- and high-demand problems across both pressure groups, with high-demand problems having the greatest decrease in time. There was a non-significant difference when comparing the two pressure conditions on high-demand problems. Those in the high-pressure condition decreased their reaction times slightly more than the low-pressure group when solving high-demand problems. There was no interaction between pressure condition, problem demand, and test condition.

Additionally, Beilock et al. (2004) wanted to examine practice effects on cognitive problems. They hypothesized that if an individual could practice low- and high-demand problems enough to eventually solve the problems through automatic answer retrieval, their performance would improve leading to a further understanding of the mechanisms of both explicit monitoring and distraction theories. In their second experiment, Beilock et al. (2004) divided participants into two groups (low- and high-pressure conditions) and asked them to complete 12 modular arithmetic problems (pre-test) at three levels of demand. Then all participants practiced each, individual problem 48 times across three training blocks before entering the post-test phase of the study. In the post-test, participants completed the same 12 problems, once, in the opposite pressure condition (low- and high-pressure). The results indicated that performance did not vary on low-demand problems solved in a low-pressure condition in pre- or post-test or on high-demand problems solved in either pressure condition during the post-test block. Performance only decreased when high-demand problems were solved in the pre-test high-pressure condition. This provides support for distraction theories because individuals who practiced the problems several times were not susceptible to performance decrements even in the high-pressure situation, while completing high-demand problems. Those completing high-demand problems in the high-pressure, post-test condition were able to provide answers because they were retrieving them from memory, rather than solving them on the spot.

Lastly, Beilock et al. (2004) provide one more marker of support during their third experiment by asking individuals to complete low- and high-demand problems in low- and high-pressure situations. In their third experiment, the participants first practiced 720 problems (12 low- and high-demand problems repeated 50 times, 48 low- and high-demand problems repeated once, and 24 low- and high-demand problems never repeated). Afterwards, they completed 36 problems in a low-pressure condition followed by 36 additional problems in a high-pressure condition. The 36 problems are randomized from three sets: six low- and high-demand problems (multiple repeats), six low- and high-demand problems (seen once), and six low- and high-demand problems (never seen). The results indicated that in a high-pressure condition only high-demand problems that were practiced once or never seen resulted in performance deficits. All other performances were maintained or improved from the low-pressure situation to the high-pressure situation. This provides further support for distraction theories over explicit monitoring theories because individuals that practiced problems 50 times, regardless of their demand on WM, did not perform poorly. The problems were sufficiently proceduralized yet performance was maintained, which contradicts explicit monitoring theories. Performance only worsened when individuals completed high-demand problems that they had never been exposed to or exposed only once. This indicates that both worries about performing well, as a result of perceived pressure, and solving high-demand problems that were never or minimally practiced, and therefore could not be retrieved from memory, resulted in performance decrements because too heavy of a demand was placed on WM. Overall, these cognitive performance decrements are thought to be the result of pressure-induced limitations when solving problems that place a heavy demand on WMCs. These findings contradict evidence suggesting that explicit monitoring theories provide the only explanation as to why people choke under pressure now that evidence demonstrates that choking can result from anxiety and performance pressure while completing a task with heavy demands on WM.

One additional variable was added to understand the relationship between WM and choking under pressure. In Beilock and Carr's (2005) study, individuals completed modular arithmetic problems in a similar low- and high-pressure condition and completed two complex WM span tasks. Individuals' scores on the span tasks determined if individuals were placed into the low or high WM groups, based on a median split of their average scores. Results indicated that individuals with high WMCs performed the best, as measured by accuracy, on high demand problems in the low-pressure condition but were also the individuals that were most suspectable to choking under pressure when solving high demand problems. High and low working memory participants performed comparably on low demand problems in the low- and high-pressure conditions. WM groups did not differ with regards to performance measured by reaction time. It is not surprising that those with higher WMCs were found to perform better on high demand problems when stress was not induced because they have greater attentional capabilities; however, the authors did not hypothesize that those with high WMCs would be the group to perform worse under pressure. In regard to performance as measured by reaction time, those with high WMCs solved problems faster than those with low WMCs. Reaction times were also faster when solving low-demand problems than high-demand problems. However, there were no interactions between problem demand and WMC and/or pressure condition.

Beilock and DeCaro's (2007) research found that this was because individuals with higher WMCs traditionally use shortcuts to solve problems, but when placed under pressure conditions, they revert to less effective means to solve the problem, which lead to more errors. This also explains why those with higher WMCs solved more problems accurately than those with low WMCs while in the low-pressure condition. However, another task (e.g., the jug task) was introduced where a difficult formula is created to solve a set of problems, but the second set of problems was simpler and could be solved with the same difficult formula or a simpler formula. The associations needed to solve the problems had been developed as individuals were exposed to the first set of problems. However, those with higher WMCs persisted in solving the second set of problems with the difficult strategy, not using the shortcut, and performed worse than those with low WMC in a low-pressure condition, while those with low WMCs recognized the shortcut and utilized it. However, in the high-pressure condition the use of the shortcut strategy was used at a rate comparable to those with low WMC. These findings suggest that using the simpler strategy (less effort) generally pays off when trying to accurately solve non-computational problems or evens the playing field between the two WM groups. Individuals with less WM resources were most likely to use the simple strategy as were those in the high-pressure condition where WM resources were reduced due to divided attention. Therefore, the type of process being used to solve problems (demanding rule-based processes, for modular arithmetic, or associative processes, to derive simpler solutions) determines whether utilizing shortcuts assists performance. It appears that individuals with high WMCs want to use their skills regardless of the demands placed on their WM, which leads to performance decrements under pressure. Overall, these findings provide evidence that divided attention (worry + demanding task) can lead to performance decrements and that an individual's WMC influences the way they will approach different types of problems under different pressure environments. It is both the consumption of WM resources and the type of problem-solving processes used among those with high WMCs that lead to performance decrements for distraction theories rather than a disruption in automatic procedures.

Overall, it appears that both theories for choking under pressure are plausible and remain open for the continued study of their impacts on individuals' performance. The role of arousal and stress are important but do not entirely describe the reason as to why individuals choke. In relation to working memory and cognitive task performance, Beilock & DeCaro (2007) describe that those greater WMC have difficulty using efficient performance strategies. This aligns with PET (Eysenck & Calvo, 1992) wherein anxiety affects processing efficiency, primarily the central execution portion of the working memory system. Hill et al. (2010) state that PET is "the established distraction theory" (p. 27), meaning that the theory lends itself to describing the relationship between stress and performance. By understanding the relationship between cognition and anxiety, researchers and professionals can become better informed about their mutual relationship with academic or cognitive performance. One way to add to this body of research is by introducing another variable that has been found to disrupt performance among college students. Research indicates that a variety of sleep-related problems disrupt performance (Buboltz, Brown, & Soper, 2001; Carskadon & Roth, 1991; Dewald et al., 2010; Iarovici, 2014; Lockley & Foster, 2012; Mendelson, 2017; Short, Garadisar, Lack, & Wright, 2013; Trockel et al., 2000). Sleep deprivation, poor sleep quality, and variances in sleep-wake cycles are experienced by many college students and can lead to impairments in their functioning (Buboltz et al., 2001; Hawkins & Shaw, 1992; Lack, 1986; Lund et al., 2010; Singleton & Wolfson, 2009). Because there are no studies examining the relationship between choking under pressure and sleep, they will be examined together.

Sleep

Sleep and sleepiness naturally occur in all individuals. Humans typically follow a 24-hour circadian rhythm, meaning that there is a period of the day when humans naturally wake up and become active, typically during day-light hours, and a time when they become less active and eventually fall asleep, typically at night. Sleep is a state in which the body's awareness and responsiveness to its surroundings diminishes, as does consciousness (Mendelson, 2017). Sleep follows a rhythmic pattern throughout its course, cycling through different sleep stages of non-rapid eye movement (NREM) and rapid eye movement (REM) sleep (Mendelson, 2017). During periods of NREM sleep, brain activity subsides and respiration slows; whereas in REM sleep, the brain's activity mimics that of wakefulness, the eyes begin to move, and muscle tone relaxes (Mendelson, 2017). Sleep is a necessary and recurring component of human life and adequate sleep duration and quality are essential for cognitive capabilities and performance, neurological functioning, psychological and physical health, and safety (Alhola & Polo-Kantola, 2007; Harvey, Stinson, Whitaker, Moskovitz, & Virk, 2008; Watson et al., 2015).

Sleep characteristics. There are multiple constructs that can be used to understand and conceptualize sleep health, such as: sleep duration, quality, and efficiency; sleepiness; symptoms of sleep disorders; sleep timing; and more (Buysse, 2014). This study will examine how sleep characteristics such as sleep duration, sleep quality, and delayed sleep phase disorder, with emphasis on inadequate sleep duration, can lead to inadequate performance, especially under pressure within a college student population. *Sleep duration* is defined as "the total amount of sleep obtained per 24 hours" (Buysse, 2014, p. 10) and "the actual time during which an individual is asleep" (Dewald et al., 2010, p. 180). It is also commonly referred to as sleep quantity (Pilcher, Ginter, & Sadowsky, 1997). *Sleep deprivation* is defined as "not obtaining adequate total sleep" (American Sleep Association, n.d.). *Sleep quality* is defined as "the subjective indices of how sleep is experienced including the feeling of being rested when waking up and satisfaction with sleep" (Dewald et al., 2010, p. 180). *Sleep timing* is defined as "the placement of sleep within the 24-hour day" (Buysse, 2014, p. 11). Adolescents and young adults experience a natural, biological tendency for sleep onset and wake time to shift toward a later time (Lund et al., 2010; Mendelson, 2017), which can be exacerbated by environmental factors and behavioral habits (Mendelson, 2017). Over time, these unstable sleep patterns can develop into *delayed sleep phase syndrome or disorder (DSPS/D)*, defined as "a circadian rhythm disorder including a delay in the onset of sleep and a great difficulty getting up at conventional hours, (affecting school performance in children, and work, social or family-life in older patients)" (Moreno-Galarraga & Katz, 2019, p. 387) and can include "significantly later sleep and awakening times during the weekend than during the week" (Brown, Soper, & Buboltz, 2001, p. 474). It is "identified by normal and stable sleep cycle that occurs 2-6 [hours] later relative to patients' desired and socially conventional sleep and rise times" (Micic et al., 2015, p.

29). For college students, balancing academic and social demands often alters the amount of time a student will spend sleeping, may diminish their sleep quality, and cause disturbances in their sleep-wake cycle (Buboltz et al., 2006).

Restricted sleep duration. Sleep deprivation, or restricted sleep duration, is a phenomenon that all humans experience – be it jet lag, a late night in the office, cramming for an examination, daylight saving time, or due to psychiatric symptoms such as anxiety or depressed mood. Restricted sleep duration impacts alertness, performance, cognition, memory, attention, metabolism, and health (Lockley & Foster, 2012), and can negatively impact an individual's well-being, safety, and achievement. It can leave individuals feeling fatigued, sluggish, foggy, confused, and off-balance. Without sleep, individuals become more susceptible to disease and experience decreased well-being (Mendelson, 2017). Unsurprisingly, students who go to sleep late are more likely to report being sleepy during the daytime (Lack, 1986; Singleton & Wolfson, 2009). While scholars have made varying recommendations for adequate sleep duration, the research is clear that there is no exact amount of required sleep that is suitable for all individuals.

In the literature on sleep, sleep deprivation is differentiated into total and partial sleep deprivation (Mendelson, 2017; Philibert, 2005; Pilcher & Huffcutt, 1996). Pilcher & Huffcutt (1996) defined short-term total sleep deprivation as not sleeping for a period of 45 hours or less and partial sleep deprivation as sleeping for less than five hours in a 24-hour period. Researchers have studied partial sleep deprivation with a wide range of sleep hours: 3.5 to 7.5 hours, noting that individuals require varying amounts of sleep (Carskadon & Roth, 1991; Mendelson, 2017; Otmani, Pebayle, Roge, & Muzet, 2005; Watson et al., 2015). Carskadon and Roth (1991) discuss conflicting findings in their review of the research on sleep deprivation, indicating that while 7.5 hours of sleep is optimal for some individuals it may not be enough sleep for others, as restricted sleep duration of less than 7.5 hours per night can result in deficits in daytime functioning, alertness, wakefulness, and performance (Carskadon & Roth, 1991; Mendelson, 2017). However, there appears to be a consensus regarding the minimal period of sleep duration needed before entering into partial sleep deprivation. The National Sleep Foundation (2015), recommends seven to nine hours of sleep for all adults ages 18 to 64, recently adding the new age category of 18 to 25, which incorporates the ages of traditional college students. The American Academy of Sleep Medicine and Sleep Research Society released a join consensus statement regarding sleep health, duration, and recommendations (Watson et al., 2015). They finalized their recommendation to include a minimal threshold for sleep. Their initial consensus also suggested that adults should obtain seven to nine hours of sleep per night for their overall health. However, due to potential perceived consequences of sleeping longer than nine hours, which vary among individuals with limited consensus, they moved toward a minimum threshold of seven hours of sleep for adults. With conflicting findings and discussions on sleeping for a time period between six and seven hours, they determined that sleeping for six hours or less is likely to have detrimental effects on an individual. Further evidence supports these parameters, as experiments that have provided adults with the opportunity to sleep without being disturbed remained asleep for 7.5 to 8.5 hours with an average of 8.17 hours (Mendelson, 2017). While scholars have made varying recommendations for adequate sleep duration, the research is clear that there is no exact amount of required sleep that is suitable for all individuals. However, for the general public, to avoid sleep deprivation, adults should aim for a period of sleep duration that is at least seven hours (Watson et al., 2015).

While there is an established consensus among the research community that adequate sleep is important for physical and mental health, many people tend to remain awake late into the night receiving less sleep or sacrificing their sleep schedules to fit other needs. In the United States, society, and the predominant culture drive people to produce more, work harder, and be socially involved in their communities to the point that our work has become a significant portion of our identity (Fryers, 2006). It is then without surprise, that in America, people are conditioned to ignore bodily cues and work past mental signs of sleepiness. Therefore, individuals believing they are maximizing their productivity may attempt to ward off their sleepiness by continuing to work, study, socialize, or remain awake to relax. People ward off sleepiness in a variety of ways. Some remain in well-lit rooms or are exposed to blue light via television, computer, tablet, or cellphone screens late into the day and up until bedtime. Others use substances to ward of sleepiness or are unaware of the sleep consequences of using caffeine, nicotine, or stimulant drugs, while relying on medications or alcohol to “help” them sleep (Buboltz et al., 2006). All of these factors, and more, have the potential to reduce sleep duration, which could lessen sleep quality and alter sleep-wake patterns.

Sleep quality. The National Sleep Foundation (Ohayon et al., 2017) conducted a study to further identify the key determinants of good sleep quality, which consist of sleeping at least 85% of the time while in bed, a period of sleep latency lasting 30 minutes or less, one or less night time awakenings, and waking for no more than 20 minutes after initially falling asleep. Aligning with research and the subjective experience of poor sleep quality (Dewald et al., 2010; Ohayon et al., 2017; Yu et al., 2012), sleep disturbances encompass a variety of sleep-related problems, including but not limited to initiating and maintaining sleep, drowsiness, sleep quality, fatigue, variances in sleep-wake cycle, health-related problems, and psychiatric illnesses (Cormier, 1990; Mendelson, 2017; Patient-Reported Outcomes Measurement Information [PROMIS], 2018). Sleep quality has been found to be associated with behavior, cognitive function, emotional state, and daytime sleepiness more than sleep duration (Dewald et al., 2010). Additionally, using path analysis, Short et al. (2013) found that sleep quality directly impacted sleep duration, with poor sleep quality resulting in less sleep. These sleep-related problems may be the result of a variety of psychological, physical, and environmental concerns (Cormier, 1990). Howell, Jahig, and Powell (2004) suggest that sleep quality may be a more direct indicator of sleep disturbances than daytime sleepiness since the latter can result from ordinary occurrences, such as recent physical exertion or boredom. In a longitudinal study spanning across one semester, college students were found to have better sleep quality on the weekends than on weekdays, and that by the end of the semester their time in bed decreased while their sleep quality remained the same (Hawkins & Shaw, 1992). With the majority of educational activities taking place during the week, decreased sleep quality on these days can have significant consequences. College students who experience sleep disturbances are likely to also endure difficulties with cognitive decrements, such as irritability, confusion, decreased alertness and focus, memory impairment, mood swings, anxiety, and depression, and physical symptoms, such as longer reaction times, drowsiness, increased blood pressure and sensitivity to pain, and an increase in appetite (Buboltz et al., 2001; Mendelson, 2017). A variety of dynamics can lead to college students experiencing sleep disturbances; however, one element primarily affects adolescents and college students – delayed sleep phase disorder (Curcio et al., 2006; Lockley & Foster, 2012; Wolfson, 2010).

Delayed sleep cycles. A delay in circadian rhythms and genetic factors can contribute to changes in sleep-wake patterns (Iarovici, 2014), which means that a person progressively falls asleep later and wakes up later if there are no pressures to rise at a consistent time. This differs from partial sleep deprivation, such as when an adult goes to sleep later on a weeknight but still rises early. Delayed sleep phase disorder (DSPD; also referred to as delayed sleep phased syndrome, or DSPS) can present as “difficulty falling asleep during the week, problems awakening at a planned time, and morning sleepiness that significantly impairs daily functioning” (Brown et al., 2001, p. 472) and occurs when individuals have a “chronic…but delayed, sleep-wake pattern relative to that of the community” (Mendelson, 2017, p. 84). The onset of DSPD primarily begins during puberty and begins to reverse itself in the early years of adulthood, but for some, it can last an average of 19 years after onset (Micic et al., 2016). Brown et al. (2001) replicated Lack’s (1986) study to determine if college students exhibit symptoms associated with DSPS. They also found that college students are more likely to experience DSPS as compared to the general population, with 11.5% of their college student sample exhibiting these symptoms. Lack (1986) found that 17% of their sample exhibited these symptoms. In a study conducted to understand college students’ sleep patterns and their impact on their daily functioning, researchers found that sleep patterns from high school, such as sleeping and rising later, extend into college (Lund et al., 2010). This is unsurprising as college students are often living without their families and likely experiencing a greater degree of personal freedom, which may allow them to forgo getting adequate sleep for other interests, contributing to a delayed sleep-wake cycle. Additionally, delays in sleep onset and wake times, which might not meet criterion for a sleep disorder or go undiagnosed, have been found to be a result of biological changes in circadian rhythms, early school start times, stress, and external factors, such as caffeine consumption (Lund et al., 2010).

These changes in the sleep-wake cycle can result in consequences for college students, regardless of the cause (Lund et al., 2010). DSPD impacts students’ wakefulness in the morning, as waking up in the morning for school, after sleeping later on the weekend, is comparable to an adult waking up at approximately three or four in the morning (Lockley & Foster, 2012). Even shifting the sleep-wake cycle by two hours, with adequate sleep, can result in students experiencing problems with attention and concentration (Iarovici, 2014), lead to daytime sleepiness (Curcio et al., 2006), and lead to depressive symptoms and problems concentrating (Buboltz et al., 2001). Consistently having irregular sleep-wake cycles leads to increased daytime sleepiness and decreased alertness (Manber, Bootzin, Acebo, & Carskadon, 1996). These changes in the sleep-wake cycle can lead to complications for students as they navigate through various aspects of college life while practicing becoming self-sufficient.

Students are often striving to maintain a balance between academics, interpersonal connectedness, and personal well-being, which includes rest and recovery. As merit-based institutions, universities place a heavy emphasis on academic performance measured through test scores, grades, and evaluations. To maintain these expectations, especially academic ones, it appears that high school and college students tend to sacrifice sleep (Gillen-O'Neel, Huynh, & Fuligni, 2013; Howell et al., 2004). While it may be common for students to sacrifice sleep to maintain good academic standing, this may have the previously discussed adverse effects that can minimize or negate the benefits of foregoing adequate sleep to cram for exams or finish papers. Perhaps even worse, many college students are not aware of the full implications of sleep deprivation or how to improve their sleep hygiene, incorrectly believing that they can simply "catch up" on their sleep the next night or over the weekend (Brown et al., 2001; Buboltz et al., 2006; Lack, 1986; Pilcher & Walters, 1997). Hawkins and Shaw (1992) found that across one semester, college students spent more time in bed on the weekends than on weekdays (Hawkins & Shaw, 1992). However, sleeping longer on the weekend does not replenish the amount of sleep lost during the week (Lockley & Foster, 2012).

Sleep duration, sleep quality, and changes in the sleep-wake cycle can all contribute to one another. Morning responsibilities can increase partial sleep deprivation and personal habits and collegiate lifestyles can lead to their own disruptions in the sleep-wake cycle (Buboltz et al., 2006). Unfortunately, many college students lack proper sleep habits and experience varying degrees of restricted sleep duration and diminished sleep quality, while attending to the various demands, responsibilities, and extracurricular activities in the collegiate environment (e.g., exam weeks, campus and social events) and/or due to the use of stimulants and electronics. These can all lead to total sleep deprivation, such as "pulling an all-nighter," partial sleep deprivation, such as having multiple nights of reduced sleep duration, and extend to changes in the sleep-wake cycle (Lund et al., 2010). Unfortunately, collegiate responsibilities continue as college students adjust to managing their time in a way that promotes overall success and well-being. Proper time management and decision-making skills and proper sleep habits can promote smoother transitions to college and increase their likelihood of successfully completing their academic requirements and additional responsibilities. The present study will focus on the relationship between sleep and stress as they relate to academic/cognitive performance.

Relationship Between Sleep and Stress/Anxiety

As previously discussed, stress and anxiety are not uncommon among the college student population. According to research, there is an influential relationship between sleep and stress/anxiety. Anxiety has been found to be correlated with sleep complaints in a non-clinical adult population, with anxiety being correlated with insomnia and circadian rhythm concerns (Spoormaker & van den Bout, 2005). Individuals experiencing insomnia often report higher levels of anxiety and depression (Nyer et al., 2013), and sleep deprivation significantly impacted anxiety scores (Baum et al., 2014). A meta-analysis yielded results which suggest that total sleep deprivation, not sleep restriction, can lead to increased state anxiety; however, a wide variety of sleep and anxiety measurements had been utilized across the reviewed articles and experiments (Pires, Bezerra, Tufik, & Andersen, 2016). Research indicates that, among adults, state anxiety increases sleep-onset latency duration and difficulty waking in the morning (Horváth et al., 2016), whereas among college students, a strong correlation has been identified between trait anxiety and insomnia, and sleep-onset latency and sleep quality (Sadigh, Himmanen, & Scepansky, 2014). College students seem to experience symptoms of anxiety and tension at a higher rate than older, non-enrolled adults who were also classified as poor sleepers (Jenson, 2003). College students diagnosed with or displaying significant symptoms of depression and anxiety self-reported significantly more sleep problems than those without, while those with co-morbid anxiety and depression reported the highest number of sleep problems (Boehm et al., 2016). Furthermore, some research has found that sleep quality, rather than sleep quantity, is strongly correlated with mental health and wellness symptoms (Pilcher et al., 1997). Additionally, a study found that college students self-reported that stress and tension are the greatest predictors of their diminished sleep quality (Lund et al., 2010). These studies provide evidence to suggest that there is a general relationship between stress/anxiety and sleep that is particularly pronounced among college students.

The type of anxiety being measured (e.g., cognitive arousal, physiological symptoms) could help lend further evidence to examine the relationship more thoroughly between sleep and anxiety. A bidirectional relationship has been found between anxiety, especially regarding cognitive arousal, described as rumination and worry, and both sleep-onset latency and sleep quality (Kalmbach, Arnedt, Swanson, Rapier, & Ciesla, 2017). This was further supported when anxiety symptoms, such as worry and intrusive thoughts, were found to have a bidirectional relationship with insomnia, leading to increased worries about obtaining adequate sleep and reduced sleep among undergraduate students (Kirwan, Pickett, & Jarrett, 2017). College students who reported experiencing sleep disturbances were found to score significantly higher on the Anxiety Symptom Questionnaire (ASQ), while not scoring significantly higher on the Beck Anxiety Inventory (BAI; Nyer et al., 2013), which could be due to the fact that the BAI measures primarily physiological symptoms associated with anxiety, whereas the ASQ measures both somatic and psychological symptoms of anxiety. Therefore, in this case, it is the impact of perceived stress on an individual's well-being that results in diminished sleep quality. Cognitive arousal has been shown to lead to greater sleep loss than somatic arousal (Kirwan et al., 2017). These findings suggest that there is the potential for there to be a relationship between sleep and the stress/anxiety associated with choking under pressure as described in distraction theory.

Sleep and academic performance. As previously discussed, there are variations in the way that academic performance is measured, even among sleep studies, such that these indicators of performance are the culmination of academic performance over time, which can overlook discrete performance decrements that impact academic experiences. Furthermore, these are not controlled experimental studies. As a result, this calls into question whether it is the sleep studies or the performance markers that are not capturing a potential relationship between sleep deprivation and the quality of academic performance. For example, among minors when school performance was measured by questionnaires, standardized tests, and GPA, a meta-analytic review of sleep and school performance revealed that sleepiness among children and adolescents had the strongest relationship with school performance, followed by sleep quality and sleep duration (Dewald et al., 2010). Another study on adolescents found that it was perhaps not sleep quality or duration that impacts school performance (e.g., class grades), but rather, the consequent impact of sleep quality on daytime alertness and depressed mood was found to be more directly correlated with performance decrements (Short et al., 2013). It appears that sleep and performance may have a bidirectional relationship but the causation regarding their influence on one another has not been determined. While these studies are not focused on college students as their population of interest, these studies provide insight into which avenues to explore among college students.

A study of first-year college students yielded results which indicate that variable weekday and/or weekend sleep times negatively impact GPA and that the impact of sleep times is greater than hours spent working or volunteering, support systems, mental health concerns, and wellness behaviors (Trockel et al., 2000). They discerned that for every hour of delay in weekday and weekend wake-up times, GPA decreased by 0.132 and 0.115 points, respectively, and delayed bedtimes and time spent asleep on the weekend also had significant results (Trockel et al., 2000). College students with delayed sleep phase syndrome (17%) were the only group to see a lower course grade, while those with general sleep troubles or problems with falling or staying asleep found no impaired academic performance (Lack, 1986). These results demonstrate clear evidence for a relationship between sleep and academic performance at the collegiate level. However, these studies are not experimental and may neglect to find nuances and causal relationships between sleep and performance.

Sleep, stress, and academic performance. Previous research has conclusively demonstrated that a relationship does exist between sleep, stress, and academic performance. As stated previously, there is a bidirectional relationship between stress/anxiety and sleep. Furthermore, previous research has revealed that academic stress is most likely to interfere with sleep quality among college students (Lund et al., 2010). While all three factors have now been examined in all pair configurations, it is unclear if sleep or stress is the moderating factor in academic performance. However, a research study did find that 32.8% of students with anxiety indicated that their sleep difficulties negatively affected their academic performance (Boehm et al., 2016). A study on medical students found that perceived stress, sleep quality pre-exam, and academic performance were significantly correlated but not throughout the semester or post-exam (Ahrberg et al., 2012). Based on these studies, it appears that sleep quality and stress together were required to demonstrate an effect on academic performance. Therefore, while there is evidence that demonstrates a relationship between stress, sleep, and academic performance, the exact mechanism behind the relationship is still little understood.

Sleep and cognitive performance. College students, in particular, are in a unique time period in which they must become more independent and responsible for their academic work, living situation, and physical well-being all while their prefrontal cortex is continuing to develop (Broderick & Blewitt, 2010). Poor sleep has been found to be associated with cognitive impairment (Nyer et al., 2013). Consistently receiving less than eight hours of sleep per night disrupts REM sleep leading to challenges integrating and consolidating new information (Buboltz et al., 2001). State and trait anxiety were associated with NREM sleep variances, in which stage 2 sleep increased and stage 3 sleep decreased, potentially leading to memory impairment (Horváth et al., 2016). Watson et al. (2015) recommended at least seven hours of sleep for the average adult, with anything less than that leading to diminished cognitive performance. A group of college students who underwent total sleep deprivation over a 24-hour period were found to perform significantly worse on a complex cognitive task, yet they estimated their own performance and ability to concentrate higher than another group of college students who received eight hours of sleep (Pilcher & Walters, 1997). So students who experience decreased cognitive abilities and increased sleepiness may find it difficult to complete coursework or remain attentive during a lecture, they may also seriously underestimate the degree to which reduced sleep negatively impacts their own performance.

With regards to cognitive processes, such as working memory, disrupted sleep can impair arousal and executive functioning (McCoy & Strecker, 2011). Through a meta-analysis, sleep deprivation for 24 to 48 hours was found to have a moderate effect on working memory accuracy and reaction time (Lim & Dinges, 2010). Lowe et al. (2017) also conducted a meta-analysis and found that sleep restriction impaired working memory performance with no significant differences between accuracy and reaction time. The number of days of restricted sleep did not moderate the relationship between sleep restriction and working memory performance. However, Durmer and Dinges (2005) found that repeated nights of sleep restricted to three to six hours resulted in accuracy and reaction time decrements on working memory tasks, while two weeks with four or six hours of sleep resulted in working memory and attention impairments equivalent to those of a person who had not slept for two days or one day, respectively. Positively, sleeping for eight hours at night resulted in no cognitive impairments. At this time, the primary researcher has not found substantial research that has focused on sleep quality or variations on sleep-wake cycles with specific regard to working memory.

Research has established that there is a relationship between an individual's working memory resources and how demands placed on working memory impact cognitive performance. Problems that are demanding rely more heavily on working memory resources (i.e., processing and storage). Pressure can induce stress or worry and place further demands on working memory. Those with greater working memory capacities tend to be the individuals that choke under pressure when completing high demand problems. Cognitive performance (accuracy in particular) tends to decline under pressure as working memory resources are divided to attend to both stress or worry and the task at hand. Additionally, research has established that restricted sleep leads to performance decrements (measured by accuracy and reaction time) on working memory tasks. It is reasonable then to consider that a high-pressure condition would lead to an even greater decline in performance for someone who is sleep deprived.

Proposed Study

In the proposed study, participants will complete mathematical calculations that place low and high demands on working memory resources in conditions of low- and high-pressure. Their working memory capacity will be assessed, and finally, students will complete measures assessing their sleep duration, subjective sleep quality, and variations in the sleep-wake cycle. Ultimately, this study aims to examine how individual differences in sleep duration, timing, and quality relate to cognitive task performance and working memory capacity in a high-pressure situation, while solving high demand problems. These findings could contribute to the field of counseling psychology by furthering our understanding of how sleep, stress, and pressure impact cognitive performance among college students. By incorporating such findings into related therapy and educational services, therapists, educators, other professionals could better inform college students about the necessity of good sleep hygiene and adequate sleep, and how they moderate the relationship between high-stress events and academic performance.

Research Questions and Hypotheses

Confirmatory analysis. The following hypotheses were made in regard to the confirmatory predictor variables, *pressure condition*, *sleep duration*, and *working memory capacity*, and the dependent variable, *performance* as measured by *accuracy* when solving *high demand problems*.

1. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and sleep duration, to what extent does a high-pressure scenario predict performance (i.e., accuracy) on high demand problems?
    a. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and sleep duration, participants in the high-pressure condition will be less accurate in solving high demand modular arithmetic problems than will participants in the low-pressure condition. *This prediction is based upon the findings from the Beilock et al. (2004) study where individuals who completed high demand problems in a high pressure environment, without practice effects, performed worse as measured by accuracy.*
2. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and pressure condition, to what extent does sleep duration predict performance on high demand problems?
    a. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and pressure condition, sleep duration will uniquely and positively predict accuracy on high demand modular arithmetic problems. *This prediction is based upon the research that sleep restriction across time led to cognitive impairments in working memory and attention, while eight hours of sleep resulted in no cognitive impairments (Durmer & Dinges, 2005).*
3. After controlling for caffeine intake and accounting for the other main effects of pressure condition and sleep duration, to what extent does working memory capacity predict performance on high demand problems?

a. After controlling for caffeine intake and accounting for the other main effects of pressure condition and sleep duration, working memory capacity will uniquely and positively predict accuracy on high demand modular arithmetic problems. *This prediction is based upon the research from Beilock and Carr's (2005) study that individuals with high working memory capacities will perform more accurately on high demand problems than those with low working memory capacities.*

4. To what extent does working memory capacity predict performance in a high-pressure scenario on high demand problems, as compared to those in a low-pressure scenario?

   a. Among participants in a high-pressure condition, there will be a significant and negative relationship between working memory capacity and accuracy on high demand modular arithmetic problems. *This prediction is based upon the findings from Beilock and Carr's (2005) study in that those with a high working memory capacity noticed greater performance decrements, as compared to those with low working memory capacity in a high pressure condition on high demand problems*.

   b. Among participants in a low-pressure condition, there will be a significant and positive relationship between working memory capacity and accuracy on high demand modular arithmetic problems. *This prediction is based upon the findings from Beilock and Carr's (2005) study in that those with high working memory capacities performed better, as measured by accuracy, on high demand problems as compared to their counterparts with low working memory capacities.*

5. After accounting for the above main effects and relevant two-way interactions, do sleep duration, working memory capacity, and pressure interact to predict performance on high demand problems?
    a. Among participants in the high working memory capacities, sleep duration will moderate the relationship between pressure and accuracy on high demand modular arithmetic problems:
        i. Among participants with low sleep duration, there will be a moderate negative relationship between pressure condition and accuracy on high demand modular arithmetic problems, such that participants in the high-pressure condition have less accuracy than participants in the low-pressure condition. *As previously discussed, those with high working memory capacity are expected to see a decline in performance on high demand problems in a high pressure condition and sleep restriction over time leads to cognitive impairment. Because sleep restriction is noted to impact cognitive performance so it is expected that that sleep will have a moderate, negative moderating effect between working memory capacity and accuracy.*
        ii. Among participants with high sleep duration, there will be a negative, but less strong, relationship between pressure condition and accuracy on high demand modular arithmetic problems. *As previously discussed, those with high working memory capacity are expected to see a decline in performance on high demand problems in a high pressure condition regardless of sleep duration.*

b. Among participants with low working memory capacity, sleep duration will moderate the relationship between pressure and accuracy on high demand modular arithmetic problems:

   i. Among participants with low sleep duration, there will be a small negative relationship between pressure condition and accuracy on high demand modular arithmetic problems. *As previously discussed, those with low working memory capacity are not expected to notice a significant performance decrement in a high pressure condition as compared to a low pressure condition on high demand problems. However as previously discussed, sleep restriction is noted to impact cognitive performance so it is expected that that sleep will have a small negative moderating effect between pressure and accuracy.*

   ii. Among participants with high sleep duration, pressure condition will not predict accuracy on high demand modular arithmetic problems. *As previously discussed, those with low working memory capacity are not expected to notice a significant performance decrement in a high pressure condition as compared to a low pressure condition on high demand problems. Also previously discussed, eight hours of sleep resulted in no cognitive impairments so performance decrements are not expected for those with low working memory capacities without sleep restriction.*

The following hypotheses were made in regard to the confirmatory predictor variable, *pressure condition*, *sleep duration*, and *working memory capacity*, and the dependent variable, *performance* as measured by *reaction time*.

1. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and sleep duration, to what extent does high-pressure scenario predict performance time (i.e., reaction time) on high demand problems?
    a. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and sleep duration, participants in the high-pressure condition will more quickly solve high demand modular arithmetic problems than will participants in the low-pressure condition. *This prediction is based upon the findings from Beilock and Carr's (2005) study where individuals completed problems faster in the high pressure condition.*
2. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and pressure condition, to what extent does sleep duration predict performance time on high demand problems?
    a. After controlling for caffeine intake and accounting for the other main effects of working memory capacity and pressure condition, sleep duration will uniquely and negatively predict reaction time on high demand modular arithmetic problems. *This prediction is based upon the research that different sleep disturbances result in longer reaction times to include restricted sleep (Buboltz et al., 2001; Cain et al., 2011; Mendelson, 2017).*
3. After controlling for caffeine intake and accounting for the other main effects of pressure condition and sleep duration, to what extent does working memory capacity predict performance time on high demand problems?
    a. After controlling for caffeine intake and accounting for the other main effects of pressure condition and sleep duration, working memory capacity will uniquely

and negatively predict reaction time on high demand modular arithmetic problems. *This prediction is based upon the findings from Beilock and Carr's (2005) study where individuals with higher working memory capacities solved problems faster than those with low working memory capacities.*

4. To what extent does working memory capacity predict performance time in a high-pressure scenario on high demand problems, as compared to those in a low-pressure scenario?
    a. Among participants in a high-pressure condition, there will be a nonsignificant relationship between working memory capacity and reaction time on high demand modular arithmetic problems. *This prediction is based upon the findings from Beilock and Carr's (2005) study where there was no interaction between working memory capacity and pressure condition.*
    b. Among participants in a low-pressure condition, there will be a nonsignificant relationship between working memory capacity and reaction time on high demand modular arithmetic problems. *This prediction is based upon the findings from Beilock and Carr's (2005) study where there was no interaction between working memory capacity and pressure condition.*
5. After accounting for the above main effects and relevant two-way interactions, do sleep duration, working memory capacity, and pressure interact to predict performance time on high demand problems?
    a. Among participants with high working memory capacity, sleep duration will moderate the relationship between pressure and reaction time on high demand modular arithmetic problems:

i. Among participants with low sleep duration, there will be a positive relationship between pressure condition and reaction time on high demand modular arithmetic problems, such that participants in the high-pressure condition will have significantly higher reaction times than will participants in the low-pressure condition. *As previously discussed, those with high working memory capacities are already expected to perform faster on problems and in general participants are expected to perform faster in a high pressure condition. However, a meta-analysis found that sleep restriction over time leads to cognitive impairment to include slower reaction times (Lowe et al., 2017). Thus, is it expected that their performance outcomes (as measured by reaction time) will be slower in a high pressure condition due to the additional cognitive load in that those with higher working memory capacities will lose their edge with reduced sleep. The researcher postulates that adding the moderating variable of sleep duration could reasonably be the tipping point resulting in a significant interaction.*

ii. Among participants with high sleep duration, pressure condition will not predict reaction time on high demand problems. *Those with adequate sleep are not anticipated to have impaired cognitive performance (Watson et al., 2015) and previous research has not supported an interaction between working memory capacity and pressure condition (Beilock & Carr, 2005).*

b. Among participants with low working memory capacity, sleep duration will moderate the relationship between pressure and reaction time on high demand modular arithmetic problems:

i. Among participants with low sleep duration, there will be a small positive relationship between pressure condition and reaction time on high demand modular arithmetic problems. *Those with low working memory capacities are expected to perform slower than those with high working memory capacities and in general participants are expected to perform faster in high pressure condition. However as previously discussed, sleep restriction has been found to slow reaction times. The researcher postulates that adding the moderating variable of sleep duration could lend to a positive relationship in it will take longer to perform the task in a high pressure environment but not necessarily significantly.*

ii. Among participants with high sleep duration, pressure condition will not predict reaction time on high demand modular arithmetic problems. *As previously discussed, those with adequate sleep are not anticipated to have impaired cognitive performance and previous research has not supported an interaction between working memory capacity and pressure condition.*

Exploratory analysis. The primary investigator also planned to explore additional, separate relationships between *pressure condition*, *working memory capacity*, and two sleep variables – *subjective sleep disturbance* and *variation in wake cycles* – separately on the dependent variables, *performance* as measured by *accuracy* and *reaction time*.

CHAPTER III

Method

Participants

A power analysis was used to determine the appropriate sample size for the study to obtain an acceptable effect size. The eta square effect size of .07 was used from a 3-way interaction with similar variables (working memory, problem demand, and pressure condition; Beilock & Carr, 2005). By converting eta square to f square, the effect size of .08 and was used for power analysis. A power analysis (G*Power 3.1) for three tested predictors and 6 total predictors determined that 101 participants would be required to demonstrate statistical significance ($p < 0.05$) with adequate power (0.8) when completing a hierarchical linear regression.

Participants were recruited for the study from Auburn University's College of Education SONA pool, which is populated by students enrolled in undergraduate courses in the College of Education. Participants received 4.5 SONA credits for their participation in the study. All participants in the high pressure condition received $10. The top five performances in the high pressure condition, as measured first by accuracy and then reaction time as a tie break, received $50, $40, $30, $20, and $10, respectively.

In the current study, a total of 137 individuals participated. Of the 137 respondents, 33 were excluded from all analyses. Of the 33, nine answered less than 50% of the experimental MA problems correctly in block 1. After they were excluded, another 21 were removed for not obtaining 85% accuracy on one or both working memory (WM) tasks. The final three were aware of the manipulation as evidenced though the exit survey and were removed for analyses. One was due to taking a sport psychology class were choking under pressure is taught.

Participants completed all items in the self-reported measures; thus, there was no missing data. In total, 33 participants were excluded from all analyses. After these exclusions, the final sample for analysis in the current study consisted of 104 individuals.

Measures

Demographic information. All participants completed a demographic questionnaire (Appendix A). Items were multiple choice and fill-in and included questions about their age, gender, race and/or ethnicity, sex identity, sexual orientation, educational level, and caffeine intake prior to the appointment. Participants' ages ranged from 18 to 29 years old, with a mean age of 20.25 years (median and modal age were 20 years) and *SD* = 1.64. Of the total participants, those who consumed caffeine prior to their appointment (*n* = 54) consumed a mean of 144.59mg (median 143mg and mode 200mg) and *SD* = 72.198. See Table 1 for additional participant demographic information.

Table 1

Demographic Information for Sample

Demographic	Total (*n*=104)	Percentage (% of *n*)
Gender/Gender Identity		
Woman	68	65.38
Man	36	34.62
Gender Fluid	0	0.00
Nonbinary	0	0.00
Race/Ethnicity		
African American or Black	2	1.92

Asian or Asian American	4	3.85
Caucasian or White	89	85.58
Hispanic or Latina/o/x	2	1.92
African American or Black and Caucasian or White	1	0.96
Asian or Asian American and Caucasian or White	1	0.96
Caucasian or White and Hispanic or Latina/o/x	1	0.96
Caucasian or White and Native Hawaiian or Other Pacific Islander	3	2.88
Hispanic or Latina/o/x and Native American or Alaskan Native	1	0.96
Transgender		
Yes	0	0.00
No	104	100.00
Sexual Orientation		
Asexual	5	4.81
Bisexual	3	2.88
Heterosexual	92	88.46
Lesbian	2	1.92
Queer	1	0.96
Prefer Not to Say	1	0.96
Highest educational level		
High School Diploma	21	20.19
First Year College Student	15	14.42

Second Year College Student	20	19.23
Third Year College Student	24	23.08
Fourth Year College Student	18	17.31
Fifth Year College Student	4	3.85
Degree from a 2-year College or University	1	0.96
Or Please Specify:	1	0.96
Caffeine consumed prior to appointment		
Yes	54	51.92
No	50	48.08

Note. *N*=104. Presented in the table is the demographic data collected from the sample to include gender identity, race/ethnicity, sexual orientation, highest educational level, and caffeine consumed prior to completing the procedures of the study.

Working memory. The Reading Span and Operation Span tasks were used to assess working memory capacity (WMC). Both tasks are available for download from the Engle Lab website (http://psychology.gatech.edu/renglelab/; for the user's guide, reference Conway et al., 2005). These measures are considered "dual-task" because they assess the processing and storage components of WMC (Conway, et al., 2005). The two measures that were used have been utilized together in at least three choking under pressure studies (Beilock & Carr, 2005; Beilock & DeCaro, 2007; Mattarella-Micke et al., 2011). These tasks are two of the most commonly utilized complex working memory (WM) span tasks (Conway et al., 2005). Additionally, it is important when measuring WMC to use more than one WM span task (Conway et al., 2005; Draheim, Harrison, Embretson, & Engle, 2017) or use larger set sizes when only using one WM task while evaluating WMC (Draheim et al., 2017). According to the research of Draheim et al.

(2017), completing larger set sizes is ideal when testing working memory capacity among individuals at the upper end of the distribution – that is people with average to high average abilities. Both of these tasks, among other complex WM span tasks, were designed to assess the storage, rehearsal, and processing of extraneous information to measure complex WM (Conway et al., 2005). The two complex WM task scores were combined for a total WMC score (between 0 and 75) by determining the mean score from the two individual tasks, as similarly conducted in Beilock and Carr (2005). Participants must correctly solve 85% of the problems in each task; otherwise, their data will be removed (Conway et al., 2005; Unsworth, Heitz, Schrock, & Engle, 2005).

Reading Span. The Reading Span test (RSPAN) was initially developed by Daneman and Carpenter (1980) to "measure the span of working memory" (p. 453). A modified RSPAN task has been used in a variety of choking under pressure studies to measure WMC (Beilock & Carr, 2005; Beilock & DeCaro, 2007; Mattarella-Micke et al., 2011). An automated version of the same task used in these three studies, but with larger set sizes, was used in this study. The Automated RSPAN (ARSPAN; Conway et al., 2005) task that was used for this study, demonstrated in Unsworth, Redick, Heitz, Broadway, and Engle (2009), is a 75-item measure across 15 trials. ARSPAN is designed for the computer and can be administered in a variety of settings. The automated version allows individuals to work at their own pace and monitors their response times. The monitoring of response times prompts individuals to work consistently and does not allow them the time to sit and rehearse letters (Unsworth et al., 2005).

The participant began the ARSPAN with the first of three practice sessions to familiarize themselves with the software by memorizing a set of letters that appear on the screen for 800 ms. Afterwards, a 4x3 grid of letters appeared and the participant clicked on the box next to the letter. The computer software informed the participant of their performance. The participant was then ready to begin practicing the traditional element of the task, which was reading the sentence and assessing its accuracy (Daneman & Carpenter, 1980; Unsworth et al., 2005). The participant saw a sentence (e.g., Andy was stopped by the policeman because he crossed the yellow heaven) and determined if it was sensical. The individual clicked to the next screen which asked the participant to respond to the statement, “This sentence makes sense.” Participants responded by clicking “TRUE”, if the sentence made sense and “FALSE”, if it did not make sense. Following their response, the computer told them if their answer is “correct” or “incorrect” before they clicked to advance to the next problem. They completed 15 practice sentences. After they completed the practice problems, the computer informed them of their overall score and provided a percentage. Throughout the process, their responses were timed and the program stored and calculated the average time needed to solve the math problems plus 2.5 *SD*. The final practice session required participants to read sentences as before; however, once they clicked the button to indicate that they solved the problem a letter comes up that needed be committed to memory to be recalled later. Therefore, the participant saw a sentence (e.g., Andy was stopped by the policeman because he crossed the yellow heaven) and determined if it is sensical. They quickly clicked to advance to the next screen to determine if the sentence made sense by clicking “TRUE” or “FALSE”. As soon as they answered the question, the page briefly displayed a letter (e.g., T) for 800 ms. If the problem was not solved within the average time frame plus 2.5 *SD*, then the program automatically moved on to the next problem rather than showing the participant a letter to recall and scored it as a reading error. At the end of a set, a 4x3 grid of letters appeared and the participant clicked on the letters in the order they appeared. If the participant forgot a letter, they selected “BLANK” to hold the space of a forgotten letter. Participants were informed of the number of letters they correctly recalled and the percentage of sentences that were accurately assessed as being sensical or nonsensical. Participants completed three practice trials of two sentences with letters, also referred to as a set size of two, prior to moving on to the official trials (Unsworth et al., 2005).

To complete the 15 experimental trials, individuals completed three trials of set sizes three to seven, at random, so each set size is completed three times. All sentences had a length of 10 to 15 words. Participants saw a sentence appear on the screen for no longer than their average time plus 2.5 *SD* from their practice trial. Then they clicked with their mouse to move to the next screen. They saw the same type of statement on the screen as in the last practice trial on the screen and clicked “TRUE” if the sentence is sensical or “FALSE” if the sentence was nonsensical. After they responded, the next screen displayed a letter for 800 ms, which they needed to remember. At the end of the set, letters were presented in the same grid-fashion. The participants selected the letters in the order that they were presented. Feedback regarding their letter selection and sentence performance were provided to the participant for 2,000 ms. Participants were encouraged to maintain a sentence accuracy of 85 percent or better throughout the session. Immediately following the recall period for each set, a percentage was shown at the top right portion of the screen indicating their sentence accuracy. Overall, participants read 75 sentences and were asked to recall 75 letters. Total scores for the ARSPAN range from 0 to 75. The task takes approximately 20-25 minutes (Unsworth et al., 2005).

In regard to scoring the ARSPAN, an individual needed to correctly identify if the sentences were sensical at a rate of 85 percent in order to ensure accuracy, otherwise the data was omitted. This was to ensure that participants were engaged in the task, and subsequently, their performance is representative of their WMC (Conway et al., 2005). The program totaled two scores and three types of errors (Unsworth et al., 2005). The ARSPAN score provided partial-credit load scoring, which was the number of correctly recalled items for each set regardless of order. Therefore, if the individual recalled four letters in a set size of four, two letters in a set size of five, and three letters in a set size of three their ARSPAN score would have be seven (4 + 2 + 3) out of 12. The total number correct was the total number of letters recalled in any order. Based upon empirical results, Conway et al. (2005) recommended that credit should be applied to the items that were correctly recalled even if some were omitted, which is referred to as partial-credit scoring as opposed to absolute scoring methods. Partial-credit load scoring demonstrated the best internal consistency reliability (.776) as compared to all-or-nothing load scoring (.699; Conway et al., 2005). The three types of errors were comprised of sentence errors, accuracy errors, and speed errors. Sentence errors were the combination of accuracy errors, where the individual failed to correctly comprehend if the sentence is sensical, and speed errors, where the individual exceeded the time allotted to solve the problem.

Test-retest reliability in studies with adults found correlations between r = .70-.80 across the time period of several minutes to over three months (Conway et al., 2005). Unsworth et al. (2009) reviewed research studies and found that complex span tasks have been shown to have moderate to high internal consistencies and test-retest reliabilities and load onto the broad working memory factor in exploratory and confirmatory factor analyses. Additionally, the RSPAN is moderately correlated with the AOSPAN and the counting span task, similar to the OSPAN (Unsworth et al., 2005). RSPAN has demonstrated good psychometric properties and has been found to have correlations with similar complex WM tasks as well as other tasks that rely upon WM, such as a range of cognitive tasks including complex-task learning; language, listening, and reading comprehension; writing; and reasoning (Conway et al., 2005).

Performances on the automated RSPAN and AOSPAN were found to be correlated among college and community samples r = .61-.68 (Redick et al., 2012). Discriminant validity was established by diverging from simple span tasks (e.g., digit span), as these tasks do not predict complex cognition, and it does not illustrate automatic processing or the ability to recall information without the use of a distractor (Conway et al., 2005). Cronbach's alpha for RSPAN was .78 (Kane et al., 2004). Cronbach's alpha for automated RSPAN was .86 and .88 for partial scoring and .78 and .83 for absolute scoring when using two methods from previous research studies (Redick et al., 2012).

Operation Span. The Operation Word Span task (OSPAN; Turner & Engle, 1989) was developed to further understand the relationship between working memory capacity and reading comprehension abilities. A modified OSPAN task has been used in choking under pressure studies to measure WMC (Beilock & Carr, 2005; Beilock & DeCaro, 2007; Mattarella-Micke et al., 2011) and is also considered a dual-span task (Conway et al., 2005). It has been cited for assessing complex working memory in multiple studies (Beilock & Carr, 2005; Beilock & DeCaro, 2007; Conway et al., 2005; Mattarella-Micke et al., 2011; Unsworth et al., 2005).

This study utilized the automated OSPAN task (AOSPAN). It is procedurally identical to the ARSPAN task (Unsworth et al., 2005) instead now the participant used elements of the traditional OSPAN task and solves a math operation (Turner & Engle, 1989; Unsworth et al., 2005). In the AOSPAN, the participant saw a mathematical problem (e.g., (8*2) – 8 = ?) and was instructed to click after solving the problem. On the next screen, the individual decided if the number they saw was the correct answer to solve the math problem by clicking the "TRUE" or "FALSE" button. From here, the letters, instructions, practice and experimental trials, set sizes, and accuracy requirements were identical to the ARSPAN task. Across all of the trials, participants solved 75 math problems and were asked to recall 75 letters. Total scores for the AOSPAN range from 0 to 75. The task took approximately 20-25 minutes (Unsworth et al., 2005).

The scoring process for the AOSPAN was identical to that of the ARSPAN. As with the ARSPAN, the program totaled the same two scores and three types of errors and utilizes absolute scoring (Unsworth et al., 2005). The three types of errors were comprised of math errors, accuracy errors, and speed errors. Math errors were the combination of accuracy errors, where the individual fails to correctly solve the math problem, and speed errors, where the individual exceeds the time allotted to solve the problem. When scoring the AOSPAN, an individual also needed to correctly respond to 85 percent of the items in order to ensure accuracy, otherwise the data were omitted. As with the RSPAN, Conway et al. (2005) recommended that credit should be applied to the elements that were recalled even if some were omitted. For the OSPAN, partial-unit load scoring demonstrated the best internal consistency reliability (.808) as compared to all-or-nothing unit scoring (.701; Conway et al., 2005).

Similar to the RSPAN, studies demonstrated that test-retest reliability was correlated between *r* = .70-.80, for adults, ranging from several minutes to over three months (Conway et al., 2005). The AOSPAN demonstrated good test-retest reliability (.83; Unsworth et al., 2005). The AOSPAN was found to be moderately correlated with OSPAN; however, it is speculated that this is because of the changes in presentation of the stimulus as well as the recollection of a letter rather than a word (Unsworth et al., 2005). Additionally, the AOSPAN was moderately correlated with the RSPAN and the counting span task, similar to the OSPAN (Unsworth et al., 2005). Unsworth et al.'s (2009) research found that automated complex span tasks have moderate to high internal consistencies and test-retest reliabilities and load onto the broad working memory factor in exploratory and confirmatory factor analyses. The OSPAN has demonstrated good psychometric properties (Conway et al., 2005). It has been found to correlate with similar tasks assessing WM as well as other tasks that rely upon WM (Conway et al., 2005). The AOSPAN and automated RSPAN were found to be correlated among college and community samples .61-.68 (Redick et al., 2012). Discriminant validity was established by diverging from simple span tasks, as these do not predict complex cognition, and it was unable to demonstrate one's automatic processing ability or their ability to recall information without the use of a distractor (Conway et al., 2005). Cronbach's alpha for OSPAN was .80 (Kane et al., 2004). Cronbach's alpha for AOSPAN was .84 and .86 for partial scoring and .75 and .80 when utilizing two methods from previous research studies (Redick et al., 2012).

Accuracy and reaction time. Modular arithmetic (Appendix B) was used to assess individuals' performance (e.g., accuracy and reaction time), while completing low- and high-demand problems under low- and high-pressure conditions. Modular arithmetic has been utilized in at least three choking under pressure studies in low- and high- pressure scenarios (Beilock & Carr, 2005; Beilock & DeCaro, 2007; Mattarella-Micke et al., 2011). For this study, performance scores on modular arithmetic were determined by scoring participants' *accuracy* and measuring *reaction times* when solving high-demand problems in low- and high-pressure situations. Each individual completed two experimental blocks, either two in low-pressure conditions or one in the low-pressure followed by one in the high-pressure condition. Scores in the pre-test block (T1) were subtracted from their scores in the post-test block (T2) for a difference score for each individual. Reaction times were also configured by subtracting their T2 times from their T1 times (in ms) for a difference score for each individual. Individuals who did not correctly solve the MA problems 50% of time or more on the first low-pressure condition were removed to ensure participants are performing above chance, as suggested in Beilock and DeCaro (2007).

Modular arithmetic**.** J.C.F. Gauss' (1801) modular arithmetic (MA) task, as demonstrated in Beilock (2008), Beilock and DeCaro (2007), Beilock et al. (2004), and Mattarella-Micke et al. (2011), was used in this study because the task requires WM capabilities to mentally hold information (e.g., storage), while solving (e.g., processing) the entire problem.

In this study, all MA problems followed the formula "x ≡ y (mod. z)". The first number (x) was always greater than the second number (y). The first number ranged from 2-99. To solve the problem, the participant took y and subtracted it from x to get a number. The last number (z) was an integer 2-9, which is called the mod. function. If the subtracted number (x-y) was divisible by z as a whole number integer, then the answer was true. For example, 5 ≡ 3 (mod. 2) is true because 5 – 3 = 2 and 2 ÷ 2 = 1, which is a whole number integer. This type of mathematical problem was ideal because it is a novel mathematical task for many individuals. More challenging problems, or high-demand problems, required a borrowing operation and two double digit numbers (e.g., 34 – 19) and were not readily divisible by a simple heuristic (e.g., mod. 2 or 5), while low-demand problems were single digits (e.g., 7 – 2), did not require borrowing (e.g., 27 – 15), or could be readily solved by using a simple heuristic (Mattarella-Micke et al., 2011). Simple heuristics were found to place less demand on WM (DeCaro, Wieth, & Beilock, 2007). Participants' response time and accuracy in correctly solving the problems was collected. Participants were provided with a set of practice problems and need to solve 50% or more of the problems correctly to demonstrate that they were not solved correctly by chance alone; otherwise, their data were removed from analysis (Beilock & DeCaro, 2007).

All participants completed 36 MA problems in each experimental block: 18 high-demand problems and 18 low-demand problems. Half of the problems at both demand levels were true and the other half were false. Similar to Beilock and DeCaro (2007) and Beilock et al. (2004), each true problem also had a false correlate within the same set. The false correlate was differentiated by only the mod. function, which was the number used in the division step. Therefore, a MA problem that was true $63 \equiv 19$ (mod. 4) was presented during the same set as its false correlate $63 \equiv 19$ (mod. 3). The purpose of these true problems and false correlates was to reduce confounds generated as a result of not equating the problems. Problems were presented in random order to each participant and each problem was only presented once. The problems in the two experimental blocks were counterbalanced to eliminate the possibility of the particular set of problems contributing to the results of the participants' performance.

The reason that this type of problem was useful is because tasks that require WM are susceptible to choking under pressure due to the strain that pressure places on WM. Borrowing subtraction problems with large numbers are believed to place greater demands on WMC than those with small numbers and without a borrowing operation (Ashcraft & Kirk, 2001). WM requires attentional control in order to operate at its highest potential (Engle, 2002). Anxiety or worry is also believed to reduce WMC (Eysenck, 1992). Multidigit arithmetic is believed to require the central execution and phonological loop of the WM system and place greater demand on the WM system as a whole (DeStefano & LeFevre, 2004; Raghubar, Barnes, & Hecht, 2010). As such, high-demand problems require greater WMC because of the borrowing component and cannot be readily solved with simple heuristics. As a result, these problems were ideal for measuring distraction theories.

Pressure. As previously described, modular arithmetic problems were completed in both low- and high-pressure situations (see Procedures section). Questionnaires were completed following the second set of experimental problems to ensure that the high-pressure situation significantly induced perceived stress/anxiety and perceived pressure to perform well above those in low-pressure group, serving as a manipulation check.

***Manipulation check*.** Participants completed the Revised Competitive State Anxiety Inventory-2 (CSAI-2R; Cox, Martens, & Russell, 2003). The CSAI-2R is a 17-item self-reported measure consisting of three scales to assess their somatic anxiety (seven items), cognitive anxiety (five items), and self-confidence (five items) right now. Each item has a 4-point Likert scale with responses ranging from 1 (*not at all*) to 4 (*very much so*). Confirmatory factor analysis demonstrated good model fit with CFI, NNFI, and RMSEA of .95, .94, and .054, respectively (Cox et al., 2003). For the purpose of this experiment, the primary investigator used the cognitive anxiety and somatic anxiety scales to measure state anxiety for the manipulation check. The results of these two scales were combined for an overall total ranging from 12 to 48 with higher scores indicating increased state anxiety. In this study, these two subscales were combined and had a high level of internal consistency, as determined by Cronbach's alpha of 0.867.

The second questionnaire included the following three questions intended to assess the participants' perceptions of their performance across the following areas: importance, performance pressure, and performance success. Participants responded to three questions on a 7-point Likert scale to indicate 1) how important it felt for them to perform at a high-level during the previous set of problems, with answers ranging from 1 (*not at all important to me*) to 7 (*extremely important to me*); 2) how much performance pressure they felt to perform at a high level during the previous set of problems, with answers ranging from 1 (*very little performance pressure*) to 7 (*extreme performance pressure*); and 3) how well they thought they performed in the previous set, with answers ranging from 1 (*extremely poor*) to 7 (*extremely well*; Beilock et al., 2004; Appendix C). Beilock et al. (2004) found state anxiety (e.g., increased), performance pressure (e.g., increased), and performance success (e.g., perceived worse performance) to have significantly different results between the low- and high-pressure groups with no mean differences for importance. Beilock and DeCaro (2007) replicated the findings for state anxiety, performance pressure, and importance.

Sleep. Sleep was intended to be measured using two questionnaires to assess *sleep duration*,[1] *variances in the sleep-wake cycle* throughout the week,[2] and *sleep disturbance,* with a greater focus on sleep duration. The following tasks were intended to provide the researcher with the average number of hours a participant slept on weeknights and weekends, variations in their sleep-wake times from weeknights to weekends, and subjective sleep quality.

Sleep duration and variation in wake cycles. The Sleep Timing Questionnaire (STQ; Monk et al., 2003) was used to measure quantitative data on sleep duration as well as to assess for variations in the sleep-wake cycle. All items were intended to be administered, but only the initial half of the questionnaire was entered into Qualtics in error. Thus, only goodnight times were collected. The STQ can be utilized as a substitute to a traditional sleep diary and is recommended to be used in conjunction with other sleep questionnaires (Devine, Hakim, & Green, 2005). The questionnaire asks individuals to respond to all items during a recent week in which they had a "normal average week" regarding these sleep and wake times. There are three sections of items on this measure: "GOOD NIGHT TIME" (GNT), "GOOD MORNING TIME" (GMT), and "how much sleep you lose to unwanted wakefulness". The first two sections ask the individual to indicate the earliest, latest, and usual night time of when they tried to fall asleep and

[1] Sleep duration was intended to be measured with the Sleep Timing Questionnaire (STQ) but data on this variable was not collected due to data entry error.
[2] Variances in the sleep-wake cycle was intended to be measured by the STQ but data on this variable was not collected due to data entry error.

the earliest, latest, and usual morning time of when they got out of bed by writing in the time (e.g., 10:15) and circling pm or am. To measure sleep duration for this study, the participant's usual sleep times across the weekdays and weekend were intended to be calculated for each time period as well as the usual wake times across the weekdays and weekend. The usual sleep and wake time were intended to be utilized to calculate the average number of hours of they sleep using a weighted 5:2 ratio. This numeric value would have been their *sleep duration*. However, due to the data collection error, this variable could not be calculated and was thus not included in the analyses.

To assess shifts in the sleep-wake cycle, the participant's usual wake time across weekdays would have been subtracted from their usual wake time on the weekend to calculate the average shift in their wake time. This numeric value would have been their *variation in the wake cycle*. Additionally, the participant's usual sleep time across the weekdays was intended to be calculated and subtracted from their usual wake times on the weekend to calculate the average shift in their sleep time. However, due to the data collection error, this variable could not be calculated and was thus not included in the analyses.

In the development of the STQ by Monk et al. (2003), convergent validity was demonstrated through moderate to large positive correlations with wrist actigraphic measures with GNT and GMT. Convergent validity was also demonstrated for GNT and GMT in two-week sleep diary measures through large positive correlations with going to bed and getting out of bed times as well as moderate negative correlations with a morningness score (derived from the Composite Scale of Morningness), meaning morning people go to bed earlier and wake up early and age, indicating older adults go to bed and get up earlier. In addition, the STQ has a moderate positive correlation with GNT and a large positive correlation with GMT, as compared to the two-week Pittsburgh Sleep Diary (Monk et al., 2003). In prior research ,the STQ was found to have significant test-retest reliabilities of r=0.705 and r=0.826 for GNT and GMT, respectively. When removing two outlying participants, the reliability rose to r=0.918 for GNT (Monk et al., 2003).

Subjective sleep disturbance. The Patient-Reported Outcomes Measurement Information System Short Form v1.0 – Sleep Disturbance 8b is an eight-item measure and intended for adults to assess sleep quality (PROMIS, 2018). The questionnaire was developed as part of PROMIS by the National Institutes of Health Roadmap Initiative to improve upon the current sleep measures and address the need for updated patient-reported outcomes (Yu et al., 2012). The sleep disturbance (SD) short form included items such as “I had difficulty falling asleep” and “I was satisfied with my sleep” (reverse scored). Respondents answered each item with options ranging from 1 (*not at all*) to 5 (*very much*) across the past seven days. One item, “My sleep quality was…” (reverse scored), has options ranging from 1 (*very good*) to 5 (*very poor*; Yu et al., 2012). Total raw scores on the short form ranged from eight to 40 (PROMIS, 2018). In this study, the scale had a high level of internal consistency, as determined by Cronbach’s alpha of 0.891.

The SD was developed using literature reviews, focus groups, Classic Test Theory, and Item Response Theory (IRT; Buysse et al., 2010; Yu et al., 2012). The theta values from IRT were found to be highly correlated between the short form and the full bank (0.96; Yu et al., 2012). Construct validity was strong when comparing correlations between self-reported sleep disorder and no sleep disorder groups and between those receiving treatment and those who were untreated (Buyess et al., 2010). Convergent and discriminant validity were demonstrated in the SD short form was found to be highly correlated with the PSQI and moderately correlated with the Epworth Sleepiness Scale (Buyness et al., 2010; Yu et al., 2012). The SD short form was found to have more accurate estimates regarding severity of sleep disturbance than the PSQI (Yu et al., 2012).

Procedures

The study received approval from the Institutional Review Board prior to collecting data. Participants were recruited through advertisement on the College of Education SONA. SONA provided students the opportunity to receive extra credit for a course they are currently enrolled in at the discretion of their course instructor. Participants signed up for an available session on SONA (Appendix D). Upon arriving to their experiment appointment, the research assistant had the participant complete and sign an informed consent form (Appendix E). They were then directed to a computer to begin the experiment.

Practice condition. Participants were informed that the experimenter was interested in studying how individuals learned a new task. They were then introduced to modular arithmetic (MA) through instructions displayed on the computer screen. As a summary, the instructions informed the participant that they would be learning how to solve MA problems and that they would be judging the truth value of each problem as quickly and accurately as possible using only mental computation. They responded “true” or “false” by pressing the *T* or *F* key, respectively. A sample item was demonstrated with the instructions. Once they read and understood the instructions, they began a practice trial. The trial began with a fixation point on the center of the screen for 500 ms and was immediately followed by the first MA item. The MA problem remained on the screen until the participant responded by pressing the *T* or *F* key. The next screen immediately appeared providing feedback by stating, *Correct*, if the problem was correctly solved, or *Incorrect*, if the problem was incorrectly solved. Then a blank screen appeared for 1,000 ms before the next problem was displayed. All participants completed 12 practice problems (eight low-demand and four high-demand) to become familiar with the new math task. All participants then completed experimental problems in a low-pressure condition.

Experimental conditions. Participants were randomized into one of four groups: two low-pressure conditions or a low-pressure condition followed by a high-pressure condition and within each of these two conditions the blocks of problems were counterbalanced. Following the same procedure as the practice problems, all participants completed 36 MA problems in each condition: 18 high-demand problems and 18 low-demand problems.

Low-pressure conditions. Participants followed the instructions on the screen indicating that they were to continue to practice the new task they learned and were informed to continue to work as quickly and accurately as possible without sacrificing speed for accuracy. Problems were displayed in the same manner as the practice condition but without the *Correct* and *Incorrect* feedback. Those participants who were randomly assigned to complete the second block of MA problems in the low-pressure condition received a similar set of instructions, regarding continual practice of the new task.

High-pressure condition. The high-pressure scenario was executed in the same manner as the low-pressure condition with some additions. The pressure situation was manipulated by utilizing three commonly used pressure-inducing sources (Beilock & Carr, 2005; Beilock & DeCaro, 2007). Studies have demonstrated that the culmination of these three sources of pressure—monetary incentives, peer pressure, and social evaluation—can be used to induce anxiety and performance pressure assisted in establishing evidence for both distraction and self-efficacy theories (Beilock & Carr, 2001; Beilock & Carr, 2005; Beilock & DeCaro, 2007; Beilock et al., 2004; Carr, 2014).

The pressure situation was introduced, via onscreen instructions and read out loud by the research assistant, prior to solving problems during the high-pressure setting. Participants were informed that the computer collected data about their individual performance on the previous set of items by recording their accuracy and reaction time. Participants were informed through on-screen instructions that if they can improve their overall MA score by 20%, relative to their performance on the prior set, they would receive $10. However, there was a caveat. They were informed that the computer had paired them with another individual who had already completed the previous set and improved their own performance by 20% or more. In order for the participant and the other individual to both receive the $10, the participant needed to engage in "team effort" to improve their score by 20%. Additionally, they were informed that the overall first place finisher (who improves their score the most, with tie breakers being determined by the fastest reaction times) would be awarded $50, second place would be awarded $40, third place would be awarded $30, fourth place would be awarded $20, and fifth place would be awarded $10. All monetary rewards were pulled from an envelope and displayed to the participant. Lastly, they were told that their performance would be recorded so that local students, teachers, and professors could study how individuals learn MA and perform on tasks for future programming. After reading the instructions, the experimenter showed the participant the $10 and the five sets of cash for the top five prizes and set up and turned on the video camera approximately 1m away. Then the participants began their next block of items. Once the block was complete, the video camera was turned off and moved away.

After the final set of problems (high- or low-pressure) was completed by the participant, all participants completed the CSAI-2R and answered three questions regarding the importance of performing well at a high level, the amount of performance pressure they perceived to perform at a high level, and if they felt they performed well. Afterwards, they were provided with a simple addition and multiplication task. They were informed that the task was independent from the MA task, and they were not expected to finish. The purpose of this task was to reduce any feelings that were generated by the high-pressure scenario before completing the automated OSPAN and RSPAN tasks (Beilock & Carr, 2005).

The participants were then asked to complete the automated complex working memory tasks and to perform their best. They first completed the ARSPAN task. Following the ARSPAN, they completed the AOSPAN task. Following the complex WM span tasks, they completed the three sleep questionnaires on the computer through Qualtrics. Lastly, they completed the demographics questionnaire. Participants were then provided the Exit Survey (Appendix F) to assess their beliefs regarding the pressure manipulation. For participants in the high-pressure condition, participants interested in being considered for the cash award signed the Additional Consent Form (Appendix I) and were dismissed. After the conclusion of data collection, the researcher emailed all participants the debriefing form (Appendix G and Appendix H). Those participants in the high-pressure condition were provided with $10 and the opportunity for their results to be considered for the top five performances and the additional cash award.

CHAPTER IV

Results

Overview

As previously indicated in Chapter III, there were 137 individuals who participated in this study. However, 33 participants were excluded from the study for not meeting the required accuracy threshold on the working memory measures and modular arithmetic problems as well as responses to the exit survey indicating they understood the intent of the study (analyzing performance under pressure). Therefore, the final sample size used for analysis was 104.

The Statistical Package for the Social Sciences (SPSS) Version 28 was used to run all analyses. Descriptive statistics were first used to analyze the demographics and manipulation variables. Bivariate correlations were conducted to determine if there was a relationship between predictor variables. A hierarchical linear regression was used to address the exploratory analyses for sleep disturbance. Confirmatory analyses for sleep duration and exploratory analyses for variations in the wake cycle were not run due to a data collection error described above wherein only the initial half of the Sleep Timing Questionnaire (STQ) was entered into Qualtrics.

Descriptive Statistics

Descriptive statistics of the main study variables of accuracy and reaction time across low- and high pressure conditions and low- and high demand problems, working memory capacity, caffeine intake today, and subjective sleep disturbance are reported in Table 2. Fifty-four of the 104 participants consumed caffeine with mean of 144.59mg and *SD* = 72.2. Means and standard deviations were calculated for all variables.

Table 2

Descriptive Statistics for Outcome, Control, and Predictor Variables

Variable	*N*	*M*	(*SD*)	Min	Max	Skew	SE	Kurtosis	SE
Accuracy									
LP, HD	55	-0.44	(2.33)	-9	3	-0.91	0.32	1.89	0.63
HP, HD	49	0.33	(2.25)	-5	5	-0.35	0.34	0.2	0.67
RT									
LP, HD	55	10100.91	(47229.2)	-137513	142112	-.29	0.32	1.67	0.63
HP, HD	49	8461.65	(48738.52)	-121754	143583	.21	0.34	1.54	0.67
WMC	104	59.10	(0.84)	35.0	74.5	-0.66	0.24	0.05	0.47
Caffeine Intake Today	104	75.08	(89.17)	0	377	0.93	0.24	0.11	0.47
PROMIS-SD-SF	104	18.42	(6.40)	8	35	0.70	0.24	-0.11	0.47

Note. *N*=104. The table shows the descriptive statistics to include the number of participants, mean, standard deviation, minimum and maximum values, skew and kurtosis, and their respective skew for participants' data on two outcome variables (accuracy and reaction time) across the two pressure conditions on high demand problems, the control variable (caffeine), and two continuous predictor variables (WMC and sleep disturbance) from the final sample. LP = Low Pressure Condition; HP = High Pressure Condition; HD = High Demand Problems; LD = Low Demand Problems; RT = Reaction Time; WMC = Working Memory Capacity; PROMIS-SD-SF = Patient-Reported Outcomes Measurement Information System Sleep Disturbance Short Form (Patient-Reported Outcomes Measurement Information, 2015)

Manipulation check. There were 55 low pressure condition and 49 high pressure condition participants. An independent-samples t-test was run to determine if there were differences in somatic and cognitive anxiety scores as well as performance pressure between the two pressure conditions. There was not a statistically significant difference in somatic and cognitive anxiety scores between the low pressure (*M* = 18.84, *SD* = 6.100) and high pressure condition (*M* = 20.10, *SD* = 6.111), *t*(102) = -1.055, *p* = .147. There was not a statistically significant difference in performance pressure scores between the low pressure (*M* = 3.82, *SD* = 1.588) and high pressure condition (*M* = 4.29, *SD* = 1.581), *t*(102) = -1.502, *p* = .068. There was homogeneity of variances for both manipulation checks for low- and high pressure conditions, as assessed by Levene's test for equality of variances (*p* = .619, *p* = .759). Thus, the manipulations utilized in this study did not produce the desired effect of creating a high pressure environment. Further results are reported in Table 3.

Table 3

Descriptive Statistics for Manipulation Checks Across Pressure Conditions

Variable	*N*	*M*	(*SD*)	Min	Max	Skew	SE	Kurtosis	SE
Performance Pressure									
Low Pressure	55	3.82	(1.59)	1	7	-0.24	0.32	-0.86	0.63
High Pressure	49	4.29	(1.58)	1	7	-0.26	0.34	-0.71	0.63
Average Somatic and Cognitive Anxiety									
Low Pressure	55	18.84	(6.10)	12	38	1.49	0.32	2.02	0.67
High Pressure	49	20.10	(6.11)	12	39	0.91	0.34	0.53	0.67

Note. *N*=104. Information presented in the table provides the descriptive statistics for the two manipulation checks used to determine if the pressure condition produced a significant difference between the high and low pressure conditions.

Bivariate correlations. Tests for nonindependence were run to determine if there was a shared relationship between any of this study's predictor variables and determine if there was multicollinearity. Pearson's correlations were run, see Table 4. There were no significant findings between the predictor variables. There is no evidence of multicollinearity among the predictor variables.

Table 4

Pearson Correlations Among Control and Predictor Variables

Variable	M	SD	1	2	3	4
1. Caffeine	75.08	89.17	-	-.076	.061	-.029
2. Average WMC	59.10	8.53	-	-	-.031	.104
3. PROMIS-SD	18.42	6.40	-	-	-	.161
4. Pressure Condition	1.47	.51	-	-	-	-

Note. N=104. The table provides the Pearson correlations for the control variable (caffeine) and all three predictor variables (WMC, sleep disturbance, and pressure condition).

Hierarchical Linear Regression

As noted above, a data collection error prevented the researcher's ability to test all confirmatory hypotheses and one set of exploratory hypotheses. The purpose of this study was to explore the effects of sleep on those in a high pressure situation where it was previously determined that those that have higher cognitive abilities, namely greater working memory capacity, have a greater tendency to choke under. This study served as a replication of Beilock and Carr's (2005) study and intended to examine the impact of sleep disturbance, variations in the sleep-wake cycle, and sleep disturbance on performance as measured by accuracy and reaction time on correctly solved high demand problems. All continuous predictor variables (working memory capacity and sleep disturbance) were standardized prior to running all analyses, and the dichotomous predictor variable (pressure condition) was dummy coded (0 = low pressure and 1 = high pressure).

Exploratory regression for accuracy. To ensure normality and that no transformations were needed, SPSS was used to examine regression residuals for skewness and kurtosis. An alpha level of .01 (z = +/-2.58) was used and the residuals were within the normal range for skewness (z = -2.38) and kurtosis (z = .597). Therefore, no transformations of the data were necessary to conduct the regression. In step one, the control variable caffeine consumed same day, prior to the study, was entered. This model was not significant ($R^2 = .001$, *F* change (1,102) = .073, *p* = .788). In step two, the three main effects (working memory capacity, sleep disturbance, and pressure condition) were added. When examining step two, higher sleep disturbance did not significantly predict accuracy (*B* = -.1, *p* = .668). High pressure condition did not significantly predict accuracy (*B* = .754, *p* = .107). WMC did not significantly predict accuracy (*B* = .187, *p* = .418). The results of this model show that the addition of these three main effect variables did not explain additional variance ($\Delta R^2 = .036$, *F* change (3,99) = 1.221, *p* = .306). In step three, all three two-way interactions were entered into the model. One main effect became significant in model 3: working memory capacity (*B* = .706, *p* = .039). However, this model did not add significant variance ($\Delta R^2 = .065$, *F* change (3,96) = 2.257, *p* = .082). Finally, in step four, the predicted three-way interaction was entered into the model. One main effect remained significant: working memory capacity (*B* = .702, *p* = .042). As a whole, model four did not add significant variance ($\Delta R^2 < .001$, *F* change (1,95) = .013, *p* = .910).

Table 5

Summary of Hierarchical Linear Regression Analysis for Accuracy

Predictor	R^2	ΔR^2	*B*	*SE*	*β*	*t*
Step 1	.001	.001				
Caffeine			-.062	.229	-.027	-.27
Step 2	.036	.036				
Caffeine			-.03	.229	-.013	-.133
Sleep Disturbance (PROMIS)			-.1	.232	-.043	-.43
Pressure Condition (PC)			.754	.464	.164	1.625
Working Memory Capacity (WMC)			.187	.230	.081	.813
Step 3	.101	.065				
Caffeine			.011	.232	.005	.048
Sleep Disturbance (PROMIS)			-.419	.285	-.181	-1.47
Pressure Condition (PC)			.727	.46	.158	1.581
Working Memory Capacity (WMC)			.706	.337	.305	2.094*
WMC*PC			-.891	.461	-.282	-1.933
WMC*PROMIS			.054	.249	.022	.217
PC*PROMIS			.769	.479	.198	1.605
Step 4	.101	<.001				
Caffeine			.009	.233	.004	.041
Sleep Disturbance (PROMIS)			-.417	.288	-.18	-1.448
Pressure Condition (PC)			.733	.465	.159	1.576
Working Memory Capacity (WMC)			.702	.34	.304	2.065*
WMC*PC			-.89	.463	-.282	-1.921
WMC*PROMIS			.034	.309	.014	.109
PC*PROMIS			.756	.496	.195	1.523
PC*WMC*PROMIS			.059	.516	.014	.114

Note. N=104. The table provides a summary of the hierarchical linear regression analysis for all variables and steps entered into the model for the outcome variable accuracy. PROMIS = sleep disturbance measure PROMIS-SD; WMC = average working memory capacity; PC = pressure condition.

*$p<.05$

Exploratory regression for reaction time. To ensure normality and that no transformations were needed, SPSS was used to examine regression residuals for skewness and kurtosis. An alpha level of .01 (z = +/-2.58) was used and the residuals were within the normal range for skewness (z = -.75) and kurtosis (z = 1.63). Therefore, no transformations of the data were necessary to conduct the regression. Reaction time change was calculated for each participant by taking the reaction time for correctly solved items in the first experimental block (T1) and subtracting the reaction time for items solved correctly in the second experimental block (T2; T1-T2). The reaction time changes for each individual correctly solved item were summed together. In step one, the control variable caffeine consumed same day, prior to the study, was entered. This model was not significant ($R^2 = .016$, F change (1,102) = 1.694, p = .196). In step two, the three main effects (working memory capacity, sleep disturbance, and pressure condition were added. When examining step two, higher sleep disturbance was significantly associated with greater reaction time changes in that their reaction times were longer (B = 9617.344, p = .045). High pressure condition did not significantly predict reaction time changes (B = -4886.207, p = .607). Higher WMC did not significantly predict reaction time changes (B = -1190.807, p = .800). However, the results of this model show that the addition of these three main effect variables did not explain additional variance ($\Delta R^2 = .041$, F change (3,99) = 1.431, p = .238). In step three, all three two-way interactions were entered into the model, explaining an additional 9% of the variance ($\Delta R^2 = .091$, F change (3,96) = 3.406, p = .021). There was a significant interaction between WMC and sleep disturbance (B = 13065.317; p =

.010). A simple slope analysis was conducted for 2-way interaction in model 3, below. In addition, sleep disturbance remained a significant predictor (*B* = .284, *p* = .02). There was not a significant interaction between WMC and pressure condition (*B* = 4141.355; *p* = .656). There was not significant interaction between the final two-way interaction, pressure condition and sleep disturbance (*B* = -17587.903; *p* = .071). Finally, in step 4, the predicted three-way interaction was entered into the model, but its addition was not significant (ΔR^2 = .001, *F* change (1,95) = .082, *p* = .775). The interaction between WMC and sleep disturbance was not significant in the final model (*B* = 12026.747; *p* = .055). However, because Step 4 did not add significant variance, the significant interaction in Step 3 was examined for clarity on that effect. As a whole, model four accounted for 14.9% of the variance (R^2 = .149) and was significant (*p* = .046). All of the 2-way or 3-way interactions were not significant in step 4; therefore, no simple slope analyses were conducted.

Table 6

Summary of Hierarchical Linear Regression Analysis for Reaction Time

Predictor	R^2	ΔR^2	*B*	*SE*	*β*	*t*
Step 1	.016	.016				
Caffeine			-6099.405	4686.145	-.128	-1.302
Step 2	.057	.042				
Caffeine			-6851.520	4680.684	-.144	-1.464
Sleep Disturbance (PROMIS)			9617.344	4733.743	.202	2.032*
Pressure Condition (PC)			-4886.207	9469.905	-.051	-.516
Working Memory Capacity (WMC)			-1190.807	4699.191	-.025	-.253
Step 3	.148*	.091*				
Caffeine			-4354.308	4655.409	-.091	-.935
Sleep Disturbance (PROMIS)			13572.260	5730.293	.284	2.369*
Pressure Condition (PC)			-971.421	9238.327	-.010	-.105

Working Memory Capacity (WMC)			-3507.197	6769.954	-.073	-.518
WMC*PC			4141.355	9256.903	.064	.447
WMC*PROMIS			13065.317	5003.501	.260	2.611*
PC*PROMIS			-17587.903	9620.352	-.220	-1.828
Step 4	.149*	.001				
Caffeine			-4436.309	4686.552	-.093	-.947
Sleep Disturbance (PROMIS)			13705.461	5776.582	.287	2.373*
Pressure Condition (PC)			-696.232	9332.262	-.007	-.075
Working Memory Capacity (WMC)			-3680.057	6829.196	-.077	-.539
WMC*PC			4183.232	9302.616	.064	.450
WMC*PROMIS			12026.747	6195.951	.239	1.941
PC*PROMIS			-18275.015	9959.127	-.229	-1.835
PC*WMC*PROMIS			2971.274	10360.010	.035	.287

Note. *N*=104. The table provides a summary of the hierarchical linear regression analysis for all variables and steps entered into the model for the outcome variable reaction time. PROMIS = sleep disturbance measure PROMIS-SD; WMC = average working memory capacity; PC = pressure condition.

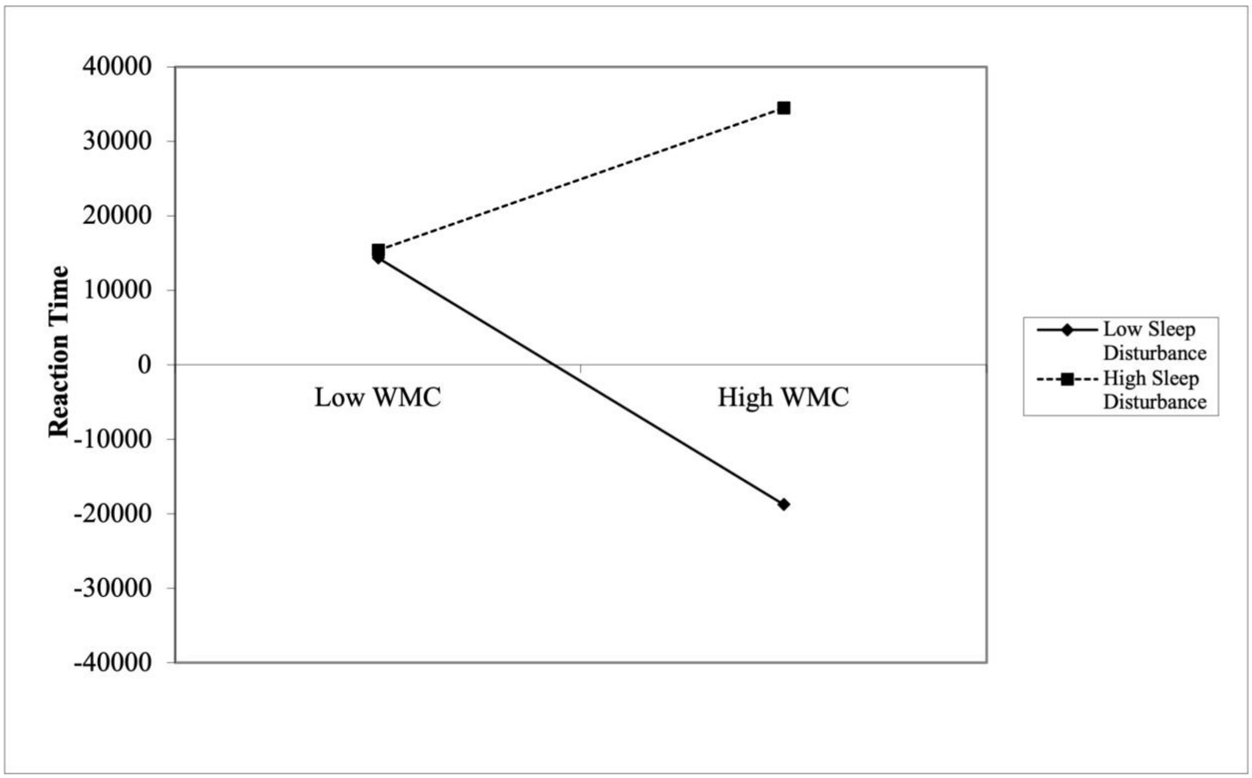
*$p<.05$.

Simple slope analysis for reaction time. In the exploratory regression for reaction time, the three-way interaction was not significant; however, one of the two-way interactions in Step 3 was significant: working memory capacity and sleep disturbance. Step 4 did not account for additional variance, and thus, Step 3 was examined. The interaction was probed using the work of Dr. Jeremy Dawson (n.d.). See Figure 1 for results. Results of the simple slope analysis showed that among students with low sleep disturbance, higher working memory was associated with significantly greater difference between T1 and T2 indicating faster reaction times (*B* = -16572.514, *t* = -2.114, and *p* = .037). For students with high sleep disturbance, working memory capacity was not significantly associated with reaction time (*B* = 9558.120, *t* = 1.067, and *p* =

.289). Sleep disturbance served as a moderator in the relationship between working memory capacity and reaction time, such that the relationship is significant for those who reported low sleep disturbance. Therefore, it can be concluded that reaction times were faster among those who reported low sleep disturbance and demonstrated higher working memory capacities. High sleep disturbance does not explain the relationship between working memory capacity and reaction time.

Figure 1

Interaction of Working Memory Capacity by Sleep Disturbance



Note. The figure provides a visual of the simple slope analysis for the two-way interaction between WMC and sleep disturbance where high WMC was moderated by low sleep disturbance resulting in a positive change score for reaction times (T1-T2), indicating faster reaction times. WMC = average working memory capacity.

CHAPTER V

Discussion

The purpose of this study was to replicate many features of the study conducted by Beilock and Carr (2005) and to determine if there was consistency in the results. Secondly, this current study aimed to explore the separate moderating effects of sleep duration, variations in the wake cycle, and sleep disturbance on cognitive performance in a high pressure environment. Choking under pressure (stress/worry competing for working memory resources or focusing on the task execution process) is a phenomenon experienced in all kinds of professions to include athletics, academics, medical, first responders, and more (Lewis & Linder, 1997; Masters, 1992; Wine, 1971). Specifically, the theory behind choking under pressure in a cognitive capacity is that worry and cognitive tasks both utilize working memory capacity (WMC; Beilock 2010) and when working memory resources are allocated more toward attending to anxiety and stress instead of toward the task at hand (Eysenck, 1992), This results in reduced performance capabilities.

Summary of Findings

When examining the proposed exploratory analyses for sleep disturbances, there were several unexpected findings for the manipulation check, replication aspect of the study, and from the addition of the sleep disturbance variable.

Manipulation check. First and foremost, the manipulations that were utilized in the current study and were utilized across multiple studies (Beilock and Carr, 2005; Beilock and DeCaro, 2007; Beilock, Kulp, Holt, & Carr, 2004), were not found to be significant in the current study. According to a report completed by Staal (2004), several studies have found the presence of other people leads to decrements in performance when tasks are complex, poorly learned, or new. Additionally, some found a discrepancy between their own evaluation of their performance and their expectations about their performance (Staal, 2004). Lastly, an audience can be beneficial if one believes that they will perform well whereas an audience can be detrimental if they believe they will perform poorly. However, this could also differ if the audience has the ability to evaluate the performer. Thus, greater impairment with an evaluative audience (Staal, 2004). Also, in order for choking, or poorer performance than anticipated based upon skill level, to occur the individual must desire high performance (Beilock and Carr, 2001). Thus, the high pressure scenario (monetary, peer, and evaluation pressures) failed to produce the desired effect of creating a high pressure environment. Given the manipulation check results, those in the high pressure scenario were likely not to feel increased pressure to improve their performance and likely did not place a greater cognitive load on working memory resources. This could explain why there were no significant effects found by pressure condition, as there were no statistically significant pressure differences between the two groups.

Exploratory analysis for accuracy and sleep disturbance. From here, accuracy and reaction time were used to measure performance on modular arithmetic, a type of multi-step math problem that can use a high to low cognitive load to solve the problem mentally. Those with a higher working memory capacity have previously been found to be more likely to choke while attempting to solve high demand problems accurately (Beilock and Carr, 2005). However, the current study failed to replicate the findings for performance in a high pressure setting among those with higher working memory capacities while solving high demand problems. The addition of the sleep variable, sleep disturbance, did not account for any additional variance on performance as measured by accuracy. The only significant finding was for WMC in step three and four of the model when the interactions were added. The main effect was significant after the

2-way (*B* = .305, *p* = .039) and 3-way (*B* = .304, *p* = .042) interactions were included in the model. However, the overall models did not predict significant variance (model 3: $R^2 = .101$, $p = .163$ and model 4: $R^2 = .101$, $p = .236$). It is difficult to draw meaningful conclusions for why this might be the case as the manipulation did not result in a perceived high pressure condition.

Exploratory analysis for reaction time and sleep disturbance. Results were consistent with previous bodies of research on choking under pressure as measured by analyzing reaction times. Specifically, there have been no significant findings regarding reaction time as a measure of performance in high pressure environments across numerous studies (Beilock and Carr, 2005; Beilock, Kulp, Holt, & Carr, 2004). The replication portion of the current study (e.g., WMC and pressure condition on high demand problems) did not include significant predictors. However, the current study found one significant main effect for sleep disturbance across models 2, 3, and 4, which is an extension of prior research. These results indicate that greater subjective sleep disturbance resulted in slower reaction times. This finding is supported across multiple studies on sleep disturbances and sleep quality impacting cognitive performance to include impairments in memory, focus, alertness, drowsiness, and longer reaction times (Buboltz et al., 2001; Mendelson, 2017). Several studies focus on sleep duration; however, sleep quality has been found to have four features to include sleep efficiency, sleep latency, sleep duration, and wake after sleep onset (Nelson, 2021). When examining the results of the exploratory regression for sleep disturbance as a moderator in the relationship between WMC and reaction time, there was a significant finding. The finding suggests that low sleep disturbance serves as a moderator between working memory capacity and reaction time, in that college students performed the cognitive tasks more quickly when they reported low sleep disturbance and demonstrated greater working memory capacities. This explained an additional 0.1% of the variance. Thus, there is reason to believe that increased sleep disturbance would have negative impacts on performance, at least in areas of executive functioning, as numerous research articles and texts have shown to be the case with reduced sleep duration (Durmer & Dinges, 2005; Lim & Dinges, 2010; Lowe et al., 2017). A meta-analysis found that when participants are instructed to work as fast as possible from the start, their speed increased and even their performance accuracy (Stall, 2004). If this were the case, this would support the possibility that they are working more automatically, which is beneficial to performance (i.e., those with greater cognitive abilities; Stall, 2004). Individuals are more likely to work faster with greater time pressure for continuous manipulations but not for categorical (e.g., reminded once at the beginning) and their performance accuracy was impacted only by continuous time pressure. They also noted that cognitive tasks were not one of the tasks where accuracy was most negatively affected and was also not as significantly impacted by performance speed (i.e., they went faster but not as much compared to other pattern recognition and reaction tasks).

Implications

While it is difficult to draw implications from this study due to the manipulation failing to produce increased pressure to improve performance, the results indicate that future research and clinical practice should consider how sleep can affect cognitive functioning and performance outcomes, primarily in the form of reaction time. Results from this study and future research could be applied to clinical practice as well when justifying the use of therapy interventions to improve sleep habits (e.g., CBT-i; Perlis et al., 2008). Higher order cognitive skills were found to be moderately to highly correlated across numerous career fields (Bakhshi et al., 2017). Those who are well rested are likely to make less errors in their line of work, which could have significant implications on life-saving measures or even in down-to-the-wire business decisions

(Durmer & Dinges, 2005). In a society where long hours and near constant productivity are rewarded, it would be valuable to consider how increasing sleep quality could instead further improve job performance. Poor sleep quality contributes to poor health outcomes, strained relationships, slowed responses, reduce health-conscious choices, memory impairment, and difficulty sleeping (Locke, 2011; Nelson, 2022). Yet despite knowing these concerns, several work centers continue to push keeping smaller staff with longer work hours or prize late nights in the office or picking up extra shifts, while ignoring the possible consequences. Future research should continue to examine specific workings of the brain that are affected by sleep quality across multiple areas of higher-order thinking in order to support possible changes in business practices and moving toward rewarding positive health behaviors.

Limitations

Procedures. First and foremost, the largest limitation in this study was researcher error when setting up the study in the research lab. When creating the Qualtrics surveys, only the first half of the Sleep Timing Questionnaire was entered. Due to this, the sleep variables of sleep duration and variations in the wake cycle could not be analyzed because participants were never able to respond to items about their wake times. Consequently, the researcher could not calculate how long they slept and if their wake times varied between the weekends and weekdays. Valuable information was never captured; thus, the researcher could not study the main (confirmatory) hypotheses of this study, nor could they run two of four exploratory analyses. However, meaningful results and implications were still generated with regard to sleep disturbance. Sleep disturbances can result from a range of sleep-related disorders and external factors in include work, electronics, education, mental health concerns, environment (Cormier, 1990; Mendelson, 2017; Nelson, 2022, PROMIS, 2018) and lead to cognitive decrements and physical and psychological symptoms (Buboltz et al., 2001; Mendelson, 2017). Thus, valuable information was obtained from the study despite procedural limitations.

There were other procedural considerations for assessing the effects of sleep deprivation in a high pressure condition. Participants were also not asked to deprive themselves of sleep for any period of time prior to the study. As a result, sleep was not held constant between participants and self-report measures can lead to individual variations in the sleep variable. By using self-report measures, the researcher attempted to ensure that there was enough participation in the study to generate the number of required participants to generate a strong effect as the students may not be able to keep themselves awake due to their other responsibilities for the day. Additionally, the use of the self-report measure had a greater potential to lead to more naturalistic results that may be applicable to a wider variety of settings.

When examining differences in the number of modular arithmetic problems, Beilock, Kulp, Holt, and Carr (2004), Beilock and Carr (2005), and Beilock and DeCaro (2007) used 24 problems in each experimental condition, whereas this study utilized 18 problems in each experimental condition due to the amount of time needed to complete the entire study and elicit college students' participation. There is a small possibility that more problems could have produced a greater effect. Enough time may not have been spent on the problems for the pressure condition to have felt competitive or allow the pressure to build; however, distraction theories note the importance of worry/pressure competing for working memory resources to ultimately lead to performance decrements (Hill et al., 2010). It is difficult to conclude if more problems would have explicitly resulted in a greater effect or instead led to cognitive fatigue.

Another procedural limitation is the fact that this study took place during the COVID-19 global pandemic. Throughout parts of data collection, the researcher and participants were required to maintain a minimum of six feet of space between themselves. This required the participant to move in and out the lab space frequently to allow the researcher to adjust the computer and set up the manipulations for high pressure condition. It is unclear the effect this could have had but the constant movement of the participant may have allowed for their anxiety to decrease as they were offered frequent breaks. It is also unclear if this impacted the legitimacy of the deception for those in the high pressure condition. The manipulation not being significant would suggest that people did not feel compelled to perform their best in the high pressure condition or just did not experience pressure to try to improve their performance. If the manipulation was not strong enough, the incentives may have been good enough to lead to increased focus.

Measures. The use of self-report measures in this study for sleep may have resulted in an inaccurate portrayal of their sleep. Ideally, an actigraphic device, which can collect data on sleep and wakefulness throughout the night, or even a sleep journal, that could better capture sleep and wake times, would be better at capturing a more accurate picture of their sleep patterns than a best estimate from memory. These techniques were unfortunately not feasible due to the timeframe and available resources for this study, but they may have given a more accurate picture of actual sleep duration/quality than self-report alone, which were used as a good approximation (Devine, Hakim, & Green, 2005; Monk et al., 2003). Future research would benefit from a multi-modal assessment to better assess different aspects of sleep quality.

Gender. A gender moderation effect was unlikely to be found due to the sample size selected for this study, and thus was not tested. However, stereotype threat (Beilock, Rydell, & McConnell, 2007) can be taken into consideration and in the future gender differences could be examined within the manipulation check and among the two outcome variables to determine if gender should be included as a control variable. Beilock, Rydell, and McConnell (2007) dove into the literature and developed their own studies to explore the effects of stereotype threat on the working memory system. They found that when women in the experimental condition were instructed to consider gender differences when completing mathematical problems performed worse on high demand, horizontal problems. This was due to the inner speech dialogue to maintain intermediate steps to solve the problem. These resources may be suspectable to stereotype threat due to the co-opting of resources between maintaining inner dialogue and simultaneous worry. Due to the literature considering the relationship between gender and math anxiety, it would be worth examining the relationship between gender and variables used within the study moving forward.

Future Considerations

Overall, this study would likely benefit from being conducted in an environment where the physical separation does not change the dynamic of the lab environment due to a global pandemic. It is difficult to know fully why the manipulation check was unsuccessful and if that is ultimately why the high pressure condition did not have a significant effect on the participants' accuracy and reaction scores. Ideally with the appropriate resources and time, participants would be asked to limit their sleep under the 7-hour recommended mark to possibly four hours or even total sleep deprivation. As an active duty service member working in mental health, this continued research is extremely important in understanding the effects of reduced sleep quality or duration, especially when tensions are high and/or decision-making strategies are needed. It would be beneficial to determine ethical tasks that are applicable to specific career fields (e.g., simulations of performing life saving measures by a participant that is a first responder and being evaluated by others in their career field), which may make the effect of the pressure condition greater. Whereas in this study, students were participating for extra credit. However, a recent study by Xu et al. (2021) found that performance pressure can positively and negatively affect employees based upon their own motivation to attain goals and workplace anxiety that can lead to avoidant behaviors. Work meaningfulness was found to be a moderator that influences their perception of workplace performance pressure. It can positively improve performance by inspiring employees yet could also lead to increased worry and anxiety (Xu et al., 2021). Thus, it appears important for future research to find a balance between finding a meaningful task, while raising the stakes by manipulating the value of completing the task effectively. It would also be beneficial to consider how pressure could enhance performance for some participants and not others and understanding the underlying mechanisms.

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Appendix A

Demographic Questionnaire

1. What is your age?: ___________

2. What is your race and/or ethnicity? (select all that apply)
    a. African American or Black
    b. Asian or Asian American
    c. Caucasian or White
    d. Hispanic/ or Latina/o/x
    e. Native American or Alaskan Native
    f. Native Hawaiian or Other Pacific Islander
    g. Other: ___________

3. What is your sex identity?
    a. Female
    b. Male
    c. Or please specify: ___________

4. What is your gender or gender identity?
    a. Gender Fluid
    b. Man
    c. Nonbinary
    d. Woman
    e. Or please specify: ___________

5. Do you identify as transgender?/Do you consider yourself to be transgender?
    a. Yes
    b. No

6. What is your sexual orientation?
    a. Asexual
    b. Bisexual
    c. Demisexual
    d. Gay
    e. Heterosexual
    f. Lesbian
    g. Pansexual
    h. Queer
    i. Other: ___________

7. Your highest level of education completed?

a. High School Diploma
b. General Education Diploma (GED)
c. Vocational or Technical School
d. First year college student
e. Second year college student
f. Third year college student
g. Fourth year college student
h. Fifth year college student
i. Degree from a 2-year college or university
j. Degree from a 4-year college or university
k. Some graduate or professional school
l. Master's degree (e.g., MA, MS, MEd)
m. Professional degree
n. Other graduate degree
o. Other: __________

8. How much caffeine do you consume on an ***average*** weekday? Please select all of the following methods of caffeine that you consume. Please write in the ***typical*** drink type and ounces to the best of your knowledge.
   a. Do you consume coffee (e.g., coffee, americano, latte)?
      i. Yes or No
      ii. If yes, type of coffee drink: __________ Amount: __________
   b. Do you consume energy drinks?
      i. Yes or No
      ii. If yes, type of energy drink: __________ Amount: __________
   c. Do you consume energy shots (e.g., 5-hour energy)?
      i. Yes or No
      ii. If yes, type of energy shot: __________ Amount: __________
   d. Do you consume soda/pop/soft drinks?
      i. Yes or No
      ii. If yes, type of soda: __________ Amount: __________
   e. Do you consume tea?
      i. Yes or No
      ii. If yes, type of tea: __________ Amount: __________
   f. Do you consume another caffeinated drink that is not listed?
      i. Type: __________ Amount: __________

9. Did you consume caffeine prior to your appointment today?
   a. Yes
   b. No
   c. If yes, what type: __________
   d. If yes, how many ounces: __________

Appendix B

Modular Arithmetic

Practice block of 12 Problems

High Demand Problems		Low Demand Problems	
Answer: True	Answer: False	Answer: True	Answer: False
42 ≡ 20 (mod. 6)	42 ≡ 20 (mod. 8)	6 ≡ 4 (mod. 2)	6 ≡ 4 (mod. 3)
62 ≡ 13 (mod. 7)	62 ≡ 13 (mod. 8)	8 ≡ 3 (mod. 5)	8 ≡ 3 (mod. 4)
		4 ≡ 2 (mod. 2)	4 ≡ 2 (mod. 3)
		9 ≡ 3 (mod. 3)	9 ≡ 3 (mod. 5)

First block of 36 problems

High Demand Problems		Low Demand Problems	
Answer: True	Answer: False	Answer: True	Answer: False
40 ≡ 24 (mod. 8)	40 ≡ 24 (mod. 9)	5 ≡ 2 (mod. 3)	5≡2 (mod. 2)
45 ≡ 27 (mod. 6)	45 ≡ 27 (mod. 4)	6 ≡ 3 (mod. 3)	6≡3 (mod. 2)
51 ≡ 19 (mod. 4)	51 ≡ 19 (mod. 3)	7 ≡ 2 (mod. 5)	7≡2 (mod. 4)
63 ≡ 27 (mod. 3)	63 ≡ 27 (mod. 7)	7 ≡ 3 (mod. 2)	7≡3 (mod. 3)
65 ≡ 16 (mod. 7)	65 ≡ 16 (mod. 6)	8 ≡ 6 (mod. 2)	8≡6 (mod. 3)
85 ≡ 17 (mod. 4)	85 ≡ 17 (mod. 6)	8 ≡ 4 (mod. 4)	8≡4 (mod. 3)
73 ≡ 25 (mod. 6)	73 ≡ 25 (mod. 7)	9 ≡ 3 (mod. 6)	9≡3 (mod. 4)
92 ≡ 26 (mod. 3)	92 ≡ 26 (mod. 9)	9 ≡ 7 (mod. 2)	9≡7 (mod. 4)
93 ≡ 39 (mod. 9)	93 ≡ 39 (mod. 4)	9 ≡ 4 (mod. 5)	9≡4 (mod. 4)

Second block of 36 problems

High Demand Problems		Low Demand Problems	
Answer: True	Answer: False	Answer: True	Answer: False
43 ≡ 29 (mod. 7)	43 ≡ 29 (mod. 8)	5 ≡ 3 (mod. 2)	5 ≡ 3 (mod. 3)
62 ≡ 46 (mod. 4)	62 ≡ 46 (mod. 7)	6 ≡ 2 (mod. 4)	6 ≡ 2 (mod. 3)
66 ≡ 48 (mod. 6)	66 ≡ 48 (mod. 4)	7 ≡ 3 (mod. 2)	7 ≡ 3 (mod. 5)
70 ≡ 34 (mod. 6)	70 ≡ 34 (mod. 8)	7 ≡ 4 (mod. 3)	7 ≡ 4 (mod. 2)
72 ≡ 18 (mod. 3)	72 ≡ 18 (mod. 7)	7 ≡ 5 (mod. 2)	7 ≡ 5 (mod. 3)
73 ≡ 46 (mod. 9)	73 ≡ 46 (mod. 8)	8 ≡ 2 (mod. 3)	8 ≡ 2 (mod. 4)
86 ≡ 47 (mod. 3)	86 ≡ 47 (mod. 6)	8 ≡ 5 (mod. 3)	8 ≡ 5 (mod. 4)
90 ≡ 48 (mod. 7)	90 ≡ 48 (mod. 9)	9 ≡ 5 (mod. 4)	9 ≡ 5 (mod. 3)
91 ≡ 79 (mod. 3)	91 ≡ 79 (mod. 7)	9 ≡ 6 (mod. 3)	9 ≡ 6 (mod. 2)

Appendix C

(Manipulation Check Part 2)

1. How important was it for you to perform at a high level during the last set of problems? (*circle one*)

Not at all important to me						Extremely important to me
1	2	3	4	5	6	7

2. How much performance pressure did you feel to perform at a high level during the last set of problems? (*circle one*)

Very little performance pressure						Extreme performance pressure
1	2	3	4	5	6	7

3. How well did you think you performed during the last set of problems? (*circle one*)

Extremely poor						Extremely well
1	2	3	4	5	6	7

Appendix D

SONA Recruitment Form

PRINCIPAL INVESTIGATOR: Katherine Cler, M.S.
RESEARCHER INFORMATION: Katherine Cler (kbc0016@auburn.edu)

STUDY NAME: Processes Involved in Learning a New Skill

STUDY TYPE: In-person Study

BRIEF ABSTRACT: Complete a computer simulated task where you will learn a new cognitive skill. Your working memory will also be assessed. Also complete a few brief questionnaires related to your experience in learning the new skill as well as about your sleep habits and caffeine intake. Participation will take approximately two hours.

STUDY DESCRIPTION: This is an in-person appointment during which you will meet with the researcher to complete the study online in the research office. You will be asked to learn a new cognitive task and practice completing several problems to enhance your new cognitive skill. Your working memory will also be assessed. You will also be asked to complete some brief questionnaires regarding your experience in learning the new skill as well as about your sleep habits and caffeine intake. The appointment will take approximately two hours to complete. Due to the nature of this study, you will be in a shared space with the researcher. Due to COVID-19, all precautions and procedures outlined by Auburn University will be followed. The experiment is designed so that you will remain seven to eight feet apart at all times. You and the researcher will wear a mask at all times. Please wear a mask to your appointment and bring a pen. All surfaces will be disinfected before and after your appointment, and you will be provided with hand sanitizer. You will be screened prior to the experiment.

Participation in this study is voluntary and your data will be confidential. Your responses will be coded and stored separately from your name.

ELIGIBILITY REQUIREMENTS: You must be at least 18 years of age to participate, and you must be a student taking a course in the College of Education that is participating in the SONA research pool.

DURATION*:* 2 hours
CREDITS: 4.5
PREPARATION: None
IRB APPROVAL CODE:
IRB APPROVAL EXPIRATION:

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COVID-19 Screener

Symptom check and screening questions:

In the last 14 days have you experience ANY of the following symptoms:

- Shortness of breath
- Muscle aches
- Cough (not related to known seasonal allergies)
- Fever
- Sore throat
- Body aches
- Nausea, vomiting, diarrhea, abdominal pain
- Unexplainable fatigue (cannot function normally, no energy)

If yes to ANY of the following for the researcher and/or the participant, reschedule the participant and recommend that they consult with the Auburn Medical Clinic.

Appendix E

Informed Consent

AUBURN UNIVERSITY

COLLEGE OF EDUCATION

DEPARTMENT OF SPECIAL EDUCATION, REHABILITATION, AND COUNSELING

(NOTE: DO NOT SIGN THIS DOCUMENT UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)

INFORMED CONSENT
for a Research Study entitled
"Processes Involved in Learning a New Skill"

General Information	**You are being asked to take part in a research study. This research study is voluntary, meaning you do not have to take part in it. The procedures, risks, and benefits are fully described further in the consent form.**
Purpose	**The purpose of this study is to better understand the processes involved in learning a new skill and assessing basic cognitive abilities.**
Duration & Visits	**There will be one visit lasting two hours.**
Overview of Procedures	**You will be asked to complete a two types of cognitive tasks and complete a survey about with questions about the tasks, your sleep patterns, and caffeine use.**
Risks	**The only risk is related to the potential loss of confidentiality.**
Benefits	**Participants will be offered 4.5 SONA credits and may be eligible for a cash award. The benefit to the researchers is understanding how college students learn a new skill.**
Alternatives	**The alternative is to not participate in this study.**

You are invited to participate in a research study that is examining processes involved in learning a new task. The study is being conducted by Kat Cler, M.S., a doctoral candidate in Auburn University's Counseling Psychology program, under the direction of Marilyn Cornish, Ph.D., Associate Professor and Training Director of the Counseling Psychology program in the Auburn University Department of Special Education, Rehabilitation, and Counseling. You were selected as a possible participant because you are currently enrolled as a student at Auburn University and are age 18 or older.

What will be involved if you participate? If you decide to participate in this research study, you will be asked to learn and practice a task, complete problems associated with cognitive ability, and complete several questionnaires about lifestyle factors. You will also be asked to provide demographic information. Your total time commitment will be approximately two hours.

2084 Haley Center, Auburn, AL 36849-5222; Telephone: 334-844-7676; Fax: 334-844-7677 www.auburn.edu/serc

Are there any risks or discomforts? If you decide to participate in this study, there may be a risk of mild discomfort from sitting for approximately two hours while completing the aforementioned tasks and questionnaires as well as potentially experiencing some distress while learning and performing a new task. All participants will be randomly selected to be in one of two participant groups. You may be subject to video recording for data collection purposes. All recordings will be destroyed after data collection.

As such, at any point in time you will be given the opportunity to decline to continue participation in the study. As with any research, there is some possibility that you may be subject to risks that have not yet been identified. While risks of participation are considered to be minimal, should you experience any discomfort as a result of this study, please contact the Auburn Student Counseling & Psychological Services (334-844-5123), Auburn Medical Clinic, or a therapist in your area. You are responsible for any costs associated with treatment. There is a risk of loss of confidentiality of your information that is used in this study. All physical documents will be maintained in a locked drawer, within locked cabinets, within a locked room in the Dawson Building and will be destroyed upon completion of the study. All electronic data will be stored in a secure online server (Box). Due to the nature of this study, you will be in a shared space with the researcher. Additionally, there is risk for exposure to COVID-19, as in-person interactions can increase your chance of being exposed to the virus. All precautions and procedures outlined by Auburn University will be followed.

To mitigate risk associated with COVID-19, all participants will be screened prior to the experiment. The experiment is designed so that you will remain seven to eight feet apart at all times from the researcher within a larger workspace to allow for proper ventilation. You and the researcher will wear a face mask at all times. All surfaces will be disinfected before, during, and after your appointment, and you will be provided with hand sanitizer. If a face mask was provided to you by the study team, you may keep it. However, it is important to note that this face mask is primarily to protect others from you and does not protect you from others that may be infected with the virus.

Will you receive compensation for participating? To thank you for your time you will be offered 4.5 SONA credits. All participants may be eligible for a cash award.

Are there any costs? There are no costs to participating in the study.

If you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the Department of Special Education, Rehabilitation, and Counseling, or the researchers.

Your privacy will be protected. Any information obtained in connection with this study will remain confidential. This Informed Consent document, a Code List, and a Contact List will be the only study-related items with your name. All other data will be coded using participant numbers and will be stored separately. All identifying information will be kept in a locked laboratory, separate from data forms containing participant identification numbers. Information obtained through your participation may be used to fulfill an educational requirement, published in a professional journal, and/or presented at a professional meeting, but will be void of identifying information.

If you have questions about this study, *please ask them now or* contact Kat Cler at kbc0016@aubum.edu or Dr. Marilyn Cornish at mac0084@auburn.edu or (334) 844-7601. A copy of this document will be given to you to keep.

Participant's initials ____________

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If you have questions about your rights as a research participant, you may contact the Auburn University Office of Research Compliance or the Institutional Review Board by phone (334)-844-5966 or e-mail at lRBadmin@auburn.edu or lRBChair@auburn.edu.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES YOUR WILLINGNESS TO PARTICIPATE.

______________________________ ______________________________

Participant's signature **Date** **Investigator obtaining consent** **Date**

______________________________ ______________________________

Printed Name **Printed Name**

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Appendix F

Exit Survey
(these questions are to be asked verbally)

1. First, I want to make sure that you understand what the purpose of the experiment was. Can you tell me in your own words, what we were looking at in this experiment?

2. Did you believe that you were in a competition for money? (Yes or No)

3. Did you believe that your videotape would be analyzed and used for teaching and future programming purposes? (Yes or No)

4. Alright, any other thoughts or other ideas?

    a. If participant says that they thought the pressure scenario was not genuine, ask: *"What makes you think that?"*

If they seem suspicious, further explore what tipped them off, what was said, when it occurred, what seemed odd or didn't fit. Basically, get any information from them that we can use to find out how we can improve the protocol to make it more believable.

Appendix G

High-pressure condition

DeBriefing Form
For the Study entitled:
"Processes Involved in Learning a New Skill"

Dear Participant;

During this study, you were asked to learn modular arithmetic, and practice the task, across two trials. You were told that you were randomly paired with another participant who had improved their performance and that a video recording of your performance would be reviewed by local students, teachers, and professors. You were told that the purpose of the study was to examine processes involved in learning a new task. The actual purpose of the study was to determine how individuals' working memory capabilities and varying degree of sleep-related factors impacted performance on a task that relied on working memory resources under pressure conditions. No video was actually recorded and there was no participant in which you were paired with and that relied on your performance to earn the cash prize.

We did not tell you everything about the purpose of the study because it was necessary to evoke performance pressure. Creating this environment was necessary to test the effects that stress may have on cognitive performance.

However, the monetary rewards were real. We told you that you would be awarded $10 if you increased your performance by 20%. We will provide you with this compensation today, regardless of your performance. To receive this $10, you will need to sign a Participant Compensation Form for our records. In addition, should you have scored well enough on the task to receive an award, you will be contacted by email following completion of the study. At this point, you will be required to come pick up the cash, in person, and provide your email address as proof of identity. If you would like to be eligible to receive the prize, your name will be connected with your responses in order to contact the persons with the top five performances.

You are reminded that your original consent document included the following information: *"If you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the Department of Special Education, Rehabilitation, and Counseling, or the researchers."* If you have any concerns about your participation or the data you provided in light of this disclosure, please discuss this with us. We will be happy to provide any information we can to help answer questions you have about this study.

If your concerns are such that you would now like to have your data withdrawn, and the data is identifiable, we will do so.

If you have questions about your participation in the study, please contact me at kbc0016@auburn.edu, or my faculty advisor, Dr. Marilyn Cornish at mac0084@auburn.edu or (334) 844-7601.

If you have questions about your rights as a research participant, you may contact the Office of Research Compliance (334-844-5966, IRBadmin@auburn.edu or an Auburn University Institutional Review Board (IRBChair@auburn.edu).

If you have experienced distress as a result of your participation in this study, a referral list of mental health providers is attached to this document for your use. (Please remember that any cost in seeking medical assistance is at your own expense.)

Please again accept our appreciation for your participation in this study. Please refrain from discussing the methods or details about this study to anyone, as it could corrupt the results.

____

Name Date

Referral List

Agency	Address	Phone
Auburn University Student Counseling & Psychological Services http://wp.auburn.edu/scs/	400 Lem Morrison Dr #2086 Auburn University, AL 36849	(334) 844-5123
Auburn University Psychological Services https://cla.auburn.edu/psychology/aupsc	101 Cary Hall Auburn University, AL 36849	(334) 844-4889

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Appendix H

Low-pressure Condition

DeBriefing Form
For the Study entitled:
"Processes Involved in Learning a New Skill"

Dear Participant;

During this study, you were asked to learn modular arithmetic, and practice the task, across two trials. You were told that the purpose of the study was to examine processes involved in learning a new task. The actual purpose of the study was to determine how individuals' working memory capabilities and varying degree of sleep-related factors impacted performance on a task that relied on working memory resources under different pressure conditions.

While you were not exposed to the pressure sources, we did not tell you everything about the purpose of the study because it was necessary to examine the differences in performance across different pressure conditions.

You are reminded that your original consent document included the following information: *"If you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the Department of Special Education, Rehabilitation, and Counseling, or the researchers."* If you have any concerns about your participation or the data you provided in light of this disclosure, please discuss this with us. We will be happy to provide any information we can to help answer questions you have about this study.

If your concerns are such that you would now like to have your data withdrawn, and the data is identifiable, we will do so.

If you have questions about your participation in the study, please contact me at kbc0016@auburn.edu, or my faculty advisor, Dr. Marilyn Cornish at mac0084@auburn.edu or (334) 844-7601.

If you have questions about your rights as a research participant, you may contact the Office of Research Compliance (334-844-5966, IRBadmin@auburn.edu or an Auburn University Institutional Review Board (IRBChair@auburn.edu).

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If you have experienced distress as a result of your participation in this study, a referral list of mental health providers is attached to this document for your use. (Please remember that any cost in seeking medical assistance is at your own expense.)
Please again accept our appreciation for your participation in this study. Please refrain from discussing the methods or details about this study to anyone, as it could corrupt the results.

Referral List

Agency	Address	Phone
Auburn University Student Counseling & Psychological Services http://wp.auburn.edu/scs/	400 Lem Morrison Dr #2086 Auburn University, AL 36849	(334) 844-5123
Auburn University Psychological Services https://cla.auburn.edu/psychology/aupsc	101 Cary Hall Auburn University, AL 36849	(334) 844-4889

Appendix I

Additional Consent Form
For the Study entitled:
"Processes Involved in Learning a New Skill"

To be considered for the top five cash rewards (1st place = $50, 2nd place = $40, 3rd place = $30, 4th place = $20, 5th place = $10), your responses will need to be connected with your identifying information. All identifying information will be kept in a locked laboratory, separate from data forms containing participant identification numbers. You may opt in or opt out from being considered for the cash reward. Your decision about whether or not to participate will not jeopardize your future relationships with Auburn University, the Department of Special Education, Rehabilitation, and Counseling, or the researchers. Your name and email address will be required to contact you should you score within the top five participants. You will not be contacted if you are not within the top five participants.

Your signature indicates your willingness to connect your identifying information to your responses to be considered for the cash reward.

___________________________________ _____________ ___________________________________ _____________

Participant's signature Date Investigator obtaining consent Date

___________________________________ ___________________________________

Printed Name Printed Name

____

Participant's email address

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