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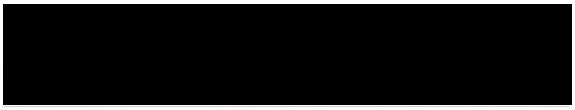

Signature of Faculty Advisor

05/21/24

Date

The Effects of Psychosocial Threat on Working Memory Performance in Anxious Individuals

A Plan B Research Defense
SUBMITTED TO THE FACULTY OF THE UNIVERSITY
OF MINNESOTA
BY

Jillian C. Anderson

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF ARTS

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Abstract

A large area of anxiety research assesses two key characteristics, state and trait anxiety. Scholars find that individuals with high trait anxiety have difficulty disengaging their attention away from threatening stimuli. When in a threatening situation, people may experience elevated heart rate, increased skin conductance, and ruminating thoughts. This can distract the individual during decision-making and further disturb their memory. Thus, the current experiment intended to examine specific variables that affect the relationship between stress and working memory performance in anxious and non-anxious individuals. Variables that were expected to influence working memory performance included levels of state and trait anxiety, and physiological arousal. Participants first completed a complex working memory task (OSPAN task) followed by undergoing a common psychosocial stressor (Trier Social Stress Test) and completed the OSPAN task again. Heart rate and skin conductance levels were also collected. Results showed that heart rate and skin conductance levels were significantly elevated during the Trier Social Stress Test compared to baseline measures. State anxiety also significantly increased from baseline to after the stress test. Furthermore, overall working memory performance was better on the second round of the working memory task. However, participants who experienced the greatest increases in state anxiety performed the worst on the second round. The current findings contribute to the growing body of literature on the individual's cognitive and physiological responses as they experience anxiety and stress.

Keywords: state anxiety, trait anxiety, working memory, attentional control, sympathetic arousal, psychosocial threat

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The Effects of Psychosocial Threat on Working Memory Performance in Anxious Individuals

Symptoms of anxiety include uncontrollable worry, hyperresponsiveness to threat and engrossing thoughts (American Psychiatric Association, 2022; Jiang et al., 2017). These reactions are distinguished into two facets, including state anxiety, or the sympathetic arousal one feels in response to threat, and trait anxiety, or one's general tendency to feel threatened. Individuals with high trait anxiety tend to appraise ambiguous or neutral stimuli as more threatening compared to individuals with low trait anxiety (Cisler & Koster, 2010). Additionally, they have difficulty disengaging their attention away from threatening stimuli and continue to ruminate when the presence of threat has been removed (Gavric et al., 2017; Pacheco-Unguetti et al., 2010). Attending to threat can in turn affect other areas of functioning such as decision-making and memory. Threat can produce circling thoughts and is assumed to reduce the attention towards task performance. This can further disturb working memory and the ability to choose correct answers (Moran, 2016). The goal of the present study is to examine the relationship between individual anxiety and working memory performance before and after the presence of threat.

State and Trait Anxiety

State anxiety is the transitory emotion and physiological arousal someone may feel during a potentially threatening situation, with common feelings of apprehension, dread, and tension (Endler & Kocovski, 2001; Pacheco-Unguetti et al., 2010). Cognitively, one may endure ruminating thoughts or worry in response to a threatening stimulus. Physiologically, one may experience sympathetic arousal such as increased

heart rate, blood pressure, and sweating, and a delay in the ability to return one's heart rate to baseline following the threatening stimulus (Hoehn-Saric & McLeod, 2000). Common events that increase state anxiety are verbal conflicts, public performance, or completing a high-stakes exam in a short amount of time.

Researchers have used psychosocial stressors including social rejection and the Trier Social Stress Test to increase state anxiety (Frisch et al., 2015; Kirschbaum et al., 1993; Wagels et al., 2017). The Trier Social Stress Test induces stress in participants by having them create an impromptu interview-style presentation. With only a few minutes to prepare, the participants find out they will need to create a speech on a topic and that judges (researchers) will be evaluating their performance. Immediately after the presentation, the participants complete a challenging task, generally mathematics involving subtraction by a double-digit odd number. In more recent studies, participants who performed the test reported higher state anxiety, elevated heart rate, and increased skin conductance compared to baseline (Bigalke et al., 2022; Jiang et al., 2017; Shiban et al., 2016; Villada et al., 2016). Although many people have experienced stress in these situations, fewer people report feelings of anxiety in everyday scenarios.

Trait anxiety is defined as an individual’s predisposition to respond adversely to, and experience negative attitudes towards any stimuli (Endler & Kocovski, 2001; Pacheco-Unguetti et al., 2010). These stimuli can include, but are not limited to, social evaluation, physical danger, ambiguous situations, and daily routines. Individuals high in trait anxiety may respond to stimuli with feelings of stress, anger, guilt, and depressed mood (Hur et al., 2015). Trait anxiety is relatively stable, but it is thought to interact with state anxiety in which individuals who report high trait anxiety tend to display higher

state anxiety in a variety of settings. For instance, when someone is presenting a speech, their heart rate may increase, and they may worry about not recalling the material or how they are perceived by the audience. Someone with high trait anxiety can experience significantly greater levels of physiological arousal and ruminating thoughts than those with low trait anxiety when exposed to the same threat.

Trait anxiety is typically assessed via self-report measures such as the Trait Anxiety Inventory and the Generalized Anxiety Disorder Screener as high levels of trait anxiety could signal a possible anxiety disorder (Spielberger, 1983; Spitzer et al., 2006). Previous literature also shows that individuals diagnosed with generalized anxiety disorder score higher on the Trait Anxiety Inventory, report lower perceived attentional control, and have an increased need to regulate their thoughts than self-reported high worriers (Hirsch et al., 2013). These findings demonstrate key differences in the way anxious individuals respond to and perceive threats.

Physiological Arousal

The autonomic nervous system (ANS) regulates involuntary physiological processes such as heart rate, blood pressure, and respiration. The ANS is composed of the sympathetic and parasympathetic nervous systems. As part of the parasympathetic nervous system, the vagus nerve regulates heart rate and aids in calming the body. The vagus nerve also transmits information to the amygdala, an area in the brain responsible for emotions such as fear and aggression. Previous studies show that extreme changes in vagal tone are a key factor in individuals high in anxiety (Scott & Weems, 2014). In contrast, the sympathetic nervous system activates in response to stressful situations, and an individual may experience heart palpitations, shortness of breath, and greater muscle

tension consistent with state anxiety (Hoehn-Saric & McLeod, 2000). Sympathetic arousal in response to threat has been associated with increased resistance to blood flow, in addition to elevated systolic blood pressure and production of sweat (Kemeny, 2003).

Researchers have tested a variety of procedures to induce this type of arousal, such as solving a string of arithmetic problems, completing cognitively challenging puzzles, or playing competitive games (Trotman et al., 2019). Participants in Trotman et al. (2019) performed these challenges in a random order and rated the arithmetic and puzzle challenges as the most stressful. Their heart rates increased significantly more during the arithmetic condition than the other conditions. While these methods may induce anxiety in some individuals, one of the most commonly reported fears cross-culturally involves some form of public performance.

As aforementioned, the Trier Social Stress Test is frequently used to induce anxious arousal. Compared to baseline levels, Bigalke et al. (2022) found that participants experienced significantly increased heart rates during the speech preparation, the speech itself, and the mathematics portion of the Trier, with participants' heart rates increasing the most during the speech. It has also been consistently shown that in healthy participants, heart rate returns to baseline levels when given a five to ten minute recovery period (Jiang et al., 2017; Olver et al., 2014; Wemm & Wulfert, 2017). While there is extensive research on how the Trier affects participants' heart rate, fewer studies that have used this task have measured skin conductance levels as physiological responses to stress.

Skin conductance, or electrodermal activity, measures the changes in the electrical resistance of the skin. Electrodermal activity is an involuntary process produced by the

autonomic nervous system, and increases during stressful situations (Markiewicz et al., 2022). Previous literature has shown that participants who undergo the Trier Social Stress Test respond with significantly elevated skin conductance levels while preparing for the speech, delivering the speech, and during the mathematics portion compared to baseline measures and control groups, and was the highest when delivering the speech (Guez et al., 2016; Shiban et al., 2016). Individuals with high trait anxiety or diagnosed with an anxiety disorder, most notably social anxiety disorder, show even greater levels of stress and sympathetic arousal than healthy groups during the Trier Social Stress Test (Grace et al., 2022).

Attentional Bias and Appraisal of Threat

A prominent feature of anxiety is hyperresponsiveness, or exaggerated sensitivity, to threat (Bashford-Largo et al., 2021; Mogg et al., 2000). From an evolutionary standpoint, this can be seen as a defensive mechanism (e.g., hypervigilance) meant to protect the individual from something that is likely to cause harm or danger (Moran, 2016). The threat response seen in anxiety can be partly explained by the attentional bias theory, or the tendency to focus on certain (threatening) elements while ignoring other (neutral) elements (Berggren & Derakshan, 2013). The heightened encoding of threatening stimuli affects other processes involving top-down control (Wolf, 2017). Deficits in attentional bias and control occur in all anxiety disorders, and people higher in trait anxiety attend to threat more than people lower in trait anxiety (Angelidis et al., 2019; Cisler & Koster, 2010). With uncontrollable worry as a symptom of high trait anxiety and anxiety disorders, cognitive resources are occupied by these thoughts, and

distractibility rises while attentional control is diminished, and worry persists (Eysenck et al., 2023).

Researchers typically use methods such as visual search tasks (detecting and responding to a target stimulus) or Stroop tasks (processing congruent and incongruent stimuli) to examine participants' attentional bias and perception of threatening stimuli. In a previous experiment with generalized anxiety disorder and healthy patients, Albu (2008) had participants read short lists of neutral and anxiety-related words. Participants were then instructed to remember half of these words and forget the other half, and then performed a free recall of the words. Afterwards, participants completed an emotional Stroop task with a larger list of neutral and anxiety-related words containing words from the lists prior in either black or colored ink. Results revealed that participants with generalized anxiety disorder remembered more words associated with anxiety and had more trouble distinguishing the color of these words than healthy controls. This provides further evidence that anxious individuals have a greater attentional bias to, and limited attentional control over threatening stimuli.

Additionally, research has shown that there are individual differences in the appraisal of threat (Banks et al., 2015). People higher in anxiety can appraise something as threatening when people lower in anxiety appraise it as neutral. This can come in the form of negative interpretation biases and difficulty inhibiting intrusive thoughts (Mogg et al., 2000; Moran, 2016). If someone creates a certain appraisal of an event, this moderates the stressor's impact; negative appraisals can lead to rumination and increase the likelihood of circling worries (Banks et al., 2015). Individuals with social anxiety disorder also have a decreased tendency to reappraise threatening stimuli, or to reframe

the negative event into something positive (Lewis et al., 2018). This can lead to post-event processing, or prolonged rumination of psychosocial stress (Gavric et al., 2017). Collectively, attending to, and ruminating about threatening events often slows our appraisal of them, creating a feedback loop affecting the autonomic nervous system and increasing emotions of fear and physiological arousal (Cisler & Koster, 2010).

Working Memory and Measurements

Working memory is the system that retains access to a limited amount of information (seven +/− two items) in the service of more complex cognitive operations, or manipulating stimuli into memorable information (Gazzaniga et al., 2019; Moran, 2016). In the 1970's, Alan Baddeley and Graham Hitch hypothesized that working memory is composed of three parts: the central executive, the phonological loop, and the visuospatial sketchpad. The central executive oversees and controls the flow of information to and from the phonological loop, which stores auditory and verbal content, and the visuospatial sketchpad, which stores visual information (Gazzaniga et al., 2019). The phonological loop carries information throughout the temporal and parietal lobes, as well as the prefrontal cortex. Anxiety can disturb working memory performance when the phonological loop is overloaded with a high memory load, in turn affecting decision-making, a key function associated with the prefrontal cortex (Johnson & Gronlund, 2009).

Examples of working memory tests include the *n*-back, which measures functions such as attention to detail, processing speed, and immediate recall, and delayed response tasks, where participants respond to stimuli that they saw or heard previously (Gajewski et al., 2018; Kalat, 2019). *N*-back tasks use a variety of stimuli including letters, numbers,

or pictures that are displayed one at a time, and participants must identify if the stimulus in a given sequence is identical to the one presented *n* items previously (Coulacoglou & Saklofske, 2017). *N*-back tasks range in difficulty, for example, from 0- to 3-back, with 3-back demonstrating higher cognitive load.

In the operation span (OSPAN) task, participants complete simple mathematical equations while simultaneously remembering a sequence of words or letters (McMorris, 2016). Participants first see a math equation (e.g., (2*5) = 8), and are instructed to indicate whether or not the presented digit is the correct answer. At the same time, participants see a word (e.g., DOG), and they say the presented word out loud. These steps are repeated for *n* number of sets, and then participants are instructed to recall the words in the same order in which they were shown in that set. Individuals with higher working memory capacity generally have better attentional control and perform better on the OSPAN compared to those with lower working memory capacity (Luo et al., 2017).

Covariations of Anxiety and Threat on Working Memory Performance

Attentiveness to threat, stressors, and intrusive thoughts seen in anxious individuals can disrupt one's working memory (Banks et al., 2015). Because anxiety is associated with deficits in attentional control, and working memory only allows for minimal cognitive resources, these resources are occupied by rumination about threatening stimuli, not allowing someone to focus on ongoing or future tasks (Longstaff & Belz, 2020). Findings further show a poorer ability to flexibly shift attention between tasks and update working memory (Berggren & Derakshan, 2013; Shackman et al., 2006; Wolf, 2017). Higher cognitive load, such as remembering a sequence of six letters compared to three letters, is also associated with poorer working memory performance,

shown more in anxious individuals than non-anxious individuals (Kerestes et al., 2012; Moran, 2016). To gauge the effects of threat on working memory, researchers often induce emotional or psychosocial stress in their participants.

Banks et al. (2015) had participants complete a working memory task while going through stress or control conditions. Participants in the stress condition nominated a negative life event to write about, while participants in the control group wrote about events that occurred the day before. The participants were instructed to remember a list of letters while also completing simple arithmetic equations. After verifying the answer to an equation, participants were shown a random letter. This sequence of events occurred multiple times, and the participants had to indicate the order in which the letters were presented. Results showed that participants' state anxiety significantly increased in the stress condition compared to the control group, and that overall increased state anxiety led to poorer performance on the working memory task.

The Trier Social Stress Test has been shown to impair accuracy and reaction time in the *n*-back task (Schoofs et al., 2008). In Schoofs' study, participants underwent the psychosocial stressor, then alternated between four sets of 2- and 3-back tasks ten minutes later. Compared to a control group that presented their speech in a room alone, participants who presented in front of judges had slower reaction times to both 2- and 3-back conditions, most significantly in the first set of stimuli. Similarly, van Ast et al. (2016) expanded on the social evaluation aspect of the Trier in which the participants were told their responses to subsequent tasks, including an *n*-back task, would be evaluated, and the judges provided performance feedback on these tasks. Participants who underwent this stressful condition had significantly reduced accuracy and longer

response times to both a 2- and 3-back task compared to a control condition. While these studies focused on the impact of threat on working memory, few researchers have looked at trait anxiety as a potential factor.

Angelidis et al. (2019) used a comparable psychosocial threat induction procedure to the Trier; the Leiden Performance Anxiety Stress Procedure. In this study, participants verbally solved difficult mathematical equations in front of a researcher under time constraints. They were told their behavior and performance would be assessed, and researchers gave them negative feedback. In the control group, participants were not given negative feedback, and solved the equations under no time constraints. Afterwards, participants completed an *n*-back task with word stimuli. Participants in the stress condition had significantly slower reaction times and diminished accuracy on the *n*-back task compared to the control group. In addition, participants who reported higher trait anxiety regarding cognitive performance (testing anxiety) and performed the stress procedure displayed significantly reduced working memory compared to those low in trait anxiety or in the control group.

As previously mentioned, the *n*-back task is one of the most commonly used tasks that measures working memory. However, OSPAN tasks are thought to be more accurate in measuring working memory compared to *n*-back tasks (Redick & Lindsey, 2013). While the *n*-back task mainly measures attention to detail, processing speed, and immediate recognition, the OSPAN task measures information updating, attentional shift, inhibition of irrelevant stimuli, and delayed recall (Scharinger et al., 2017). There is a lack of research on how stress affects performance on more complex working memory tasks such as the OSPAN task. Furthermore, few studies have examined working memory

performance both before *and* after a stressful event to see if working memory has truly been affected. To my knowledge, the current study is the first to measure how the Trier Social Stress Test affects working memory performance using the OSPAN task. This study is also one of the first to assess working memory performance pre- and post-presence of threat.

Research Questions and Hypotheses

The goal of this study was to examine the relationship between overall trait anxiety, physiological and emotional arousal as experienced by psychosocial threat, and working memory performance. Participants reported on their levels of anxiety and completed the first round of the working memory task. Afterwards, participants prepared for and performed an unanticipated speech for two judges, and then responded again regarding their state anxiety along with the second round of the working memory task. Physiological measures including heart rate and skin conductance were recorded during the speech and separated into four time periods: baseline, preparation, performance, and post-performance mathematics. Based on previous literature regarding anxiety, memory, and physiology, the following research questions and hypotheses were proposed.

Research Question 1—What are the Relationships Between Perceived Stress, Trait Anxiety, and State Anxiety?

I first hypothesized that levels of perceived stress would be positively correlated with trait anxiety. Additionally, I hypothesized that trait anxiety would be positively correlated with state anxiety both before and after the stress test.

Research Question 2—How Does Psychosocial Threat Affect Individual State Anxiety?

I hypothesized that participants would report higher state anxiety post-speech compared to baseline measures.

Research Question 3—How Does Psychosocial Threat and Trait Anxiety Affect Physiological Arousal?

I hypothesized that all participants would experience an increase in heart beats per minute and levels of skin conductance during all three stages of the test (i.e. preparation, speech performance, and post-performance). Specifically, I hypothesized that heart rate and skin conductance would be highest during the speech performance. I also hypothesized that participants higher in trait anxiety would experience greater physiological arousal than those lower in trait anxiety.

Research Question 4—How Does Psychosocial Threat, Trait Anxiety, and State Anxiety Affect Working Memory Performance?

I hypothesized that all participants would perform with worse accuracy on the working memory task after the speech compared to before. Specifically, I hypothesized that all participants would make more math errors and have worse OSPAN scores on the second round of the task compared to the first round. I also hypothesized that participants with greater levels of state anxiety would perform with worse accuracy on the second round of the OSPAN task compared to participants with lower levels of state anxiety. The same was further hypothesized for trait anxiety, in which those with higher trait anxiety would perform with worse accuracy after the stress test compared to participants with lower levels of trait anxiety.

Method

Participants

An a priori power analysis was conducted using G*Power version 3.1 to test the effects of trait anxiety and psychosocial stress on working memory performance and physiological responses using a medium effect size (f = .20), an alpha of .05, one group, four measurements, and a 0.5 correlation among repeated measures. Results showed that a total sample of 40 participants was required to achieve a power of .85 (Faul et al., 2007). A total of 42 participants volunteered for this study via an online research recruitment tool and received research credits for their respective courses. These participants were students, unknown to the researchers, and were attending a mid-size Midwestern university. This study was conducted in a laboratory space at the university. Data collection occurred between October 2023 and March 2024. This study followed the ethical guidelines of the American Psychological Association and was further approved by the university's Institutional Review Board.

Eligibility criteria included individuals at least 18 years of age, those not taking medication for hypertension, those without conditions that affect the hypothalamic-pituitary-adrenal axis such as Addison's or Cushing's disease, those without neurological conditions such a recent concussion or epilepsy, and those without breathing-related disorders such as asthma or sleep apnea. One participant reported having a concussion as a child, and another reported taking medication to control their asthma symptoms, therefore no participants were excluded from participating in the study. Participants completed a demographics questionnaire reporting on gender, age, race, ethnicity,

education, and employment. Further questions inquired about psychopathological symptoms and diagnoses.

The final sample consisted of 42 participants. Participants' ages ranged from 18 to 28 years (M = 19.57, SD = 2.22). One participant was an African American woman, one participant was a multi-racial woman, one participant was a Latino man, one participant was a South Asian woman, 14 participants were White men, and 24 participants were White women. 38.1% of participants reported having a diagnosis of an anxiety disorder (15 with generalized anxiety disorder, one with social anxiety disorder), and 61.9% of participants did not report a diagnosis of any psychological disorder. Of the 16 participants with an anxiety disorder diagnosis, 12 were women and four were men. Eight of these participants reported having an additional diagnosis of depression, two participants reported being diagnosed with attention-deficit/hyperactivity disorder, one participant was diagnosed with obsessive-compulsive disorder, and one participant had a diagnosis of post-traumatic stress disorder. Furthermore, 12 of these 16 participants were taking medication for their diagnoses at the time of participation.

Materials

State-Trait Anxiety Inventory

To assess the effects of psychosocial stress, participants self-evaluated their state anxiety symptoms using the State-Trait Anxiety Inventory for Adults form Y-1 (Spielberger, 1983). For the current study, this form had high internal consistency (α = .85). The Y-1 form included 20 items that assess an individual's current (state) anxiety using statements such as "I feel nervous" and "I am relaxed" (See Appendix A for the entire form). Participants rated each statement using a four-point Likert-type scale from 1

(*not at all*) to 4 (*very much so*). Ten items were then reverse scored, and the sum was calculated across all items. The range of possible scores for this form was from 20 to 80.

To assess levels of trait anxiety, participants completed form Y-2 of the State-Trait Anxiety Inventory for Adults (Spielberger, 1983). For this study, this form also had high internal consistency ($\alpha = .86$). The Y-2 form included 20 statements examining general (trait) anxiety with statements such as "I am a steady person" and "I worry too much over something that really does not matter" (See Appendix A for the entire form). Participants rated each statement using a four-point Likert-type scale from 1 (*almost never*) to 4 (*almost always*). Nine items were then reverse scored, and the sum was calculated across all items. The range of possible scores for this form was from 20 to 80. Scores of 40 and below signify low to moderate levels of trait anxiety, while scores above 40 signify high trait anxiety (Ercan et al., 2015).

Perceived Stress Scale

Participants assessed their personal stress levels in the past month using the Perceived Stress Scale (Cohen et al., 1983). The Perceived Stress Scale consists of ten items that evaluate how respondents view their life as being unpredictable/uncontrollable. The measure had good internal consistency ($\alpha = .84$). Sample questions included "How often have you been upset because of something that happened unexpectedly?" and "How often have you been able to control irritations in your life?" (See Appendix B for the entire measure). Participants rated each item on a five-point Likert-type scale from 1 (*never*) to 5 (*very often*). Four items were then reverse scored, and the sum was calculated across all items. Scores for this questionnaire can range from ten to 50. Scores of 26 and

below signify low to moderate levels of stress, while scores above 26 signify high stress (Lee, 2012).

Patient Health Questionnaire-2

Participants also reported on their overall mood disturbances using the Patient Health Questionnaire-2 (Spitzer et al., 1999). The inventory consisted of two questions that gauge depressed mood and anhedonia symptoms according to the Diagnostic and Statistical Manual of Mental Disorders-5-TR (American Psychiatric Association, 2022). Participants rated each question using a four-point Likert-type scale from 1 (*not at all*) to 4 (*nearly every day*). The two questions asked how often these symptoms have been present in the last two weeks; "little interest or pleasure in doing things" and "feeling down, depressed, or hopeless" (See Appendix C for the entire measure). With the sum calculated across all items, scores of 2–4 signify lower levels of depressive symptoms and 5–8 signify greater levels of depressive symptoms (Kroenke et al., 2003).

Physiological Measures

The primary investigator trained a research assistant on applying physiological recording devices. That researcher applied the measures to all participants to keep consistency, under the supervision of the primary investigator. The researcher connected participants to an ECG100C electrocardiogram amplifier from BIOPAC® to record hemodynamic measures. To measure heart rate, the electrocardiogram detected R waves and measured interbeat intervals, or contractions of the heart muscle in beats per minute (Alkozei et al., 2015). The electrocardiogram continuously recorded heart rate at a sampling rate of 1000 Hz. Using disposable electrodes and a two-lead approach, one electrode was placed on each forearm symmetrically after cleansing with an alcohol

wipe. Mean heart rate was measured for all four time segments after I accounted for movement artifacts.

Participants were also connected to skin conductance electrodes from BIOPAC® to measure electrodermal activity, or the changes in the electrical resistance of the skin as a function of the sweat gland. To record skin conductance, GEL101A electrode paste formulated with 0.5% saline was used with two surface electrodes applied to the index and fourth fingertips of participants' right hand to measure the resistance between the electrodes (Shiban et al., 2016). Skin conductance was continuously measured in micro-Siemens (μS), and at a sampling frequency of 62.5 Hz. Skin conductance was also measured for all four time segments, specifically the mean levels of micro-Siemens.

AcqKnowledge® software was used to analyze both of these measures. Analysis included the removal of movement artifacts observed in the electrocardiogram and electrodermal recordings. To address movement artifacts in both heart rate and skin conductance analyses, I used the automated scripting function within AcqKnowledge® which combed through the data and removed any detected outliers.

Tasks

Trier Social Stress Test

The Trier Social Stress Test induces psychosocial stress by requiring participants to make an interview-style presentation for a working position in a certain profession without prior knowledge of the presentation (Kirschbaum et al., 1993). The primary investigator, who was a woman, gave directions for the interview process in which the position was for a store manager at a local grocery shop, and they were given four minutes to prepare for the interview. The participants were instructed to convince a panel

of two “judges” (the primary investigator and confederate, who was a man) that they were the best person for this job. They were also informed that the judges would be evaluating their performance. During preparation, the participants were left alone with the door closed, allowing them to consider what they were going to say during their speech. The judges remained neutral throughout the test. All participants were asked standardized questions at some point during their speech (e.g., “What are your strengths/weaknesses regarding this position?”). Post-performance, the primary researcher instructed the participants to verbally subtract the number 13 from 1,022 as quickly and accurately as possible for four more minutes.

Operation Span Task

As a measure of working memory, participants completed an automated version of the operation span task through Inquisit® software (OSPAN; Unsworth et al., 2005). Participants first completed three practice trials with both written instructions on the computer and verbal instructions from the researcher. The first practice session was a simple letter span where single capitalized letters, randomly selected from a list of 12 letters (F, H, J, K, L, N, P, Q, R, S, T, and Y), appeared on the screen one at a time, and the participants had to recall the letters in the same order in which they were presented. In both practice and experimental trials, letters were displayed for 800 milliseconds.

After a few letters were presented, the participants then saw a four by three matrix of the 12 letters. The letters remained in the same location for every recall section. Recall consisted of clicking the appropriate letters in the correct order. After clicking the letters, participants could either click a box labeled ‘exit’ to move forward, a ‘clear’ box to click to start over if the participant made a mistake, or a ‘blank’ box to mark a missing letter’s

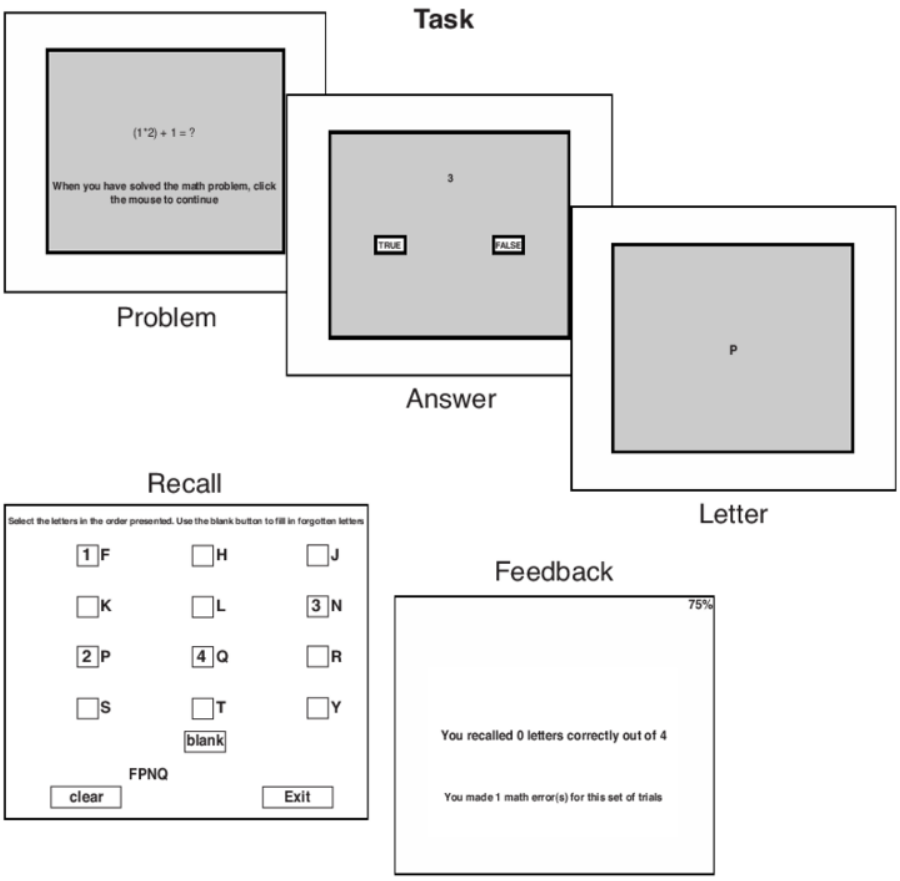
place if participants forgot a letter. There was no time limit for recalling the letters in both practice and experimental conditions. After recall, the computer provided feedback about the number of letters correctly recalled in the current set.

Participants completed four practice letter trials, two sets of two letters, and two sets of three letters. Next, the participants practiced the math portion of the task. All math equations were randomly selected from a list of 95 equations within the Inquisit® code. Participants first saw a math equation (e.g., (3*4) = ?). The participants were instructed to mentally solve the equation as quickly as possible, and then click the left mouse button to advance to the next screen. On the next screen a digit (e.g., 8) was presented and the participants were required to click either a “true” or “false” box, depending on their answer. After each equation, the participants were given feedback on their accuracy. The participants completed four math operations in this practice session.

In the final practice session, the participants performed both the letter recall and math portions simultaneously (see Figure 1). For three sets, participants first saw the math operation, and after they clicked the mouse button indicating that they had solved it, they saw the letter to be recalled. Each math problem was shown for 6000 milliseconds, and if the participant could not solve the problem within that time, the program moved on to another letter and the next math problem. These incidents were counted as speed errors. After all practice trials, participants were left alone to complete the experimental trials. The experimental trials consisted of two sets of each set size, with the set sizes ranging from three to seven, totaling to ten sets, 50 letters, and 50 math problems. The order of set sizes was random for each participant.

Figure 1

Operation Span Task



Note. From "An Automated Version of the Operation Span Task" by Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W., 2005, *Behavior Research Methods, 37*(3), p. 500. (https://doi.org/10.3758/BF03192720) Copyright 2005 Psychonomic Society, Inc.

During recall, a percentage in red was presented in the upper right-hand corner of the screen, indicating the percentage of correctly solved math operations. The task took approximately 10 to 15 minutes to complete. For the math operations, I measured the number of total math errors (speed errors + accuracy errors). An overall absolute OSPAN score was also collected, which calculated the sum of all perfectly recalled letter sets

(Dokic et al., 2018). For example, if a participant correctly recalled three letters in a set size of three, four letters in a set size of four, and four letters in a set size of five, their absolute OSPAN score would be seven (three + four + zero). OSPAN scores can range from a score of zero to 50.

Procedure

For this experiment, data were collected individually for each participant. Upon arrival at the laboratory, participants were screened for eligibility. If they were eligible, participants provided consent. The consent form indicated that they would be asked to complete questionnaires regarding sad or anxious feelings, a computerized task measuring mental capabilities, and a further challenging task. After consenting, participants first responded to the State Anxiety Inventory (Y-1 Form), the Trait Anxiety Inventory (Y-2 Form), the Perceived Stress Scale, and the Patient Health Questionnaire-2. Participants also completed the first round of the OSPAN task, including the practice trials. The researcher then attached electrodes to the participants to record physiological responses. Physiological responses were continuously measured during the Trier Social Stress Test for a total of 16 minutes and separated into four time segments: baseline (four min), preparation (four min), performance (four min), and post-performance mathematics (four min). After the mathematics segment, the researcher removed the electrodes from the participant, and participants responded again to the State Anxiety Inventory (Y-1 Form). Working memory performance was then assessed again with the OSPAN task, also including the practice trials. After all tasks were completed, participants then completed the demographics questionnaire. Finally, participants were debriefed on the

true nature of the experiment, and that their performance during the “interview” was not actually evaluated.

Data Diagnostics

Data cleaning was performed using IBM SPSS Statistics (Version 29). Regarding missing data, one participant was removed from all heart rate analyses due to technical difficulties within the AcqKnowledge® software. There were no other missing data. Outliers were assessed using skew statistics and Q-Q plots. These plots showed 32 extreme outliers across the questionnaires, working memory task scores, and physiological responses. Specifically, outliers were seen on the Patient Health Questionnaire-2, State Anxiety Inventory time 1, math errors on time 1 and 2, and heart rate and skin conductance for all stages of the stress test. Extreme outliers were winsorized and replaced with the next highest score that was not an outlier (Field, 2013). After removing the outliers, skew was assessed again, and all *z*-scores were less than 1.96.

General Analytic Strategy

All statistical analyses were performed using IBM SPSS Statistics (Version 29). Descriptive and frequency analyses were conducted to observe demographic characteristics. Pearson *r* correlations were performed to analyze the relationships between perceived stress, state anxiety, and trait anxiety. I used a repeated measures *t*-test to analyze perceived state anxiety and working memory performance before and after the stress procedure. Additionally, I used two separate one-way repeated measures ANOVAs on heart rate and skin conductance dependent variables during the four stages of the stress test. To adjust for any sphericity violations in the ANOVAs, Greenhouse-Geisser

statistics were used. A 2 x 4 mixed repeated measures ANOVA was used with the independent groups being trait anxiety (high vs. low) and the repeated measure being the stages of the Trier Social Stress Test (baseline, preparatory, speech, and mathematics) to assess main effects of trait anxiety on mean heart rate and skin conductance. Further analyses on working memory scores were conducted using independent samples *t*-tests to assess the mean differences of total math errors and absolute OSPAN scores between those with high and low trait anxiety, as well as decreases and increases state anxiety.

Results

Questionnaire Responses

Table 1 includes descriptive statistics and correlations for questionnaire responses. Levels of perceived stress significantly positively correlated with levels of and trait anxiety. Trait anxiety scores were also significantly positively correlated with state anxiety at times 1 and 2. A repeated measures *t*-test indicated that state anxiety increased significantly from before to after the stress procedure, $t(41) = 2.83$, $p = .007$, $d = .44$.

Table 1

Descriptive Statistics and Correlations for Questionnaires Regarding Depressive Symptoms, Perceived Stress, Trait Anxiety, and State Anxiety

Variable	*M*	*SD*	1	2	3	4	5
1. Patient Health Questionnaire-2	2.79	.81	—				
2. Perceived Stress Scale	25.38	5.70	.50**	—			
3. Trait Anxiety Inventory	38.21	7.93	.58**	.71**	—		
4. State Anxiety Inventory Time 1	30.38	5.36	.22	.30	.52**	—	
5. State Anxiety Inventory Time 2	34.50	10.11	.15	.54**	.47**	.39*	—

Note. N = 42. The Patient Health Questionnaire-2 is a measure of depressive symptoms. The Patient Health Questionnaire-2, Perceived Stress Scale, and Trait Anxiety Inventory were measured once at the beginning of the experiment, while participants completed the State Anxiety Inventory immediately before (Time 1) and after (Time 2) the Trier Social Stress Test.

*$p < .05$. **$p < .001$.

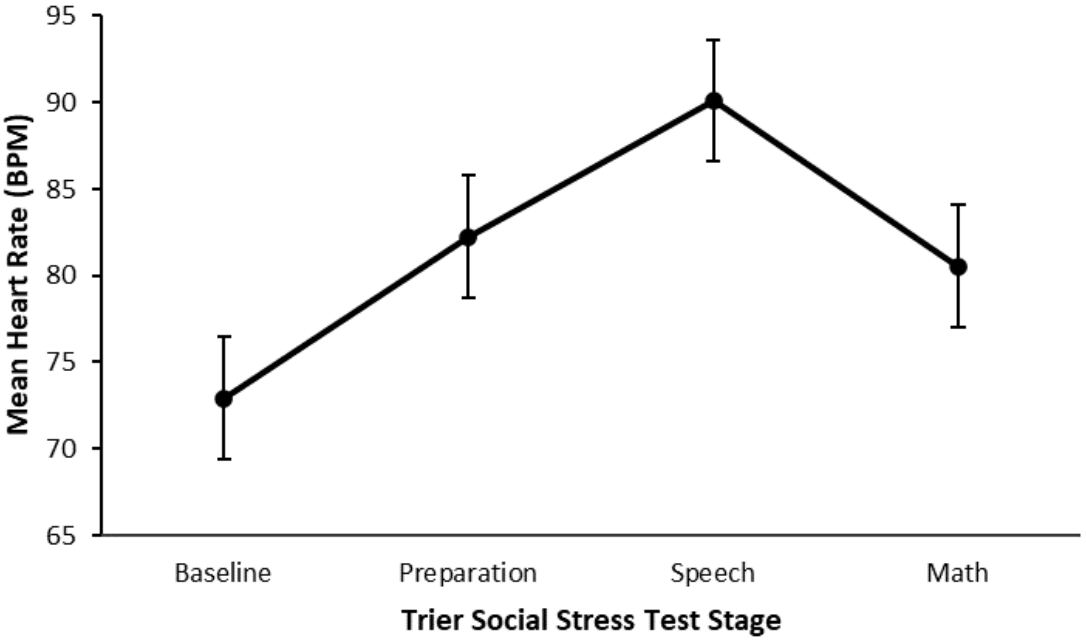
Physiological Measures

Figure 2 shows mean heart rate during the stages of the Trier Social Stress Test. The overall ANOVA was significant on heart rate, $F(2.37, 94.71) = 84.95$, $p < .001$, $\omega^2 = .67$. Post-hoc tests with Bonferroni corrections revealed that heart rate significantly

increased from baseline (M = 72.91, SD = 9.83) to the preparation stage (M = 82.24, SD = 13.03), $p < .001$, and from the preparation stage to the speech stage (M = 90.11, SD = 12.68), $p < .001$. Heart rate significantly decreased from the speech stage to the mathematics stage (M = 80.55, SD = 9.04), $p < .001$. Participants' heart rates during the preparatory and mathematics stages were not significantly different, $p = .829$.

Figure 2

Heart Rate During Stages of the Trier Social Stress Test



Note. N = 41. Error bars represent standard errors. BPM = Beats per minute.

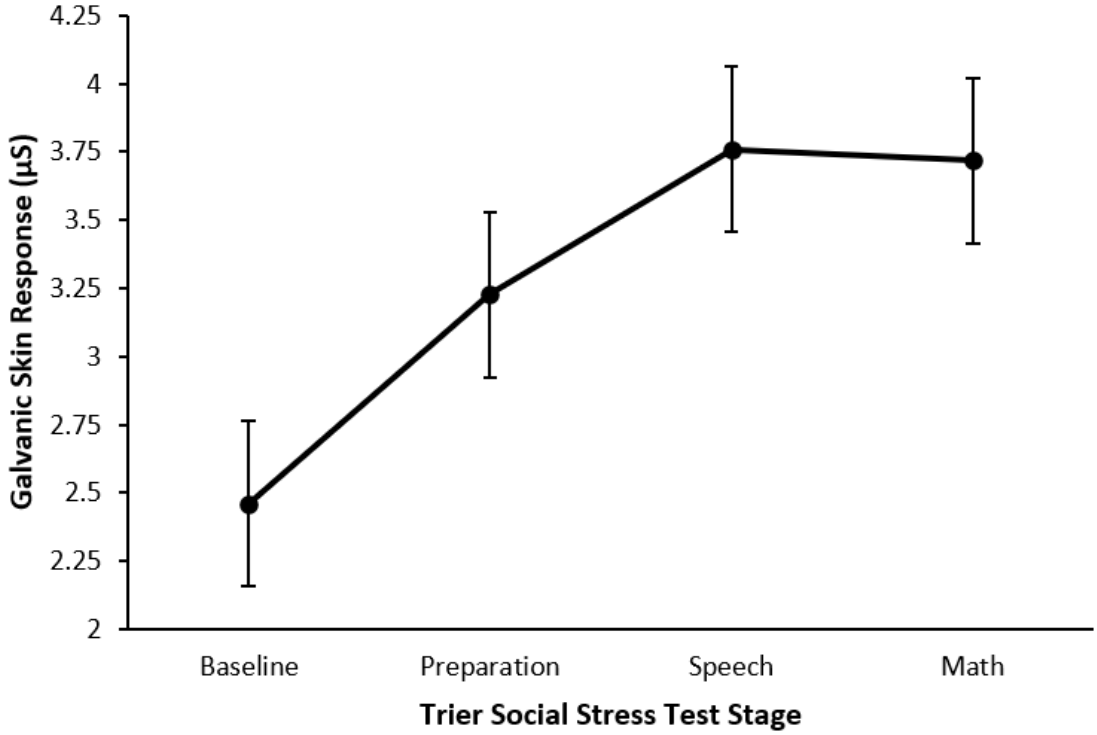
Additionally, participants were separated into two state anxiety groups, those that reported an increase in state anxiety (n = 26), and those that reported a decrease, (n = 16). There was no significant differences in heart rate between those who reported an increase or decrease in state anxiety, $p > .10$. Participants' heart rates increased regardless of

perceived state anxiety. Regarding effects of trait anxiety on heart rate, participants were separated into low trait anxiety (n = 24) and high trait anxiety (n = 18) groups based on the cutoff scores for low to moderate anxiety (40 and below) and high anxiety (41 and above). There was no main effect of trait anxiety on heart rate during the stages of the stress test, $p > .05$. Heart rate increased regardless of trait anxiety.

Figure 3 shows mean levels of micro-Siemens of galvanic skin conductance during the stages of the Trier Social Stress Test. The overall ANOVA on skin conductance was significant, $F(1.67, 68.65) = 123.19$, $p < .001$, $\omega^2 = .74$. Post-hoc tests with Bonferroni corrections revealed that skin conductance significantly increased from baseline (M = 2.46, SD = .88) to the preparatory stage (M = 3.23, SD = 1.20), $p < .001$, and from the preparatory stage to the speech stage (M = 3.76, SD = 1.28), $p < .001$. There were no significant differences in skin conductance between the speech and math stages (M = 3.71, SD = 1.26), $p > .99$.

Figure 3

Galvanic Skin Conductance During Stages of the Trier Social Stress Test



Note. N = 42. Error bars represent standard errors. µS = micro-Siemens.

Participants were separated into those that reported an increase in state anxiety and those that reported a decrease. There was no significant differences in galvanic skin conductance between those who reported an increase or a decrease in state anxiety, $p > .10$. Skin conductance increased regardless of perceived state anxiety. Additionally, participants were separated into those with high and low trait anxiety to observe these effects on skin conductance. There was no main effect of trait anxiety on skin conductance during the stages of the stress test, $p > .05$. Skin conductance increased regardless of trait anxiety.

Working Memory Performance

Table 2 shows descriptive statistics and correlations for total math errors and OSPAN scores. There was a significant positive correlation between total math errors at time 1 and time 2, indicating that participants who made more math errors at time 1 also made more math errors at time 2. There was also a significant positive correlation between OSPAN scores at time 1 and time 2, demonstrating that participants who had higher OSPAN scores at time 1 also had higher OSPAN scores at time 2. Furthermore, there was a significant negative correlation between total math errors and OSPAN scores at time 1, showing that participants who made fewer math errors at time 1 had higher OSPAN scores at time 1. Similarly, there was a significant negative correlation between math errors and OSPAN scores at time 2, indicating that participants who made fewer math errors at time 2 had higher OSPAN scores at time 2. Repeated measures *t*-tests indicated that total math errors significantly decreased from time 1 to time 2, $t(41) = 4.40$, $p < .001$, $d = .68$, and OSPAN scores significantly increased from time 1 to time 2, $t(41) = 3.26$, $p = .002$, $d = .50$.

Table 2

Descriptive Statistics and Correlations for Working Memory Scores Before and After the Trier Social Stress Test

Variable	*M*	*SD*	1	2	3	4
1. Total math errors time 1	5.57	3.60	—			
2. Total math errors time 2	3.71	2.76	.66**	—		
3. OSPAN scores time 1	18.67	11.29	-.31*	-.48**	—	
4. OSPAN scores time 2	24.02	12.95	-.23	-.52**	.62**	—

Note. *N* = 42. Total math errors = (math speed errors + math accuracy errors). Operation span = OSPAN. OSPAN scores measured the sum of all perfectly recalled letter sets.

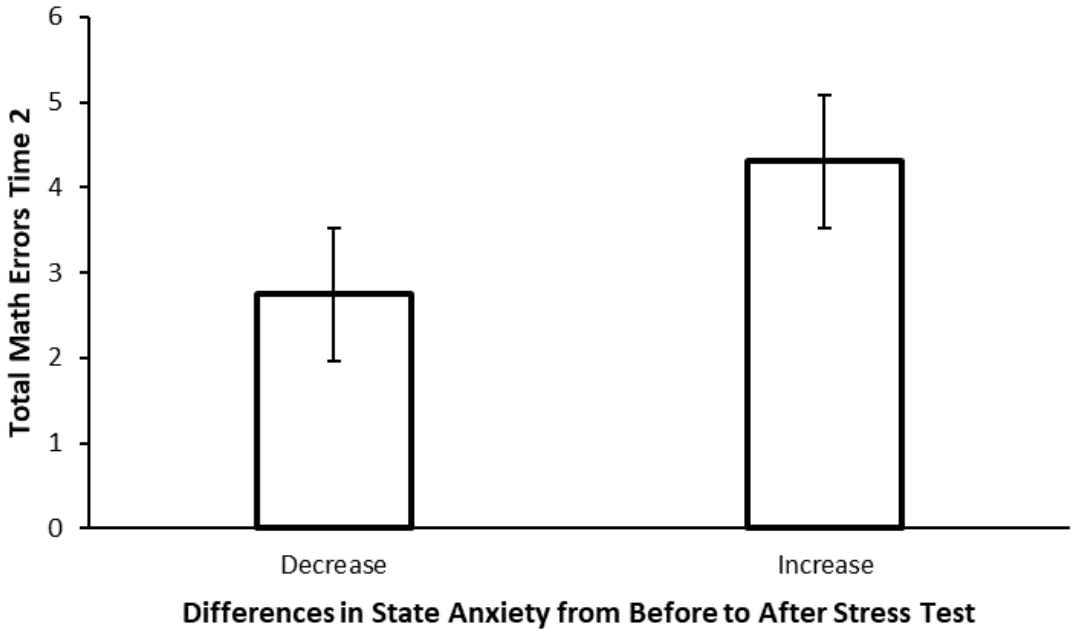
*$p < .05$. **$p < .001$.

Participants were separated into two state anxiety groups, increase versus decrease in state anxiety from time 1 to time 2. Figure 4 shows total math errors at time 2 for groups that decreased or increased in state anxiety. An independent samples *t*-test showed that those who reported an increase in state anxiety had more total math errors, ($M = 4.31$, $SD = 2.92$), after the stress procedure compared to those who reported a decrease in state anxiety, ($M = 2.75$, $SD = 2.24$), $t(40) = 1.83$, $p = .075$, $d = .60$. Figure 5 shows OSPAN scores at time 2 for groups that decreased or increased in state anxiety. Regarding OSPAN scores, another independent samples *t*-test showed that those who reported an increase in state anxiety had lower OSPAN scores, ($M = 21.00$, $SD = 12.83$), after the stress procedure compared to those who reported a decrease in state anxiety, ($M = 28.94$, $SD = 11.94$), $t(40) = 2.00$, $p = .053$, $d = .64$. Regarding effects of trait anxiety on

working memory performance, participants were separated into low trait anxiety (n = 24) and high trait anxiety (n = 18) groups. There were no significant differences in either math errors or OSPAN scores between those with high and low trait anxiety, p's > .05. Overall working memory performance was better regardless of trait anxiety.

Figure 4

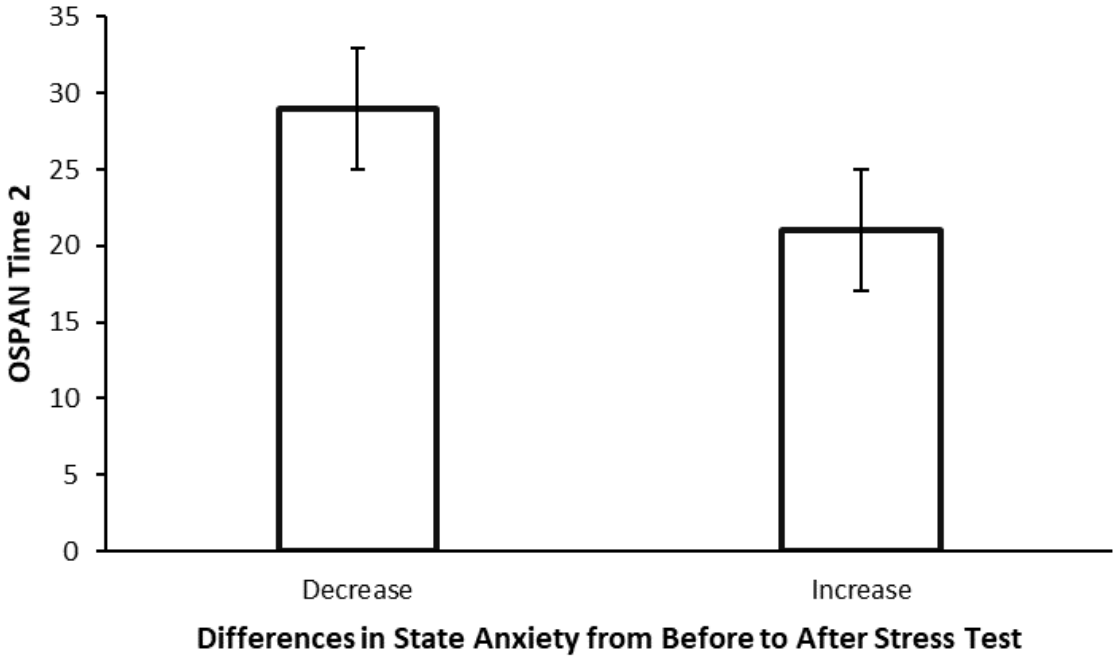
Math Errors Time 2 Between Groups that Decreased or Increased in State Anxiety



Note. Decrease: n = 16. Increase: n = 26. Total math errors = (speed errors + accuracy errors). Error bars represent standard errors.

Figure 5

OSPAN Time 2 Scores Between Groups that Decreased or Increased in State Anxiety



Note. Decrease: *n* = 16. Increase: *n* = 26. Operation span = OSPAN. OSPAN scores measured the sum of all perfectly recalled letter sets. Error bars represent standard errors.

Discussion

Although previous research has only examined working memory performance between individuals post-stress (Angelidis et al., 2019; Banks et al., 2015; van Ast et al., 2016), to my knowledge, no research to date has investigated working memory performance both before and after a stressful event. The current study is the first to measure how the Trier Social Stress Test affects working memory performance using the OSPAN task.

I first hypothesized that levels of perceived stress would be positively correlated with levels of trait anxiety. This hypothesis was supported by the results as observed by strong positive correlations between these variables. These results are consistent with previous literature demonstrating relationships between trait anxiety and perceived stress (Hur et al., 2015; Knowles & Olatunji, 2020). I also hypothesized that trait anxiety would be positively correlated with state anxiety both before and after the Trier Social Stress Test. This hypothesis was supported by the results as indicated by moderate to strong positive correlations. These results are consistent with previous literature showing that individuals with higher trait anxiety tend to display higher state anxiety (Endler & Kocovski, 2001; Hirsch et al., 2013; Pacheco-Unguetti et al., 2010).

Moreover, I hypothesized that participants would report higher state anxiety after the Trier Social Stress Test compared to baseline measurements. My hypothesis was supported by the results showing that state anxiety overall increased from before to after the stress manipulation with medium effect sizes. This finding also indicates that the manipulation of psychosocial threat through the Trier Social Stress Test was effective. This finding is consistent with previous studies demonstrating that perceived state anxiety increases after undergoing the stress test (Bigalke et al., 2022; Jiang et al., 2017; Villada et al., 2016). However, there was a subset of participants that reported a decrease in state anxiety. One explanation for this finding could be that those who reported an increase in state anxiety were preoccupied with their performance during the stress test. In contrast, those that reported a decrease in anxiety may have been less effortful during the stress test and were not worried about the aspect of performance evaluation.

Regarding physiological arousal, I hypothesized that participants would experience an increase in beats per minute and levels of skin conductance during all three stages of the test compared to baseline measurements. Specifically, I hypothesized that heart rate and skin conductance would be highest during the speech. The results partially supported my hypotheses in which participants had significantly higher beats per minute and levels of skin conductance during all three stages with large effect sizes. While heart rate was highest during the speech performance, skin conductance was highest during both the speech performance and the mathematics stage. This may be due to skin conductance having longer recovery rates as experienced by repeated or ongoing stressful stimuli (Christopoulos et al., 2019). Overall, these results indicate that physiological responses were greatly affected by psychosocial threat. Furthermore, these results were mostly consistent with previous literature measuring the effects of psychosocial threat experienced by the Trier Social Stress Test on physiological arousal (Bigalke et al., 2022; Guez et al., 2016; Jiang et al., 2017; Olver et al., 2014; Wemm & Wulfert, 2017). These findings suggest that there are individual differences in the way participants perceived anxiety in relation to similar increases in physiological arousal.

I also hypothesized that participants with higher trait anxiety would experience greater levels of physiological arousal than participants with lower trait anxiety. The results did not support my hypothesis as there were no significant differences in mean heart rate or skin conductance between these groups. This finding was inconsistent with results from previous literature where participants higher in trait anxiety experience greater levels of sympathetic arousal during the preparatory, speech, and mathematics stages of the Trier Social Stress Test compared to those lower in trait anxiety (Grace et

al., 2022). To test if there were any interactions between levels of trait anxiety and self-reported medication, I performed a 2 x 2 chi-square test of independence. The relation between these variables was significant, χ^2 (1, N = 42) = 7.00, p = .008. This result indicates that participants higher in trait anxiety were more likely to be on medication to reduce their anxiety symptoms that may contribute to increased sympathetic arousal.

To gauge the effects of psychosocial threat on working memory performance, I hypothesized that participants would make more math errors and have worse OSPAN scores after the Trier Social Stress Test compared to baseline scores. On average, the results did not support my hypotheses as they showed the opposite effect, in which participants overall made fewer math errors and had greater OSPAN scores on the second round of the task. While physiological arousal and perceived state anxiety were significantly affected by the induction of psychosocial threat, these findings suggest that there were practice effects that occurred from the first to second round of the working memory task. These findings were not expected, however, similar practice effects have been found in a recent study assessing another type of memory with item recall. Pastötter et al. (2020) found that participants who memorized and recalled lists of items before undergoing the Trier Social Stress Test performed better on a third list of items after the stress test, suggesting that practice effects were not disrupted by acute psychosocial threat.

While working memory performance increased on average, there was evidence that a subset of participants in this study showed worse performance on the working memory task that was masked by the average results. To address this, I looked further into levels of state and trait anxiety to see their influences on working memory

performance. As mentioned previously, state anxiety increased overall, however, some participants reported an increase while others reported a decrease. I hypothesized that participants who increased in state anxiety would perform with worse accuracy on the second round of the OSPAN task compared to participants who decreased in state anxiety. I also hypothesized similar results regarding levels of trait anxiety. Results from state anxiety analyses supported my hypothesis in which participants that reported an increase in state anxiety had more total math errors and lower OSPAN scores after the Trier Social Stress Test compared to those who reported a decrease in state anxiety.

One reason for this finding could be explained by the Yerkes-Dodson curve, in which those who experience the greatest amount of stress performed worse on the second round of the OSPAN task (Yerkes & Dodson, 1908). These findings may also be due to a greater lack of attentional control in these participants, or that they had a more difficult time flexibly shifting their attention between remembering the letters and completing mathematical equations (Berggren & Derakshan, 2013; Longstaff & Belz, 2020; Shackman et al., 2006; Wolf, 2017). These results are consistent with previous literature that compared *n*-back scores between those who underwent the Trier Social Stress Test and those in control groups (Schoofs et al., 2008; van Ast et al., 2016). These findings suggest that state anxiety as experienced by acute stress is detrimental to the transfer of practice effects in working memory tasks. However, results from trait anxiety analyses did not support my hypothesis. Overall working memory performance improved from time 1 to time 2 regardless of trait anxiety levels. These results suggest that individual trait anxiety did not significantly affect working memory performance or the transfer of practice effects in the working memory task after the presence of acute stress.

Limitations and Future Directions

Although this study meaningfully contributes to literature on anxiety and working memory performance, several limitations are to be acknowledged. Firstly, I used convenience sampling from a university to recruit participants, and these results may not be representative of a more general population. This sample was comprised of mostly White, cisgender U.S. adults aged 18 to 21 years. This study would benefit from a more diverse sample (gender minorities, racial minorities, older adults, etc.).

Moreover, mean scores for trait anxiety and perceived stress were quite close to the cutoff scores for moderate to high trait anxiety and stress as measured by the Trait Anxiety Inventory and Perceived Stress Scale and validated by previous literature (Ercan et al., 2015; Lee, 2012). This may indicate that this sample is higher in anxiety compared to the general population, and this could have affected the results. However, participants' scores are similar to current literature in which university students experience more stress and anxiety than other populations (Karyotaki et al., 2020). This study would benefit from including participants with a larger range of trait anxiety levels that would be more representative of the general population. Many participants that reported high trait anxiety were also taking medication to reduce their anxiety symptoms, which could have affected overall attentional control and working memory performance.

Another limitation to this study is related to the design of the method, specifically that there was no control group for comparison. If this study were to be replicated, a possible addition could include the use of the Friendly Trier Social Stress Test as a control group. The Friendly Trier Social Stress Test aims to reduce psychosocial threat in which the participant describes their aspirations or their favorite vacation instead of

performing an interview-style presentation. The “judges” do not evaluate the participant’s performance, and they use positive expressions instead of neutral ones. This version of the test is shown to have no effect on state anxiety, making it a reliable control condition (Wiemers et al., 2013).

Finally, this study observed practice effects. In general, participants made fewer math errors and had higher OSPAN scores at time 2 than at time 1. This could simply be due to being exposed to the same task twice, as individuals typically perform better on tasks their second or third time. However, future studies that replicate these methods could include a control group using the Friendly Trier Social Stress Test to truly see if acute stress reduces practice effects. With this design, one would expect to see similar OSPAN scores at time 1 between experimental and control groups, but worse OSPAN scores at time 2 in the experimental group.

Another revision to this study could include the addition of a second experimental group that undergoes the Trier Social Stress Test, but only completes a post-OSPAN task. This second experimental group would test the impact of the stress test without the possibility of practice effects. Moreover, I allowed participants to have practice sessions both at time 1 and time 2, which could have further contributed to the transfer of practice effects on the second round of the task. Future studies using this version of the OSPAN task should have a separate practice session before baseline recordings and then complete the real trials. There should be no additional practice trials during the second round of the task.

Conclusions and Implications

The results of the current study contribute to literature on stress and working memory by highlighting individual differences in state anxiety, trait anxiety, and task performance. While all participants underwent the same stress manipulation, some increased in state anxiety while others decreased. For participants that increased in state anxiety, the Trier Social Stress Test was effective in inducing psychosocial stress, and these participants did not perform as well on the second round of the working memory task as participants that decreased in state anxiety. These findings support research that emphasizes working memory training, especially when undergoing acute stress (Liang et al., 2024; Sari et al., 2016; Wolf & Kluge, 2017).

Furthermore, these findings could be useful in educational settings when students are preparing for exams or public speeches, and in professional settings that use working memory and involve stress such as air traffic, military service, and nursing professions. This study also has practical implications for clinicians in how to assist patients with anxiety disorders in regulating cognitive and physiological symptoms of stress when performing complex tasks. Through therapeutic techniques, clinicians can help patients interpret and distinguish types of physiological arousal, in turn supporting task performance. Overall, this study supports continued research on working memory performance in anxious individuals.

References

Albu, M. (2008). Automatic and intentional inhibition in patients with generalized anxiety disorder: An interdisciplinary journal. *Cognition, Brain, Behavior, 12*(2), 233–249.

Alkozei, A., Creswell, C., Cooper, P. J., & Allen, J. J. (2015). Autonomic arousal in childhood anxiety disorders: Associations with state anxiety and social anxiety disorder. *Journal of Affective Disorders, 175*, 25–33. https://doi.org/10.1016/j.jad.2014.11.056

American Psychiatric Association. (2022). *Diagnostic and statistical manual of mental disorders* (5th ed., text rev.). https://doi.org/10.1176/appi.books.9780890425787

Angelidis, A., Solis, E., Lautenbach, F., van der Does, W., & Putman, P. (2019). I'm going to fail! Acute cognitive performance anxiety increases threat-interference and impairs WM performance. *PLoS ONE, 14*(2), 1–25. https://doi.org/10.1371/journal.pone.0210824

Baddeley, A.D., & Hitch, G. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation: Vol. 2. Advances in research and theory* (47–89). Academic Press.

Banks, J. B., Tartar, J. L., & Tamayo, B. A. (2015). Examining factors involved in stress-related working memory impairments: Independent or conditional effects? *Emotion, 15*(6), 827–836. https://doi.org/10.1037/emo0000096

Bashford-Largo, J., Aloi, J., Lukoff, J., Johnson, K., White, S. F., Dobbertin, M., Blair,

R. J., & Blair, K. S. (2021). Reduced top-down attentional control in adolescents with generalized anxiety disorder. *Brain and Behavior, 11*(2), Article e01994. https://doi.org/10.1002/brb3.1994

Berggren, N., & Derakshan, N. (2013). Attentional control deficits in trait anxiety: Why you see them and why you don't. *Biological Psychology, 92*(3), 440–446. https://doi.org/10.1016/j.biopsycho.2012.03.007

Bigalke, J. A., Greenlund, I. M., Nicevski, J. R., Tikkanen, A. L., & Carter, J. R. (2022). Sympathetic neural reactivity to the Trier Social Stress Test. *The Journal of Physiology, 600(*16), 3705–3724. https://doi.org/10.1113/JP283358

BIOPAC. (2021). ECG100C Electrocardiogram Amplifier [Apparatus and software]. https://www.biopac.com/product/ecg-electrocardiogram-amplifier/

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30*(2), 203–216. https://doi.org/10.1016/j.cpr.2009.11.003

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior, 24*(4), 385–396. https://doi.org/10.2307/2136404

Coulacoglou, C., & Saklofske, D. H. (2017). *Psychometrics and psychological assessment: Principles and applications*. Academic Press. https://doi.org/10.1016/B978-0-12-802219-1.00005-5

Christopoulos, G. I., Uy, M. A., & Yap, W. J. (2019). The body and the brain: Measuring

skin conductance responses to understand the emotional experience. *Organizational Research Methods*, *22*(1), 394–420. https://doi.org/10.1177/1094428116681073

Endler, N. S., & Kocovski, N. L. (2001). State and trait anxiety revisited. *Journal of Anxiety Disorders, 15*(3), 231–245. https://doi.org/10.1016/S0887-6185(01)00060-3

Ercan, I., Hafizoglu, S., Ozkaya, G., Kirli, S., Yalcintas, E., & Akaya, C. (2015). Examining cut-off values for the State-Trait Anxiety Inventory. *Revista Argentina de Clínica Psicológica, 24*(2), 143–148.

Eysenck, M. W., Moser, J. S., Derakshan, N., Hepsomali, P., & Allen, P. (2023). A neurocognitive account of attentional control theory: How does trait anxiety affect the brain's attentional networks? *Cognition and Emotion, 37*(2), 22–237. https://doi.org/10.1080/02699931.2022.2159936

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.). SAGE Publications.

Frisch, J. U., Häusser, J. A., & Mojzisch, A. (2015). The Trier Social Stress Test as a paradigm to study how people respond to threat in social interactions. *Frontiers in Psychology, 6,* Article e14. https://doi.org/10.3389/fpsyg.2015.00014

Gajewski, P. D., Hanisch, E., Falkenstein, M., Thönes, S., & Wascher, E. (2018). What

does the *n*-back task measure as we get older? Relations between working-memory measures and other cognitive functions across the lifespan. *Frontiers in Psychology*, *9*, Article e2208. https://doi.org/10.3389/fpsyg.2018.02208

Gavric, D., Moscovitch, D. A., Rowa, K., & McCabe, R. E. (2017). Post-event processing in social anxiety disorder: Examining the mediating roles of positive metacognitive beliefs and perceptions of performance. *Behavior Research and Therapy*, *91*, 1–12. https://doi.org/10.1016/j.brat.2017.01.002

Gazzaniga, M., Irvy, R., & Mangun, G. (2019). *Cognitive neuroscience: The biology of the mind.* (5th ed.). W.W. Norton.

Grace, C., Heinrichs, M., Koval, P., Gorelik, A., Von Dawans, B., Terrett, G., Rendell, P. & Labuschagne, I. (2022). Concordance in salivary cortisol and subjective anxiety to the Trier Social Stress Test in social anxiety disorder. *Biological Psychology*, *175*, Article e108444. https://doi.org/10.1016/j.biopsycho.2022.108444

Guez, J., Saar-Ashkenazy, R., Keha, E., & Tiferet-Dweck, C. (2016). The effect of Trier Social Stress Test (TSST) on item and associative recognition of words and pictures in healthy participants. *Frontiers in Psychology*, *7*, Article e507. https://doi.org/10.3389/fpsyg.2016.00507

Hirsch, C. R., Mathews, A., Lequertier, B., Perman, G., & Hayes, S. (2013). Characteristics of worry in generalized anxiety disorder. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*(4), 388–395. https://doi.org/10.1016/j.jbtep.2013.03.004

Hoehn-Saric, R., & McLeod, D. R. (2000). Anxiety and arousal: Physiological changes

and their perception. *Journal of Affective Disorders*, *61*(3), 217–224. https://doi.org/10.1016/s0165-0327(00)00339-6

Hur, J., Miller, G. A., McDavitt, J. R., Spielberg, J. M., Crocker, L. D., Infantolino, Z. P., Towers, D. N., Warren, S. L., & Heller, W. (2015). Interactive effects of trait and state affect on top-down control of attention. *Social Cognitive and Affective Neuroscience*, *10*(8), 1128–1136. https://doi.org/10.1093/scan/nsu163

Jiang, C., Buchanan, T. W., Yao, Z., Zhang, K., Wu, J., & Zhang, L. (2017). Acute psychological stress disrupts attentional bias to threat-related stimuli. *Scientific Reports*, *7*(1), Article e14607. https://doi.org/10.1038/s41598-017-14138-w

Johnson, D. R., & Gronlund, S. D. (2009). Individuals lower in working memory capacity are particularly vulnerable to anxiety's disruptive effect on performance. *Anxiety, Stress, and Coping*, *22*(2), 201–213. https://doi.org/10.1080/10615800802291277

Kalat, J. W. (2019). *Biological psychology* (13th ed.). Cengage Learning, Inc.

Karyotaki, E., Cuijpers, P., Albor, Y., Alonso, J., Auerbach, R. P., Bantjes, J., Bruffaerts, R., Ebert, D. D., Hasking, P., Kiekens, G., Lee, S., McLafferty, M., Mak, A., Mortier, P., Sampson, N. A., Stein, D. J., Vilagut, G., & Kessler, R. C. (2020). Sources of stress and their associations with mental disorders among college students: Results of the World Health Organization world mental health surveys international college student initiative. *Frontiers in Psychology*, *11*, Article e1759. https://doi.org/10.3389/fpsyg.2020.01759

Kemeny, M. E. (2003). The psychobiology of stress. *Current Directions in Psychological Science*, *12*(4), 124–129. http://www.jstor.org/stable/20182857

Kerestes, R., Ladouceur, C. D., Meda, S., Nathan, P. J., Blumberg, H. P., Maloney, K., Ruf, B., Saricicek, A., Pearlson, G. D., Bhagwagar, Z., & Phillips, M. L. (2012). Abnormal prefrontal activity subserving attentional control of emotion in remitted depressed patients during a working memory task with emotional distractors. *Psychological Medicine, 42*(1), 29–40. https://doi.org/10.1017/S0033291711001097

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test'—A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*(1–2), 76–81. https://doi.org/10.1159/000119004

Knowles, K. A., & Olatunji, B. O. (2020). Specificity of trait anxiety in anxiety and depression: Meta-analysis of the State-Trait Anxiety Inventory. *Clinical Psychology Review, 82,* Article e101928. https://doi.org/10.1016/j.cpr.2020.101928

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2003). The Patient Health Questionnaire-2: Validity of a two-item depression screener. *Medical Care, 41*(11), 1284–1292. http://www.jstor.org/stable/3768417

Lee, E.-H. (2012). Review of the psychometric evidence of the perceived stress scale. *Asian Nursing Research, 6*(4), 121–127. https://doi.org/10.1016/j.anr.2012.08.004

Lewis, E. J., Lira Yoon, K., & Joormann, J. (2018). Emotion regulation and biological stress responding: Associations with worry, rumination, and reappraisal. *Cognition and Emotion, 32*(7), 1487–1498. https://doi.org/10.1080/02699931.2017.1310088

Liang, Y., Peng, X., Meng, Y., Liu, Y., Zhu, Q., Xu, Z., & Yang, J. (2024). Effect of acute stress on working memory in pilots: Investigating the modulatory role of memory load. *PloS One*, *19*(1), Article e0288221. https://doi.org/10.1371/journal.pone.0288221

Longstaff, M. G., & Belz, G. K. (2020). Sex differences in eyewitness memory: Females are more accurate than males for details related to people and less accurate for details surrounding them, and feel more anxious and threatened in a neutral but potentially threatening context. *Personality and Individual Differences*, *164*, Article e110093. https://doi.org/10.1016/j.paid.2020.110093

Luo, X., Zhang, L., & Wang, J. (2017). The benefits of working memory capacity on attentional control under pressure. *Frontiers in Psychology*, *8*, Article e1105. https://doi.org/10.3389/fpsyg.2017.01105

Markiewicz, R., Markiewicz-Gospodarek, A., & Dobrowolska, B. (2022). Galvanic skin response features in psychiatry and mental disorders: A narrative review. *International Journal of Environmental Research and Public Health*, *19*(20), Article e13428. https://doi.org/10.3390/ijerph192013428

McMorris, T. (2016). *Exercise-cognition interaction: Neuroscience perspectives*. Elsevier.

Mogg, K., Bradley, B. P., Dixon, C., Fisher, S., Twelftree, H., & McWilliams, A. (2000). Trait anxiety, defensiveness and selective processing of threat: An investigation using two measures of attentional bias. *Personality and Individual Differences, 28*(60), 1063–1077. https://doi.org/10.1016/S0191-8869(99)00157-9

Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and

narrative review. *Psychological Bulletin, 142*(8), 831–864. https://doi.org/10.1037/bul0000051

Olver, J. S., Pinney, M., Maruff, P., & Norman, T. R. (2015). Impairments of spatial working memory and attention following acute psychosocial stress. *Stress & Health, 31*(2), 115–123. https://doi.org/10.1002/smi.2533

Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupiáñez, J. (2010). Attention and anxiety: Different attentional functioning under state and trait anxiety. *Psychological Science, 21*(2), 298–304. https://doi.org/10.1177/0956797609359624

Pastötter, B., von Dawans, B., Domes, G., & Frings, C. (2020). The forward testing effect is immune to acute psychosocial encoding/retrieval stress. *Experimental Psychology, 67*(2), 112–122. https://doi.org/10.1027/1618-3169/a000472

Redick, T. S., & Lindsey, D. R. B. (2013). Complex span and *n*-back measures of working memory: A meta-analysis. *Psychonomic Bulletin and Review, 20,* 1102–1113. https://doi.org/10.3758/s13423-013-0453-9

Sari, B. A., Koster, E. H. W., Pourtois, G., & Derakshan, N. (2016). Training working memory to improve attentional control in anxiety: A proof-of-principle study using behavioral and electrophysiological measures. *Biological Psychology, 121*, 203–212. https://doi.org/10.1016/j.biopsycho.2015.09.008

Scharinger, C., Soutschek, A., Schubert, T., & Gerjets, P. (2017). Comparison of the working memory load in *n*-back and working memory span tasks by means of EEG frequency band power and p300 amplitude. *Frontiers in Human Neuroscience, 11,* Article e6. https://doi.org/10.3389/fnhum.2017.00006

Schoofs, D., Preuß, D., & Wolf, O. T. (2008). Psychosocial stress induces working memory impairments in an *n*-back paradigm. *Psychoneuroendocrinology, 33*(5), 643–653. https://doi.org/10.1016/j.psyneuen.2008.02.004

Scott, B. G., & Weems, C. F. (2014). Resting vagal tone and vagal response to stress: Associations with anxiety, aggression, and perceived anxiety control among youths. *Psychophysiology, 51*(8), 718–727. https://doi.org/10.1111/psyp.12218

Shackman, A. J., Sarinopoulos, I., Maxwell, J. S., Pizzagalli, D. A., Lavric, A., & Davidson, R. J. (2006). Anxiety selectively disrupts visuospatial working memory. *Emotion, 6*(1), 40–61. https://doi.org/10.1037/1528-3542.6.1.40

Shiban, Y., Diemer, J., Brandl, S., Zack, R., & Mühlberger, A. (2016). Trier Social Stress Test in vivo and in virtual reality: Dissociation of response domains. *International Journal of Psychophysiology, 111,* 47–55. https://doi.org/10.1016/j.ijpsycho.2016.10.008

Spielberger, C. D. (1983). State-Trait Anxiety Inventory for adults. *PsycTESTS Dataset*. https://doi.org/10.1037/t06496-000

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder. *Archives of Internal Medicine, 166*(10), 1092–1097. https://doi.org/10.1001/archinte.166.10.1092

Trotman, G. P., Veldhuijzen van Zanten, J. J. C. S., Davies, J., Möller, C., Ginty, A. T., & Williams, S. E. (2019). Associations between heart rate, perceived heart rate, and anxiety during acute psychological stress. *Anxiety, Stress & Coping, 32*(6), 711–727. https://doi.org/10.1080/10615806.2019.1648794

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated

version of the operation span task. *Behavior Research Methods, 37*(3), 498–505. https://doi.org/10.3758/bf03192720

van Ast, V. A., Spicer, J., Smith, E. E., Schmer-Galunder, S., Liberzon, I., Abelson, J. L., & Wager, T. D. (2016). Brain mechanisms of social threat effects on working memory. *Cerebral Cortex, 26*, 544–556, https://doi.org/10.1093/cercor/bhu206

Villada, C., Hidalgo, V., Almela, M., & Salvador, A. (2016). Individual differences in the psychobiological response to psychosocial stress (Trier Social Stress Test): The relevance of trait anxiety and coping styles. *Stress & Health, 32*(2), 90–99. https://doi.org/10.1002/smi.258

Wagels, L., Bergs, R., Clemens, B., Bauchmüller, M., Gur, R. C., Schneider, F., Habel, U., & Kohn, N. (2017). Contextual exclusion processing: An fMRI study of rejection in a performance-related context. *Brain Imaging and Behavior, 11*, 874–886. https://doi.org/10.1007/s11682-016-9561-2

Wemm, S., & Wulfert, E. (2017). Effects of acute stress on decision making. *Applied Psychophysiology & Biofeedback, 42*(1), 1–12. https://doi.org/10.1007/s10484-016-9347-8

Wiemers, U. S., Schoofs, D., & Wolf, O. T. (2013). A friendly version of the Trier Social Stress Test does not activate the HPA axis in healthy men and women. *Stress, 16*(2), 254–260. https://doi.org/10.3109/10253890.2012.714427

Wolf, O. T. (2017). Stress and memory retrieval: Mechanisms and consequences. *Current Opinion in Behavioral Sciences, 14*, 40–46. https://doi.org/10.1016/j.cobeha.2016.12.00

Wolf, O. T., & Kluge, A. (2017). Commentary: Retrieval practice protects memory

against acute stress. *Frontiers in Behavioral Neuroscience*, *11*, Article e48. https://doi.org/10.3389/fnbeh.2017.00048

Yerkes R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*(5), 459–482. https://doi.org/10.1002/cne.920180503

Appendices

Appendix A: State-Trait Anxiety Inventory

Appendix B: Perceived Stress Scale

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Appendix A: State-Trait Anxiety Inventory

SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1

Please provide the following information:

Name_____Date_____S_____

Age_____ Gender (*Circle*) **M** **F** T_____

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

STAIP-AD Test Form Y
www.mindgarden.com

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name_____Date_____

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Appendix B: Perceived Stress Scale

PERCEIVED STRESS SCALE

The questions in this scale ask you about your feelings and thoughts during the last month**. In each case, you will be asked to indicate by circling *how often* you felt or thought a certain way.**

Name _____ Date _____

Age _____ Gender (*Circle*): **M F** Other _____

0 = Never 1 = Almost Never 2 = Sometimes 3 = Fairly Often 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?	0	1	2	3	4
3. In the last month, how often have you felt nervous and "stressed"?	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems?	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way?	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do?	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life?	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things?	0	1	2	3	4
9. In the last month, how often have you been angered because of things that were outside of your control?	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	0	1	2	3	4

Appendix C: Patient Health Questionnaire-2

Over the **last 2 weeks**, how often have you been bothered by the following problems?	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	○ 0	○ +1	○ +2	○ +3
2. Feeling down, depressed or hopeless	○ 0	○ +1	○ +2	○ +3

Appendix D: Study Description

SONA Study Description: The purpose of this study is to examine physiological responses while completing a challenging task. The study involves a laboratory visit. At the beginning of the visit, participants will answer questions to determine study eligibility. Participants will receive 0.5 credits for traveling to the laboratory, 0.5 credits for screening, and 0.5 credits for participation in the study. Eligibility criteria include: 1) Participants 18 years old and older, 2) Participants not currently taking medication for hypertension, 3) Participants not diagnosed with Addison's Disease or Cushing's Disease, 4) Participants not diagnosed with a neurological condition such as a serious head injury, prolonged unconsciousness, or epilepsy, and 5) Participants not diagnosed with a breathing-related disorder such as asthma or sleep apnea.

Appendix E: Participant Consent Form

Title of Research Study: Stress, Memory, and Physiology

Investigator Team Contact Information: Eric E. Hessler, Ph.D.
For questions about research appointments, the research study, research results, or other concerns, call the study team at:

Investigator Name: Dr. Eric E. Hessler Investigator Departmental Affiliation: UMD Psychology Department Phone Number: (218) 726-8467 Email Address: eehessle@d.umn.edu	Student Investigator Name: Jillian Anderson, B.S., B.A. Phone Number: [redacted] Email Address: and05375@d.umn.edu

Supported By: This research is supported by the University of Minnesota Duluth Psychology Department.

Key Information About This Research Study
The following is a short summary to help you decide whether or not to be a part of this research study. More detailed information is listed later on in this form:
We are looking to see how individual stress levels affect areas of executive functioning, such as memory.
What is research?

- The goal of research is to learn new things in order to help people in the future. Investigators learn things by following the same plan with a number of participants, so they do not usually make changes to the plan for individual research participants. You, as an individual, may or may not be helped by volunteering for a research study.

Why am I being invited to take part in this research study?

We are asking you to take part in this research study because you are at least 18 years old, attending a psychology course at UMD, and you indicated interest in participating in this study through SONA.

What should I know about a research study?

- Someone will explain this research study to you.
- Whether or not you take part is up to you.
- You can choose not to take part.
- You can agree to take part and later change your mind.

- Your decision will not be held against you.
- You can ask all the questions you want before you decide.

Why is this research being done?

The purpose of this research study is to learn about cognitive functions (e.g., memory) and levels of individual stress. Another purpose is to measure the physical activity of the body and how it relates to stress and memory.

How long will the research last?

We expect that you will be in this research study for 1 hour.

What will I need to do to participate?

You will be asked to complete questionnaires (e.g., demographic survey, sad or anxious feelings), computerized tasks measuring mental capabilities, and a challenging task. Additionally, you will be connected to technology used to measure your body's response to these computerized tasks. ***More detailed information about the study procedures can be found under*** "What happens if I say yes, I want to be in this research?"

Is there any way that being in this study could be bad for me?
In some cases, participants experience some irritation of the skin from the electrodes. Participants may also experience negative emotions during the study. More detailed information about the risks of this study can be found under ***"What are the risks of this study? Is there any way being in this study could be bad for me? (Detailed Risks)"***

Will being in this study help me in any way?

There are no benefits to you from your taking part in this research. We cannot promise any benefits to others from your taking part in this research. However, possible benefits include gaining knowledge about psychology, and experiencing positive emotions.

What happens if I do not want to be in this research?

If you do not wish to participate, there are no known alternatives other than deciding not to participate in this research study. This study is completely voluntary, and you may stop or withdraw from the study at any time or refuse to answer any particular question for any reason without it being held against you.

Detailed Information About This Research Study
The following is more detailed information about this study in addition to the information listed above.

How many people will be studied?

We expect 60 people here will be in this research study out of 60 people in the entire study nationally.

What happens if I say "Yes, I want to be in this research"?

During the laboratory session, you will be quickly screened for eligibility, complete questionnaires assessing mood and stress, a computerized task measuring mental capabilities, a challenging task, and a short demographic survey. You will also have your heart rate and perspiration measured.

To measure heart rate and perspiration, two electrodes will be placed on your forearm and two on your index and middle fingertips. These will be attached by wires to machines called an electrocardiogram (ECG) and an electrodermal activity amplifier (EDA) to measure physical activity.

This session will take place in Cina Hall at UMD and last 1 hour. There will be two researchers present during the experiment. You will receive 1.5 credits for your participation. There are no follow-up experiments involved.

What happens if I say "Yes", but I change my mind later?

You can leave the research study at any time, and no one will be upset by your decision. Choosing not to be in this study or to stop being in this study will not result in any penalty to you or loss of benefit to which you are entitled. This means that your choice not to be in this study will not negatively affect your academic standing as a student and will not result in any penalty to you or loss of research credits.

What are the risks of being in this study? Is there any way being in this study could be bad for me? (Detailed Risks)

- Irritation of the skin from electrodes. If you experience irritation, there will be lotion on hand to mitigate any discomfort.
- Experiencing negative emotions.
- There is some risk of a data breach involving the information we have about you. We comply with the University's security standards to secure your

information and minimize risks, but there is always a possibility of a data breach.

Will it cost me anything to participate in this research study?

There will be no cost to you for any of the study activities or procedures.

What happens to the information collected for the research?

Efforts will be made to limit the use and disclosure of your personal information, including research study and medical records, to people who have a need to review this information. We cannot promise complete confidentiality. Organizations that may inspect and copy your information include the Institutional Review Board (IRB), the committee that provides ethical and regulatory oversight of research, and other representatives of this institution, including those that have responsibilities for monitoring or ensuring compliance.

We may publish the results of this research or share the resulting data. However, we will keep your name and other identifying information confidential. De-identified information may also be used in future research studies.

Whom do I contact if I have questions, concerns, or feedback about my experience?

To reach the research team: Please see the "Investigator Contact Information" section at the beginning of this form.

To reach someone outside of the research team: This research has been reviewed and approved by an IRB within the Human Research Protections Program (HRPP). To share feedback privately with the HRPP about your research experience, call the Research Participants' Advocate Line at 612-625-1650 (Toll Free: 1-888-224-8636) or go to z.umn.edu/participants. You are encouraged to contact the HRPP if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You are having difficulty reaching the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research participant.
- You want to get information or provide feedback about this research.

Will I have a chance to provide feedback after the study is over?

The HRPP may ask you to complete a survey that asks about your experience as a research participant. You do not have to complete the survey if you do not want to. If you do choose to complete the survey, your responses will be anonymous. If you are not asked to complete a survey, but you would like to share feedback, please contact the study team or the HRPP. See the "Investigator Contact Information" of this form for study team contact information and "Whom do I contact if I have questions, concerns or feedback about my experience?" of this form for HRPP contact information.

Can I be removed from the research?
The person in charge of the research study or the sponsor can remove you from the research study without your approval. Possible reasons for removal include if the study is cancelled and/or discontinued for other administrative reasons.

Will I be compensated for my participation?
If you agree to take part in this research study, you will receive 1.5 research credits.

Your signature documents your permission to take part in this research. You will be provided with a copy of this signed document.

_____ _____
Signature of Participant Date

_____
Printed Name of Participant

_____ _____
Signature of Person Obtaining Consent Date

_____
Printed Name of Person Obtaining Consent

Appendix F: Trier Social Stress Test Script

"Now you will be preparing for a short interview. The interview is for a position as a customer service manager at a local grocery store. You will have a few minutes to prepare your speech. You will have to convince the interviewers that you are the best person for this job. The interviewers will be evaluating your performance. Do you have any questions? Please try not to move your arms or legs."

Standardized Questions Asked to Each Participant

1. "Have any of your previous jobs included administrative activities such as scheduling meetings or answering customer phone calls?"
2. "Can you tell me about a time you had a difficult customer and how you resolved the situation?"
3. "What is one trait that makes you stand out from other applicants?"

Appendix G: Debriefing Script

“Thank you for your participation in our study today. The true purpose of the study was to assess how stress responses influence areas of executive functioning, such as working memory, following a public speaking exercise. Sometimes participants change their behavior if they are aware of the true purpose of the study. This is called a demand characteristics. Thus, we were not able to be specific about the true purpose of the study.

“Do you have any questions about the study?

“Are you willing to allow the researchers to use the data collected during the public speaking exercise?”

Appendix H: Resource Information Sheet

Resources Information Sheet

Stress, Memory, and Physiology

Principal Investigator: Eric E. Hessler, Ph.D., Department of Psychology

If you have any questions or would like further information about this study, you may contact Eric Hessler (eehessle@d.umn.edu at (218) 726-8467). Thank you for participation in this study and please do not hesitate to contact us if you have any questions about this project.

If you have concerns about your psychological well-being, you can contact one of the following:

(1) UMD student counseling services (https://health-services.d.umn.edu/counseling-services) at 615 Niagara Court or at (218) 726-8155.

(2) A telephone support line in times of crisis at the Essentia Health-St. Mary's/Duluth Clinic Medical Center (844-772-4724 or Call 988 or 800-273-8255, 24 hours, 7 days a week).

(3) Your personal or family health care provider.