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Metacognition under pressure: The influence of acute stress on metacomprehension accuracy

by

Erin Madison, M.S.

A dissertation
submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the Department of Psychology
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RE: Study Number IRB-FY2021-199 : Metacognition under pressure: The influence of acute stress on metacomprehension accuracy

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Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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Dissertation Abstract—Idaho State University (2023)

Metacomprehension is the ability to evaluate one's own reading comprehension. Individuals use cues or heuristics to judge their cognitions, outlined by the Cue Utilization Hypothesis (Koriat, 1997). Examples of cues that individuals use to make judgments include amount of time studying, how much information is recalled, etc.; yet, stress has never been tested as a metacognitive cue despite the pervasiveness of stress. Metacognitive monitoring is likely impacted by stress, as the Attentional Control Theory posits that stress decreases attentional control (Eysenck et al., 2007). Based on this theory, it was predicted that after an experimental manipulation of stress, those participants would have worse metacognitive monitoring compared to participants in a control condition. Stress was manipulated using the Trier Social Stress Test (TSST), which was followed by a metacomprehension monitoring task. While there were no main effects of condition, higher state anxiety correlated with lower prediction magnitude, and trait anxiety was associated with improved absolute accuracy. The Attentional Control Theory did not fully explain this effect; likely, distractions caused by stress acted as a cue to improve monitoring. This study provides the first experimental evidence that stress impacts metacomprehension monitoring, and opens the discussion for stress as a state-based cue.

Keywords: metacomprehension, metacomprehension accuracy, acute stress, absolute accuracy, state-based cue

Chapter 1: INTRODUCTION

Metacognition under pressure: The influence of acute stress on metacomprehension accuracy

Metacognition, the ability to judge cognition, is pervasive in our lives, as assessing cognition occurs during many daily tasks at work, school, and even hobbies. Metacomprehension, or the ability to make judgments about one's reading comprehension (Dunlosky & Lipko, 2007; Maki & Berry, 1984), is particularly instrumental for academic performance. Students use metacognitive skills to monitor their progress and adjust learning goals during studying, a process called self-regulated learning (Dunlosky et al., 2005; Efklides, 2014; Schunk & Zimmerman, 1998; Thiede et al., 2003; Winne, 1996). Metacomprehension judgments (e.g. how well did I understand the chapter that I will be tested on?) can be influenced by factors like the state of the individual, such as mood, time of day, and caffeine use (Hourihan & Benjamin, 2014; Kelemen & Creeley, 2003; Prinz et al., 2018). However, these state-based cues are understudied in metacognitive research; not many state-based characteristics have been identified or evaluated in the literature. Stress could act as a state-based cue for metacomprehension judgments, as stress influences executive function, reading comprehension, and metacognitive judgments during a perceptual task (Rai, Loschky, Harris, 2015; Reyes et al., 2015; Shields et al., 2016). However, despite the prevalence of stress among college students (American College Health Association, 2019), stress has not been studied in the context of metacomprehension judgments. The current study focused on how acute stress impacts the metacomprehension judgments of college students, and the theoretical and practical implications of a relationship between stress and metacomprehension accuracy.

Metacomprehension in part facilitates self-regulated learning (SRL), which is the ability to set, assess, and reach learning goals (Dunlosky et al., 2005; Efklides, 2014; Lee et al., 2010; Schunk & Zimmerman, 1998; Thiede et al., 2003; Winne, 1996). Generally, there are three phases to SRL: planning, performance, and self-reflection (Zeidner & Stoeger, 2019; Zimmerman, 2000). In the planning phase, students set learning goals based on current knowledge on the topic, motivation level, and prior performance. During the performance phase, students use different strategies that have worked in the past and may adjust those strategies based on their evaluations of their progress (Winne, 1996; Zeidner & Stoeger, 2019). Finally, the self-reflection phase compares one's learning goals to their performance. During this stage, students may also evaluate which strategies worked, and which did not. SRL is most effective when students have proper strategy use and accurate assessments of their comprehension (Lee et al., 2010; Thiede et al., 2003). High performing students are more likely to engage in SRL and employ better learning strategies, perhaps due to their higher cognitive ability (Zeidner & Stoeger, 2019). Metacomprehension is crucial in the SRL process, as it allows individuals to monitor their comprehension, assess whether they met learning goals, and make necessary adjustments in order to meet these goals (Dunlosky et al., 2005). Furthermore, when students are instructed to use metacomprehension strategies, there is evidence of improved SRL. Wiley and colleagues (2016) studied this concept in a classroom context. They instructed one group of students to use self-explanation during reading and compared their results to students who did not receive the instruction. Students in the instruction condition had more accurate metacognitive judgments and, given the chance to restudy the information, read the texts in a more strategic order. The control condition was more likely to restudy the texts in the order given. Finally, those in the instruction condition earned higher scores on this assignment, providing evidence that improved metacognitive accuracy in students allows for efficient study sessions and strong academic performance (Wiley et al., 2016).

Despite the importance of metacomprehension monitoring, both relative and absolute accuracy tend to be less than optimal (Dunlosky & Lipko, 2007; Maki et al., 2005). Relative accuracy is the ability to distinguish between well-known and less well-known information (Dunlosky & Lipko, 2007; Maki & Berry, 1984). For example, after reading two passages, a person with high relative accuracy would be able to correctly state which passage they would score better on if they took a test. Relative accuracy is measured using a gamma correlation between a person's predictions of performance and test performance, with higher correlations indicating a better match between judgments and performance. Gamma correlations are used above a Pearson's r because it uses rank order rather than an interval scale to correlate prediction judgments to comprehension performance (Nelson, 1984). Relative accuracy tends to be above chance but low, with an average correlation of $G = 0.29$ (Dunlosky & Lipko, 2007; Maki, 1998). This may lead to errors in SRL, especially allocation of study time; individuals may spend too much or too little time studying inappropriate items. In contrast, absolute accuracy is a measure of over or under-confidence (Dunlosky & Lipko, 2007). This is measured with bias scores, which is the mathematical difference between one's judgments and performance. On average, individuals tend to be overconfident in their judgments; this is often most true for low performing individuals, perhaps due to low motivation to be accurate (Hacker et al., 2000; Maki et al., 2005). Overconfident judgments are detrimental to SRL because they may lead individuals to terminate their study too early. Of note, relative and absolute accuracy are not correlated, so a person may be accurate in one but not in the other (Keleman et al., 2000). And, because state-based cues are underrepresented in research, it is not clear if stress would influence both types of accuracy, one type, or neither. Generally, relative accuracy is more influenced by *task*-specific cues (i.e., familiarity with topic) than absolute accuracy (Kelemen et al., 2000). Absolute accuracy tends to be influenced by more *trait*-specific cues, such as how an individual typically does on similar tasks, or perceived reading ability (Foster et al., 2017; Kwon & Linderholm, 2014; Linderholm et al., 2008; Zhao & Linderholm, 2008). An average of past performance then acts as an anchor for judgment magnitude. When making an estimate, individuals use a heuristic where they formulate a starting point and adjust up or down based on that initial starting point; unfortunately for the estimators, they usually do not adjust from the anchor enough (Tversky & Kahneman, 1974). For example, if an individual is generally a stellar student, they might judge that they will understand and remember a text because they generally score well, thus producing a large prediction magnitude. Then, they will adjust that judgment based on how they feel about the particular reading; as people tend to under adjust, this student will have generally high prediction magnitude for anything they read. Therefore, absolute accuracy is relatively stable and compared to relative accuracy, tends not to fluctuate with experimental manipulation (Keleman et al., 2000). However, preliminary evidence suggests that state-based cues influence both absolute and relative accuracy, with mood, for example, affecting both types of accuracy (Prinz et al., 2018).

Cue Use and Metacognitive Accuracy

One explanation for why students have poor metacomprehension accuracy is inappropriate cue use (Thiede et al., 2010). According to the Cue Utilization Hypothesis (Koriat, 1997), individuals do not have direct access to their cognitions, such as their memory representations; rather, they use cues, or heuristics, to make metacognitive judgments. If individuals are using cues that provide a strong representation of their actual comprehension, then individuals tend to be accurate. For example, the situation model is an inference-based mental representation of a text (Kintsch & van Dijk, 1978; Perrig & Kintsch, 1985). Because this is representative of comprehension, the situation model is considered a valid cue (Anderson & Thiede, 2008; Fukuya, 2013). Sometimes students use invalid cues, which are not representative of comprehension. An example of an invalid cue would be interest in the passage. A person may judge that they understand a topic because they find it interesting; however, this is not a good proxy for comprehension (Reber & Greifeneder, 2017), and may lead to an inaccurate judgment. It should be noted that individuals can use multiple cues, and there is some evidence that using multiple cues can increase one's accuracy (Undorf et al., 2018). Although many cues have been identified, researchers have not greatly explored state-based cues, which may be vital in understanding what leads to accurate judgments.

The cue utilization hypothesis, one of the most robust theories in metacognitive research, focuses on three categories of cues, but does not include state-based cues (Koriat, 1997). This theory has guided metacognitive research for over 20 years, a testament to its strength. However, by not acknowledging state-based cues, researchers may be ignoring a crucial determinant of metacognitive judgments. When Koriat (1997) proposed the cue utilization hypothesis, he suggested that the three basic cue types that a person uses are intrinsic, extrinsic, and mnemonic cues. Intrinsic cues are characteristics of the material that may influence judgments. This may include difficulty of the material, concreteness of the words, emotionality of the material, etc. Extrinsic cues describe factors about the study conditions, or an individual's study habits that might influence judgments. For example, the amount of time a word is presented on a screen, the amount of time a person studies a word list, or the use of interactive imagery are all considered extrinsic cues. It is important to note that both intrinsic and extrinsic cues are theory-based cues, meaning that they reflect actual cognitive processes, albeit possibly unconscious (Koriat, 1997). A third category, mnemonic cues, are subjective cues that individuals have formed based on prior interactions with similar material. When processing the information, a person can use these experience-based cues to make judgments, such as their familiarity with the topic (Toth et al., 2011), how much information they recall (Koriat, 1993, 1997), and the speed with which they recall information (Bjork et al., 2013). These cues may lead to accurate judgments but may also mislead an individual if the information does not represent a person's actual comprehension. Each type of cue (intrinsic, extrinsic, mnemonic) has been shown to impact judgments (Anderson & Thiede, 2008; Undorf et al., 2018); however, not all cues are represented by these three categories. State-based cues represent characteristics of the individual (Hourihan & Benjamin, 2014), or environmental factors not directly related to the study material. This environment can be internal, like changes in physiology, or external, like time of day, which do not fall under any category proposed by Koriat (1997).

State-based cues are characteristics of the individual that can influence metacognitive judgments (Hourihan & Benjamin, 2014). State based cues are distinct from the cues described by Koriat (1997) as state-based cues are not necessarily related to the material or experiences related to the material. The limited studies that have analyzed state-based cues have assessed mood, time of day, and drugs. Some states, specifically time of day, influence the accuracy of metacognitive judgments, with better memory and metamemory performance in the afternoon (Hourihan & Benjamin, 2014). While the source article describes time of day as a state-based cue, it could be argued that time of day is not a state, but rather is indicative of fatigue or arousal. Prinz and colleagues (2018) conducted a particularly relevant study, as they assessed mood and metacomprehension, a similar state to stress. They induced positive, negative (sad), and neutral states in their participants, and provide evidence that metacognitive judgments can be influenced by mood. The effect of mood on accuracy is two-fold; mood can influence comprehension directly, but also may affect metacognitive judgments. This study suggests that those in a positive mood conflate their positive mood with “favorable” stimuli, increasing overconfidence (Prinz et al, 2018). Additionally, mood seems to influence level of processing. Positive states lead to more shallow processing of stimuli, whereas neutral and negative states shift processing to a deeper level and therefore better comprehension (Prinz et al., 2018). To summarize, a positive mood may lead to both worse comprehension and metacomprehension accuracy. Although mood and time of day may influence metacognitive judgments and accuracy, drug-induced states show mixed findings. Caffeine can influence judgment accuracy; relative accuracy is highest when one’s caffeine use is different during study and testing, compared to those whose caffeine was congruent during study and testing (Keleman & Creeley, 2003). However, the effect is likely because those in the incongruent conditions had poorer memory, indicating that caffeine is probably not acting as a cue. Surprisingly, alcohol consumption did not influence metacognitive accuracy (Nelson et al., 1986). Participants received multiple standard drinks based on their body weight. Researchers believe this null effect is due to asking general knowledge questions, which were learned prior to this experiment. To my knowledge, there have been no studies on the effect of stress as a state-based cue on metacomprehension judgment accuracy, even though stress is widely experienced, and influences other relevant cognitive domains. Similar to mood and time of day, stress influences cognition, generally impairing working memory and comprehension (Rai, Loschky, Harris, 2015; Shields et al., 2016; Tsai et al., 2019; see Human et al., 2018 for counterevidence), and preliminary evidence shows that stress influences metacognitive accuracy (Miesner & Maki, 2007; Reyes et al., 2015). Therefore, it is believed that stress may act as a state-based cue for metacomprehension judgments.

The Stress Response

Although stress is not defined consistently in the literature, it can be described as a psychological and physiological reaction to a perceived threat or challenge (Kemeny, 2003; Tsai et al., 2019). Stress may evoke mental states such as anxiety, sadness, frustration, and even heightened cognition, as well as physiological responses such as increased heart rate and other sympathetic nervous responses, the release of the hormones epinephrine and cortisol, and a decrease in immune functioning (Kemeny, 2003; Kim & Diamond, 2002). Stress influences individuals differently, depending on the intensity of the stressor, the interpretation of the stressor, and the reactivity of the individual's stress response (Kemeny, 2003; Tsai et al., 2019). Stress is widely experienced, impacting virtually all college students, with 57.6% of students reporting above average or tremendous stress (American College Health Association, 2019). Anxiety is a closely related construct, defined as sensory sensitivity or vigilance in response to uncertainty, which typically leads to repetitive thoughts or worry, as well as an increased attention to negative stimuli (Lukasik et al., 2019). Another way to conceptualize anxiety is an avoidant motivational state due to perceived stress (Rai, Loschky, and Harris, 2015). Stress is the broader term, which encompasses anxiety. It refers to both proactive and avoidant behaviors toward the source of stress, while anxiety tends to only include avoidant behaviors (Lukasik et al., 2019). Often, psychological stress is measured using anxiety as a proxy, specifically the State and Trait Anxiety Inventory (STAI; Birkett, 2011; Human et al., 2018), showing the overlapping nature of these constructs; the STAI was used in the current study to measure perceived stress.

One of the many responses evoked by stress is increased attention to the stressor, which consequently impacts executive functioning (Shields et al., 2016). While researchers have historically attributed impaired cognitive performance to distraction or greater attention to the stressor (Baumeister, 1984; Beilock & Carr, 2005; Steele & Aronson, 1995), the first to parse out this mechanism was Eysenck and colleagues (2007), who developed the Attentional Control Theory. The attentional control theory states that in the presence of high stress, a person's attentional control is impaired (Eysenck et al., 2007). In this context, attentional control refers to inhibiting distracting information, set shifting, and updating information in working memory. Eysenck and colleagues (2007) describe two systems of attention in the context of the attentional control theory: a goal-directed attentional system and a stimulus-driven attentional system. Typically, a person can focus their attention on their goals, a top-down process. However, high stress limits one's ability to inhibit distracting information, and their attention is driven by stimuli that may or may not relate to the task at hand (Eysenck et al., 2007; Lukasik et al., 2019). When stimulus-driven, bottom-up attentional processing is the more active system, there are typically impairments for speed of processing, but not always accuracy (Eysenck et al., 2007). However, accuracy may be impaired if the task is difficult, or if working memory capacity is low; for example, stressful circumstances lead to worse working memory performance when the task is challenging (Beilock & Carr, 2005). Using the attentional control theory as a framework, stress would reduce cognitive resources dedicated to metacognitive monitoring, as monitoring is a goal-directed process. Although this theory is well accepted and explains how stress impairs performance, it is still difficult to explain why, under some circumstances, cognition is improved under stress. Some have suggested that stress can improve cognitive processes if it induces an ideal level of arousal, especially for individuals that interpret the stressor in a positive way

(Jamieson, Nock, et al., 2013; Jamieson, Peters, et al., 2016). For example, if a student views an upcoming exam as a challenge rather than a threat, their stress response is more likely to benefit performance. However, in the current study, participants were not instructed to reappraise their situation positively, and a goal of the neutral judges was to encourage a negative appraisal of the situation. Therefore, because the researcher will encourage negative appraisal of the situation, the attentional control theory is a better candidate for predicting the effect of stress on working memory.

Stress and Working Memory

Consistent with the attentional control theory, many studies have shown a decrease in working memory performance with acute stress (see Shields et al., 2016 for a review). More specifically, evidence suggests that the chosen stress manipulation, the Trier Social Stress Test (TSST), decreases working memory performance. For example, the TSST impaired the reaction time of spatial working memory and recall performance on a verbal working memory task (Olver et al, 2013). Other studies demonstrated that when exposed to the TSST, participants exhibit fewer correct scores on the reading span (Luethi et al., 2009), and that the TSST disproportionately impacted challenging tasks, as the attentional control theory would predict (Oei et al., 2006). It should be noted that both of these studies only recruited male participants due to potential confounds of the women's menstrual cycle, and therefore may not be generalizable.

Although many studies show a decrease in working memory in response to stress, as predicted by the attentional control theory, other studies show no difference, or even an increase in performance under stress (Shields et al., 2016). One study showed that the TSST did not alter working memory measured by the N-back (Human et al., 2018). A separate study found that male performance did not change after acute stress but female performance on the digit span improved, specifically for female participants whose cortisol *decreased* after the TSST (Zandara et al., 2016). Strangely, another study demonstrated the opposite result, showing that male participants with the greatest *increase* in cortisol response improved performance on the N-back task (Lin et al., 2020). This study unfortunately did not recruit female participants, so gender differences cannot be assessed or compared to Zandara and colleagues' study (2016). A third study found that the TSST might lead to improved working memory performance in men but a non-significant change in women (Schoofs et al., 2013). As Lin and colleagues (2020) stated, many factors contribute to the impact of stress on working memory, including the interpretation of the stressor, the type of working memory task used, the gender of the individual, and the individual's reactivity to stress.

Stress and Comprehension

Evidence suggests that comprehension is also negatively impacted by stress, likely mediated by working memory. Stress seems to impact comprehension by restricting cognitive resources dedicated to the reading process (Rai, Loschky, & Harris, 2015). Low working memory can disrupt the formation of a strong situation model, which is a type of mental representation of the text that guides comprehension and metacomprehension (Anderson & Thiede, 2008; Kintsch & van Dijk, 1978). The situation model connects the content of the texts with prior knowledge, allowing inferences to be made. Working memory is integral in holding and retrieving information and is therefore necessary for the formation of the situation model (Radvansky & Copeland, 2004). Although Radvansky and Copeland (2004) found inconsistent empirical evidence for a relationship between working memory and the situation model, other studies have found that individuals with lower working memory capacity tend to make fewer inferences (Linderholm & van den Broek, 2002; Singer et al., 1992). This association suggests that higher working memory is necessary for a strong situation model and a full understanding of complex or difficult reading tasks. A recent meta-analysis found that there is a moderate relationship between reading and working memory; using data from 197 studies, the mean correlation is $r = 0.29$ (Peng et al., 2018). Therefore, if stress has a strong impact on working memory, it is likely that reading comprehension might also be negatively affected.

In addition to the connection between working memory and reading comprehension, empirical evidence demonstrates a direct connection between stress and comprehension. For example, test anxiety was found to interfere with comprehension for those with lower working memory capacity (Calvo & Castillo, 1995), and there is a moderate relationship between self-reported stress and reading comprehension (Peyman & Sadighi, 2011). One study has assessed reading comprehension under the TSST manipulation; after the TSST, reading times were slower for those with lower working memory capacity compared to those with higher working memory, whose reading times improved (Rai et al., 2015). The stress manipulation did not decrease the accuracy of reading comprehension, demonstrating a tradeoff between reading speed and accuracy, consistent with the attentional control theory (Rai et al., 2015). Cognitive resources are essential to making accurate metacomprehension judgments (Griffin et al., 2008), so even if comprehension does not decrease under stress, there may be insufficient cognitive resources to dedicate to monitoring accurately, but few studies have addressed the link between metacognition and any type of stress.

Metacognition and Stress

Studies of metacognition under stress primarily focus on test anxiety, and none to my knowledge have explicitly manipulated stress. First, test anxiety tends to decrease student’s predictions of their memory, leading to a higher reliance on external memory aids, which demonstrates that test anxiety can influence control related behaviors (Stober & Esser, 2001). Another study assessed metacognitive predictions made during a psychology course, and reported similar results, that higher test anxiety was associated with lower predictions (Lusk, 1981). This study also showed that anxiety was associated with improved absolute accuracy, but only for female students. Hong and colleagues (2019) replicated this effect in fourth grade students using a language learning program, finding that higher anxiety was associated with improved absolute accuracy. The study by Miesner and Maki (2007) is particularly relevant to the current study, as they looked specifically at metacomprehension, and assessed both absolute and relative accuracy. They did not find that absolute accuracy differed between groups, but they found that relative accuracy improved with reported higher test anxiety. The authors suggested that when participants reported higher stress, that they might experience disruptions during their reading; these disruptions during reading likely act as a cue that can improve relative accuracy (Miesner & Maki, 2007). There has been one study since this study's proposal that assessed test anxiety and metacognitive accuracy in a classroom setting (Sijas et al., 2021). This study has found that in a class setting, when reporting higher levels of trait anxiety, students tend to have lower predictions and more underconfident results; relative accuracy was not measured (Sijas et al., 2021). Taken together, these studies demonstrate that despite reduced confidence, metacognitive accuracy seems to improve under test anxiety conditions. It should be noted that test anxiety did not benefit comprehension performance. Additionally, it was unknown whether experimentally manipulated stress would elicit similar responses as test anxiety.

Only one study to my knowledge has measured metacognition under stress outside of the context of test anxiety. This study assessed stress reactivity, or the intensity of physiological and psychological responses toward a stressor, finding it may negatively affect metacognitive accuracy (Reyes et al., 2015). Although this study did not explicitly induce stress, the researchers measured stress reactivity prior to the metacognitive task, and concluded that the metacognitive task was inherently stressful, particularly for those with high stress reactivity. This study used a perceptual decision task, where participants viewed two similar slides, determined which slide included a shape with greater contrast to the background color, and made a judgment about their accuracy on this task. Participants with higher stress reactivity had a lower relative accuracy, but no differences for absolute accuracy. It should be noted that the authors of this study leave several questions unanswered. Participants were tested for stress reactivity a full year before they were tested on metacognitive accuracy, with no justification for this gap. Not only was this length of time not explained, the authors also did not explain how people were chosen for the second half of the study. Although they tested 120 people for stress reactivity, only 27 participants were included in the metacognitive evaluation. The researchers included three stress reactivity groups (high, medium, and low), with only 9 people in each group, which is a small sample for their 3-way ANOVA analysis. Although the authors report robust effect sizes for stress reactivity on metacognitive accuracy, these methodological oddities call for a replication. The current study differed from Reyes's study, as it focused on metacomprehension instead of a perceptual metacognitive task. Additionally, stress was experimentally manipulated prior to the metacognitive task, and included a larger sample size to assure adequate power.

Gender and Trait Anxiety

Many factors shape the stress response; two variables that could alter the results of the current study include trait anxiety and gender. Trait anxiety can be defined as the level of anxiety that a person tends to feel over time (Spielberger et al., 1983). If a person is generally high in trait anxiety, they may feel anxious even in the control condition. Therefore, trait anxiety, as measured by the trait anxiety subscale of the STAI, was controlled for in this analysis. Additionally, stress differentially impacts men and women, leading to different physiological and psychological reactions (Kirschbaum et al., 1992). Men tend to release more cortisol in response to stress (Schoofs et al., 2013), which has been observed in response to the TSST specifically (Herbison et al., 2016). The gender differences associated with the effect of stress on working memory are not consistent in the literature. Some studies show that working memory is more impaired by stress in women than in men (Schoofs et al., 2013). Another study showed that women's working memory performance improves, while no changes were observed for men (Zandara et al., 2016). Generally, a meta-analysis supports that men's working memory is more impaired by stress than women's working memory (Shields et al., 2016). Because stress differentially affects cognitive performance based on gender, gender was analyzed as a moderator of the link between acute stress and metacognitive performance.

Present study

The present study tested the effects of induced stress on metacomprehension accuracy. This study has both practical and theoretical implications. First, many college students experience high levels of stress throughout the semester; if findings suggest that metacognitive performance decreases under stressful conditions, then this may impact a large number of students, exacerbating the poor comprehension performance that is typical under stress. This study also aimed to clarify whether stress impacts relative accuracy, absolute accuracy, or both, as this may have different implications for potential interventions. Second, the results of this study may provide support for the idea that state-based cues influence metacognitive judgments. Finally, the attentional control theory was utilized as the framework for the current study. This theory predicted that stress induced participants would show impaired monitoring based on impaired cognitive control, which may ultimately hinder the SRL process.

Hypotheses

1. a.) Participants in the stress condition will have lower prediction judgments than the control condition, controlling for trait anxiety.

b.) Participants in the stress condition will demonstrate lower relative accuracy compared to the control condition, controlling for trait anxiety.

c.) Participants in the stress condition will have lower absolute accuracy than the control condition, controlling for trait anxiety.

Stress has been shown to impair facets of cognition, including working memory (Shields et al., 2016) and potentially metacognition (Reyes et al., 2015). Stress limits the cognitive resources available, directing attention away from goal driven tasks like metacognitive monitoring (Eysenck et al., 2007; Griffin et al., 2008). Therefore, it was predicted that participants would experience impaired metacognitive monitoring under a stress manipulation. Relative accuracy was predicted to be negatively affected by stress, as it is often affected by task-specific cues, and attention to these cues may be disrupted by stress (Dunlosky & Lipko, 2007). There is mixed evidence for whether absolute accuracy would be affected; absolute accuracy tends to be stable, but some evidence suggests it can be manipulated by state-based cues (Hourihan & Benjamin, 2014). Additionally, some evidence suggests that prediction judgments and absolute accuracy are lower under test anxiety (Hong et al., 2018), which may be analogous to how acute stress would influence prediction judgments and absolute accuracy in the current study. Each hypothesis was assessed with a two-tailed test because this study is novel, and it is more important to find any difference than to look for directional differences.

In this analysis, differences in multiple-choice scores was also assessed between conditions. There was not a hypothesis about this effect because I did not believe comprehension scores would differ between conditions. Due to decreased reading speeds under stress, comprehension will likely remain intact as it did in past research (Rai et al., 2015), but analyzing whether comprehension differs between groups can explain whether multiple-choice performance is in part driving differences in metacomprehension performance. Finally, trait anxiety was assessed as a control variable as it can systematically influence the effect of stress on the different components of metacomprehension.

2. a.) Self-reported state anxiety, measured at time two, will correlate negatively to prediction judgments, controlling for trait anxiety.

b.) Self-reported state anxiety, measured at time two, will correlate negatively to relative accuracy, controlling for trait anxiety.

c.) Self-reported state anxiety, measured at time two, will correlate negatively to absolute accuracy, controlling for trait anxiety.

Similar to hypothesis 1, it was predicted that higher state anxiety would relate to impaired relative accuracy, as well as lower predictions and absolute accuracy. However, there is mixed evidence on whether stress would help or hinder cognitive functioning (Shields, 2016), so this was assessed using a two-tailed test. The relationship between state anxiety and multiple-choice scores was also measured, as this may have explanatory power. Trait anxiety was a control variable as it can systematically influence the effect of acute stress on the different components of metacomprehension.

Exploratory hypotheses:

1. Gender will moderate the effect of stress on metacomprehension.

Gender has been shown to differentially impact the stress response. Typically, stress impacts the magnitude of working memory impairment more in men more than women (Shields et al., 2016). However, this effect is small, and the literature shows mixed findings, with some studies indicating that men show an increase in working memory performance under stress (Lin et al., 2020; Shoofs et al., 2013). Therefore, there was not a hypothesized direction for this effect.

2. Absolute accuracy will correlate to trait anxiety.

This study assessed whether trait anxiety contributes to one's absolute accuracy to determine whether trait anxiety can act as an anchor that individuals use. Currently, the literature suggest that individuals tend to base their judgments on how they generally do on similar tasks, or on their perceived reading ability (Foster et al., 2017; Kwon & Linderholm, 2014; Linderholm et al., 2008; Zhao & Linderholm, 2008). Those with test anxiety sometimes have less overconfidence (Hong et al., 2018), but not always (Lusk, 1981; Meisner & Maki, 2007). Absolute accuracy is fairly stable and has been hypothesized to be related to an average of past performances (Foster et al., 2017), perceived reading ability (Kwon & Linderholm, 2014), and even personality (Madison et al., 2021). If there is a correlation between these two variables, it suggests that how individuals generally perform on similar tasks is not the only contributor to the stability of absolute accuracy.

3. Stress will significantly increase the time it takes to complete the reading task.

In prior literature, some evidence suggests that while stress does not affect comprehension performance, it can increase reading times (Rai, Loschky, Harris, 2015). Although reading time was not a primary interest of this study, it might provide explanatory power. For example, if metacomprehension accuracy was found to be equal between groups, this could be explained by an increase in reading times for the stress condition.

Chapter 2: METHOD

Recruitment and Power Analysis

To participate, students had to be at least 18 years of age. Participants were required to abstain from drinking alcohol for 24 hours and abstain from marijuana and other illicit drugs for at least one week. While they were not excluded based on these criteria, participants reported English fluency, as well as diagnosed psychological and learning disorders such as depression, anxiety, ADHD, specific learning disorders, and autism. They were asked about caffeine consumption, and tobacco use. The demographic questionnaire is included in Appendix A.

I sought to collect 128 participants. Originally, I aimed to collect close to an equal amount of men and women by collecting only male participants once I tested 70 female students. However, I started data collection at The College of Idaho at about the same time that I collected 70 female participants, so I chose not to halt data collection for women, as gender would have been confounded with location. This sample size is based on a power analysis to test our most complex analysis, a 2x2 ANCOVA, with gender acting as a pseudo-independent variable, and trait anxiety as a covariate (G*Power). This power analysis was calculated using power of .80 and the effect size $\eta^2 = .06$, which is considered a medium effect. Additionally, the numerator degree of freedom was entered as one, number of groups was four, and covariate was one. This effect size was taken from the Miesner and Maki (2007) study, showing the effects of test anxiety on relative accuracy. I chose this study because it assessed both test anxiety and relative accuracy, and provides the most reasonable sample size. For example, based on the large effect sizes found in Reyes and colleagues (2015) or Leuthi and colleagues (2009), which looked at the effect of stress on meta-perception and working memory respectively, about 52 participants was appropriate, but I did not want to miss smaller effects. Alternatively, a meta-analysis showed that the average effect size for stress's effect on working memory was small, so the required sample size was 351 which I did not think could be realistically collected using the available research pool.

Participants

Participants were 136 undergraduate students from both Idaho State University and the College of Idaho. At both sites, students were recruited for course credit. Due to experimenter error (i.e. administering measures in incorrect order), there were three students excluded. An additional student was excluded for incomplete data. In total, 132 participants were included in the final analysis, with 63 participants in the stress condition and 69 participants in the control condition. Participants were primarily women (71.2%). This sample was primarily white (86%) and non-Hispanic (86%). Most of the sample were in their first or second year of university (83.3%). Finally, most of the sample came from Idaho State University (75.8%). See Table 1 for a more detailed description of demographics, and see Table 2 for the relation of demographic characteristics to the dependent variables of this study. Further, see Figure 3 for a comparison of metacognitive variables by site location.

Whenever assessing relative accuracy, as measured by gamma correlations, an additional five participants were excluded from the analysis. This is because four students had predictions that did not vary, and so a gamma correlation could not be calculated. For example, if a person predicted they would score five out of eight questions correct on every text that they read, a correlation cannot be calculated. One student scored the same on each multiple-choice test so similarly, a gamma correlation could not be calculated. These participants were included for the other analyses.

Table 1

Demographic Characteristics

Item	Total (N = 132)	Stress (n = 63)	Control (n = 69)
Age			
18-19	79	34	45
20-21	22	13	9
22+	31	16	15
Gender			
Identifies as Male	35	21	14
Identifies as Female	94	41	53
Identifies as Non-binary or other	3	1	2
Race			
White	114	55	59
Black or African American	6	2	4
Asian	6	4	2
American Indian or Alaska Native	4	4	0
Native Hawaiian or Pacific Islander	4	1	3
Other	9	2	7
Hispanic or Latino	22	7	15
Year in University			
Year 1	83	36	47
Year 2	27	16	11
Year 3	15	8	7
Year 4	7	3	4
Mood or Anxiety Disorder			
Present	50	24	26
Absent	82	39	43
Learning Disability			

Present or Probable		17	10	7
Absent		115	53	62
Chronic Illness				
Present		12	10	2
Absent		120	53	67
Collection Site	**Average Age**			
ISU	21.6	100	44	56
College of Idaho	19.3	32	19	13

Table 2

Mean and Standard Deviation of Dependent Variables in Relation to Demographic Characteristics

	Prediction Magnitude	**Bias Score**	**Gamma Correlation**	**Multiple-Choice Accuracy**	**STAI-1**	**STAI-2**	**Trait Anxiety**
Mood or Anxiety Disorder							
Present	4.80 (.20)	1.18 (.24)	.11 (.07)	3.60 (.16)	33.18 (1.00)	35.42 (0.87)	42.12 (1.20)
Absent	4.90 (.14)	1.35 (.15)	.20 (.06)	3.59 (.14)	31.82 (0.71)	33.94 (0.73)	35.45 (0.84)
Learning Disability							
Present	4.84 (.29)	1.18 (.24)	.14 (.16)	3.49 (.30)	32.41 (1.60)	34.00 (1.54)	41.76 (2.50)
Absent	4.80 (.13)	1.28 (.14)	.17 (.05)	3.61 (.11)	32.33 (0.63)	34.57 (0.60)	37.42 (0.74)
Chronic Illness							
Present	5.06 (.33)	0.66 (.35)	.10 (.17)	4.39 (.37)	34.50 (2.43)	37.17 (1.72)	38.33 (2.47)
Absent	4.87 (.12)	1.35 (.14)	.18 (.05)	3.52 (.11)	32.13 (0.59)	34.23 (0.59)	37.94 (0.76)
School Attended							
ISU	4.95 (.13)	1.43 (.15)	.20 (.05)	3.51 (.13)	31.68 (0.60)	34.05 (0.62)	37.60 (0.77)
College of Idaho	4.67 (.24)	.83 (.25)	.09 (.10)	3.84 (.17)	34.41 (1.47)	35.91 (1.22)	39.16 (1.82)

Materials

State and Trait Anxiety Inventory

The State and Trait Anxiety Inventory is composed of 40-questions (Spielberger et al., 1983; Appendix B). It has two subscales, 20 questions to evaluate a person's state anxiety, and 20 questions to assess their trait anxiety. All questions are asked on a 4-point scale that ranges from 1 (almost never) to 4 (almost always). Test-retest reliability for the trait subscale ranges from 0.73 to 0.86, and is predictably lower for the state subscale, ranging from 0.16 to 0.62. Internal consistency is high, with alpha coefficients at 0.90 and 0.93 for trait and state subscales questions (Spielberger et al., 1983). This measure is considered valid, as higher trait anxiety is reported in those with diagnosed anxiety disorders, and higher state anxiety found immediately after stressful events like a high stress training program for military recruits (Spielberger et al., 1983). For the current study, the first time this survey was administered, it was administered in full (STAI-1). During time 2 and time 3 (STAI-2 and STAI-3 respectively), only the 20 questions for the state anxiety subscale were administered.

Passages and Comprehension Test

These texts and test questions come from the Scholastic Aptitude Test (Board, 1997) and are at a Flesch-Kincaid grade-level of 9.8-12.0 (M = 11.6). The titles of the texts are: Television Newscast, Precision of Science, Women in the Workplace, Zoo Habitats, American Indians, and Real vs Fake Art (see Appendix C for sample). Each text is associated with 8 multiple-choice questions, so that the full comprehension test is 48 questions.

Procedure

Participants were first asked to sign a consent form then take the STAI-1 on Qualtrics. The primary researcher remained relatively flat in affect when welcoming the participant, as this researcher was one of the neutral judges. Participants were randomly assigned to the stress or control condition.

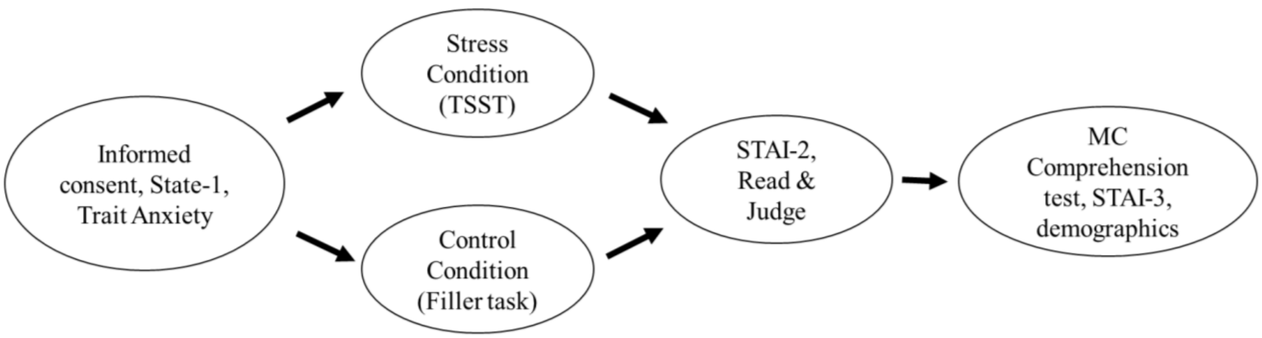
The stress condition followed the protocol for the TSST (Birkett, 2011; Kirschbaum et al., 1993). Participants were told to prepare a five-minute speech about why they would make a good candidate for their ideal job. They had three minutes to prepare for the interview, and paper was provided during this preparatory period if participants wished to take notes. After this preparatory period, the participants gave a speech in front of two neutral judges, one of whom was the primary researcher. The judges were instructed to maintain neutral facial expressions while the participant talked. The judges only responded if the participant stopped talking, by reminding the participant to continue to speak for the entirety of the 5-minute session. The judges then informed the participant about the arithmetic task. The participant was instructed to subtract 13 from the number 1,022 out loud for 5 minutes, while being as fast and accurate as possible. If the participant made an error, they were told to restart at 1,022. Once the participant finished the TSST, they completed the STAI-2 on Qualtrics. The control group instead completed a neutral computer task, specifically the games solitaire or snake, that took the same amount of time, 13 minutes. After this period was complete, the control participants took the STAI-2 to assess whether state anxiety increased from baseline.

All the participants followed the same procedure from this point forward. They read six different expository texts. Immediately after the first text, the participants made a prediction judgment, predicting how many questions about the text they would get correct on an upcoming test. They then read text two, and made their prediction about text two. They read a total of six separate texts, presented in a random order. After they finished the reading task, they began the multiple-choice comprehension exam, answering 8 questions for each text, leading to a total of

48 questions. The texts and questions were presented using E-Prime in order to accurately assess reading time. Finally, they took the STAI-3 to assess for a return to baseline and take a demographic questionnaire. The researcher debriefed the participant. All participants were offered the option to watch positively valanced videos or a short meditation video to increase positive mood. See Figure 1 for a visual summary.

Figure 1

Overview of Experimental Procedure



Data analysis

First, a data screener was completed to assure that the data are normal, and fit all assumptions for ANCOVA, especially for normality, homoscedasticity, and for the presence of outliers, which for the purpose of this study was defined as a value three standard deviations above or below the mean. A correlation matrix was used to assess the relationships between each of the stress and metacognitive variables. To assess whether the stress manipulation was successful, a repeated measures ANOVA was used to assess changes in state anxiety at time one and time two by condition. All data was analyzed using SAS/STAT® software.

Hypothesis 1

Relative accuracy was calculated for each individual. Relative accuracy is measured by correlating a person's comprehension performance and prediction judgments using a gamma correlation. Similarly, each person's absolute accuracy was measured using bias scores. Each comprehension score was subtracted from its respective predicted score, so that every participant had six different bias scores. These were averaged, so that each person had one average bias score.

To compare the dependent variables across conditions, four ANCOVAs were calculated. This method was chosen above a MANCOVA because despite the dependent variables being related, the dependent variables answer different research questions; additionally, it is not standard practice in metacognitive research (Anderson & Thiede, 2008; Undorf, Sollner, Broder, 2018). The independent variable is the stress condition (stress vs no stress). The four dependent variables are prediction magnitude, relative accuracy, absolute accuracy, and comprehension scores. Trait anxiety was a controlled variable.

Hypothesis 2

The relationship between state anxiety and metacomprehension was assessed with a hierarchical regression. Four regressions were conducted using the four dependent variables: prediction magnitude, relative accuracy, absolute accuracy, and comprehension scores. Trait anxiety was added to the first model, in order to control for its effects, and the state anxiety subsection of the STAI-2 was added to the second model.

Exploratory Hypothesis 1

First, gender was tested as a moderator for the relationship between condition and each dependent variable (prediction judgment, relative accuracy, absolute accuracy, and comprehension scores). Gender acted as a pseudo-independent variable. Those who identified their gender as non-binary or other were excluded from any gender analysis. Transgender individuals were assessed in the category of their preferred gender; this analysis was run with and without transgender individuals, who were excluded if their inclusion changes the results. This moderation analysis was assessed using a 2x2 ANCOVA, with both condition and gender acting as independent variables, and trait anxiety being controlled for.

Second, the relationship between state stress level measured by the STAI-2 and each dependent variable (prediction judgment, relative accuracy, absolute accuracy, and comprehension scores) was tested with gender in the model as a moderator. This was measured with a hierarchical regression. Trait anxiety was added as the first step to control for its effects, with STAI-2 and gender entered as the second step.

Exploratory Hypothesis 2

To assess whether absolute accuracy and trait anxiety were related, a simple regression was used, with trait anxiety as the predictor variable and bias scores as the outcome variable. This is highlighted for its relevance to past research, but because Hypothesis 2B included this analysis as the first step of the hierarchical regression, there is not a separate section in the results section for this hypothesis.

Exploratory Hypothesis 3

To test whether stress impacted reading time, an average reading time was calculated for each person. Differences in reading times between conditions was assessed using a *t*-test. An additional assessment looked at reading times as a function of the state anxiety. A simple regression tested state anxiety at time two as the predictor variable and reading times as the outcome variable.

Covid-19 Safety Procedures

The study was able to be completed safely using precautions to protect the researchers and participants from Covid-19. Participants were required to wear masks for the entirety of the study, even when mask restrictions were loosened. In the stress condition, researchers either wore a face shield, or a clear face mask when testing participants. This was so that participants could observe their neutral expressions. In the control sessions, because there was no need to observe a neutral expression, the researchers wore face masks. In both conditions, the researchers maintained a distance of six feet when possible. The work area was sanitized before and after each participant, and hand sanitizer was available.

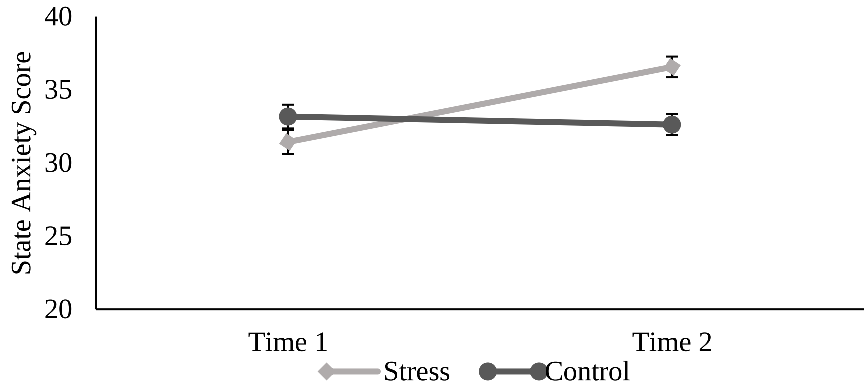
Chapter 3: RESULTS

Manipulation Check

A repeated measures ANOVA was utilized as a manipulation check to assess changes in state stress between conditions from time one to time two. Though there were no main effects of condition ($F(1, 130) = 1.18$, $p = .28$; see Figure 2), state stress was found to increase from time one to time two ($F(1, 130) = 22.88$, $p < .0001$). Notably, there was a significant interaction effect ($F(1, 130) = 35.22$, $p < .0001$), such that average stress increased in the stress condition (STAI-1: $m = 31.43$, $SE = .81$; STAI-2: $m = 36.56$, $SE = .71$; $t(62) = 7.29$, $p < .0001$) but did not increase in the control group (STAI-1: $m = 33.17$, $SE = .83$; STAI-2: $m = 32.62$, $SE = .79$; $t(68) = -0.85$, $p = .40$). This approximates the STAI scores of Birkett's TSST protocol (2011), where healthy volunteers reported an average score of 30 on the STAI before the TSST, and approximately 40 on the STAI after the TSST. It should be noted at Time-1 and Time-2, the means of both conditions fell in the low stress range, which is considered 20-40 on this subscale, with medium stress ranging from 40-50, and high stress ranging from 50-80 (Ping et al., 2008). Each time the STAI was measured, it had strong measures of reliability, which is considered above α = .70. On the STAI, the trait anxiety subscale had a Cronbach's alpha of α = .89. For state-1 anxiety, the alpha was α = .86. And for state-2 anxiety, the alpha was α = .81. Additionally, see Table 3 for a correlation matrix with stress and metacognitive variables included.

Figure 2

State Anxiety at Time 1 and Time 2, by Condition



Note. Represents state anxiety between conditions at time one, administered after the consent form, and time two, administered after the stress manipulation or control task. There is a significant interaction effect. Higher scores on the y-axis indicate increased stress. Error bars represent standard error.

Table 3

Correlation Matrix for Metacognitive and Stress Variables

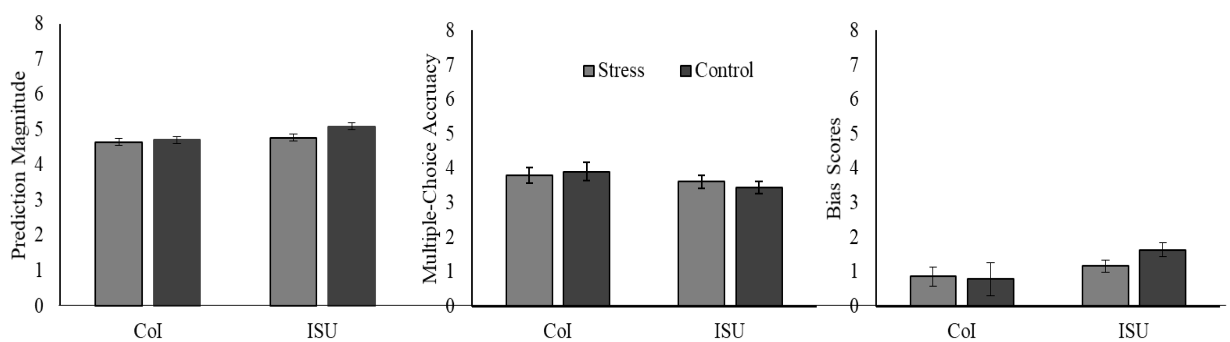
	1. Prediction Magnitude	2. Bias Score	3. Gamma Correlation	4. Multiple-Choice Accuracy	5. STAI-1	6. STAI-2
1. Prediction magnitude	-	-	-	-	-	-
2. Bias score	.64**	-	-	-	-	-
3. Gamma correlation	.05	-.002	-	-	-	-
4. Multiple-choice accuracy	.32**	-.52**	.06	-	-	-
5. STAI-1	-.27*	-.30**	.06	.07	-	-
6. STAI-2	-.24*	-.23*	.02	.01	.56**	-
7. Trait anxiety	-.18*	-.29**	-.03	.16	.57**	.32**

*= $p < .05$

**= $p < .001$

Figure 3

Means of Prediction Magnitude, Bias Scores, and Multiple-Choice Accuracy, separated by Gender and Condition.



Note. Error bars represent standard error.

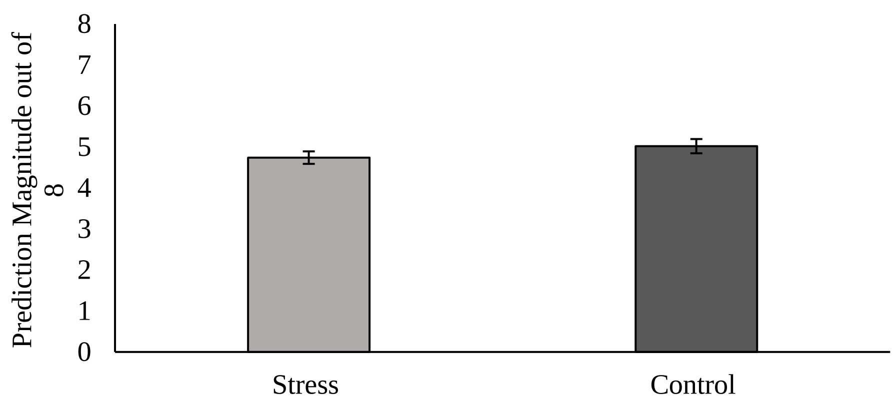
Hypothesis 1

The first set of hypotheses is designed to test whether condition (Stress or Control) would lead to differences in prediction magnitude, relative accuracy, and absolute accuracy, as well as multiple-choice accuracy. Each was assessed with an ANCOVA to control for potential effects of trait anxiety.

1(a). There was a marginally significant effect of the stress condition on prediction magnitude [$F(2, 129) = 3.06$, $p = .0501$, $\eta^2 = .05$; see Figure 4]. The stress condition had lower mean prediction magnitude ($M = 4.72$, $SE = .17$) compared to the control condition ($M = 5.03$, $SE = .16$). However, a Tukey posthoc test comparing prediction magnitude between conditions was non-significant ($p = .17$), suggesting that any marginal differences in means is explained by one's level of trait anxiety ($F(1, 129) = 4.62$, $p = .03$). In essence, hypothesis 1(a) was not supported.

Figure 4

Average Prediction Magnitude in the Stress and Control Conditions.

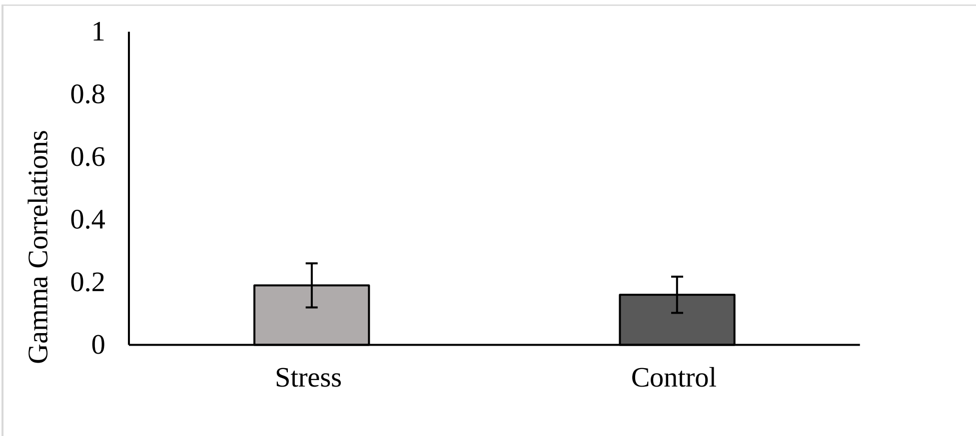


Note. Error bars represent standard error.

1(b). Relative accuracy, measured by gamma correlations, was not significantly influenced by stress [$F(2, 124) = .09$, $p = .92$]. The stress condition had approximately the same gamma correlation (*M* = .19, *SE* = .07) as the control condition (*M* = .16, *SE* = .06). As mentioned previously, this analysis excluded 5 participants who did not have variability in their prediction magnitude or multiple-choice score. Hypothesis 2(b) was not supported.

Figure 5

Average Gamma Correlation in the Stress and Control Conditions.

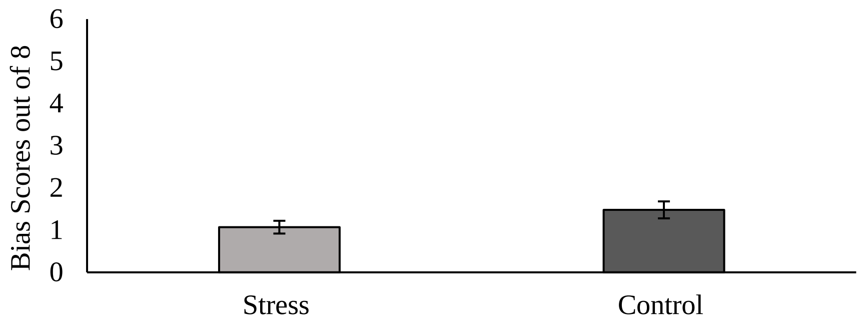


Note. Error bars represent standard error.

1(c). The ANCOVA for absolute accuracy could not be run. When checking assumptions, the Levene's Test for Homogeneity of Variance was found to be significant [$F(1, 130) = 4.64$, $p = .03$], indicating the variance in bias scores between the stress and control condition were significantly different from each other, which violates an assumption of an ANCOVA. Using Welch's ANOVA to account for this breach, the ANOVA was not significant ($F(1, 123.2) = 2.62$, $p = .11$). It should be noted that Welch's ANOVA is a one-way test, and therefore, trait anxiety is not controlled for in this instance. Though non-significant, the mean for the stress condition (*M* = 1.07, *SE* = .18) was lower than the control condition (*M* = 1.48, *SE* = .18; see Figure 6). Hypothesis 1(c) was not supported.

Figure 6

Average Bias Scores in the Stress and Control Conditions.

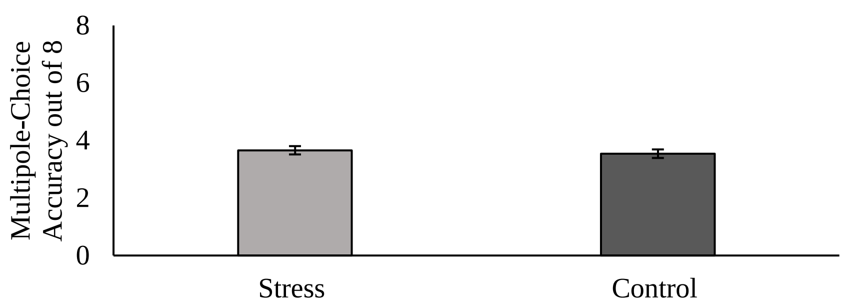


Note. Error bars represent standard error.

In addition, it was stated that multiple-choice scores would be included in this analysis, but there was not a hypothesized effect. This non-effect was supported by the data, with no significant differences found between multiple-choice accuracy for the stress (M = 3.68, SE = .15) and control condition [M = 3.52, SE = .14; $F(2, 129) = 1.97$, p = .14; see Figure 7]. The two conditions had approximately equivalent understanding of the text.

Figure 7

Average Multiple-Choice Accuracy in the Stress and Control Conditions.



Note. Error bars represent standard error.

To summarize, there was a marginal difference of conditions between prediction magnitude, with this effect being driven by trait anxiety. There was not an effect between conditions on relative accuracy, bias scores, or multiple-choice accuracy.

Hypothesis 2

The first hypothesis explored the effect of condition, which is a binary measure of stress. As stress responses can be varied regardless of condition, hypothesis 2 tests the relationship of stress as a continuous variable, using state anxiety at time 2 (after stress was induced or participants engaged in a neutral control task), to prediction magnitude, relative accuracy, and absolute accuracy. A hierarchical regression was used to assess these relationships, controlling for trait anxiety by adding it to the model in the first step.

2(a). The aim of hypothesis 2(a) was to assess the relationship of state-2 anxiety to prediction magnitude. The partial model, which included trait anxiety, found a small but significant negative relationship between trait anxiety and prediction magnitude [$R^2 = .03$, $F(1, 130) = 4.20$, $p = .04$]. Those with higher trait anxiety had lower prediction magnitude. The full model, which included trait anxiety and state-2 anxiety, was also significant [$R^2 = .07$, $F(2, 129) = 4.91$, $p = .009$], with the addition of state-2 anxiety significantly improving the model [$\Delta R^2 = .04$, $F(1, 129) = 5.50$, $p = .02$; see top half of Table 4]. This regression analysis indicates that hypothesis 2(a) is supported. Across conditions, when controlling for trait anxiety, higher levels of state-2 anxiety are associated with lower confidence in one's comprehension as measured by prediction magnitude.

Table 4

Regression Coefficients for Prediction Magnitude and Bias Scores

	Model 1			***Model 2***		
Prediction Magnitude	**B (SE)**	**β**	***p*-value**	**B (SE)**	**β**	***p*-value**
Trait Anxiety	-.03 (.01)	-.18	.04	-.02 (.01)	-.11	.22
State-2	-	-	-	-.04 (.02)	-.21	.02
R^2	.03	-	.04	.07	-	.009
ΔR^2	-	-	-	.04	-	.02
Gamma Correlation	**B (SE)**	**β**	***p*-value**	**B (SE)**	**β**	***p*-value**
Trait Anxiety	-.002 (.005)	-.03	.77	-.002 (.006)	-.04	.71
State-2	-	-	-	.002 (.007)	.03	.76
R^2	.0007	-	.77	.002	-	.91
ΔR^2	-	-	-	.0013	-	.76
Bias Scores	**B (SE)**	**β**	***p*-value**	**B (SE)**	**β**	***p*-value**
Trait Anxiety	-.05 (.01)	-.29	.0008	-.04 (.02)	-.24	.007
State-2	-	-	-	-.03 (.02)	-.15	.09
R^2	.08	-	.0008	.10	-	.008
ΔR^2	-	-	-	.02	-	.09
Multiple-Choice Accuracy	**B (SE)**	**β**	***p*-value**	**B (SE)**	**β**	***p*-value**
Trait Anxiety	-.02 (.01)	.16	.07	.02 (.01)	.17	.06
State-2	-	-	-	-.01 (.02)	-.05	.62
R^2	.03	-	.07	.03	-	.17
ΔR^2	-	-	-	.002	-	.62

2(b). There was not a significant relationship between relative accuracy and either trait or state anxiety when looking at the full model [R^2 = .001, $F(2, 124) = .09$, p = .92]. In other words, stress level was not associated with differences in relative accuracy and hypothesis 2(b) was not supported.

2(c). The purpose of hypothesis 2(c) was to assess the relationship of state-2 anxiety and absolute accuracy. The first step in the regression model included trait anxiety, and was significant [R^2 = .08, $F(2, 130) = 11.86$, p = .0008]. The full model, which added state-2 anxiety, was still significant [R^2 = .10, $F(2, 129) = 7.53$, p = .0008] but there was not a significant change

[ΔR^2 = .021, $F(1, 129) = 2.98$, $p = .087$; see bottom half of Table 4]. Higher state-2 anxiety marginally improved absolute accuracy, but individual differences in absolute accuracy are better explained by trait anxiety. This partially supports hypothesis 2(c).

Additionally, multiple-choice accuracy was not significantly predicted by the trait and state anxiety when assessing the full model [$R^2 = .02$, $F(2, 129) = 1.83$, $p = .16$], suggesting that stress does not affect reading comprehension in this context.

In summary, across conditions, prediction magnitude was most affected by state-2 stress, and trait anxiety was the only variable related to absolute accuracy. No other effects were observed.

Exploratory Hypotheses

Gender Analysis

The first exploratory hypothesis assessed whether gender modulates the relationship between stress and metacognitive accuracy. Five participants identified as non-binary or did not disclose their gender, and therefore were excluded from the gender analysis. Two participants identified as transgender, so as stated, the analyses were run twice, both including and excluding transgendered participants. The results were unchanged whether including them as their preferred gender or excluding them; thus, they were included in the gender analysis.

This hypothesis was assessed by running four, 2x2 ANCOVAs, with condition as an independent variable, gender as a pseudoindependent variable, and trait anxiety as the covariate. The dependent variables were prediction magnitude, relative accuracy, and absolute accuracy, as well as multiple-choice accuracy. It should be noted that there were more female than male participants, so these results should be interpreted cautiously.

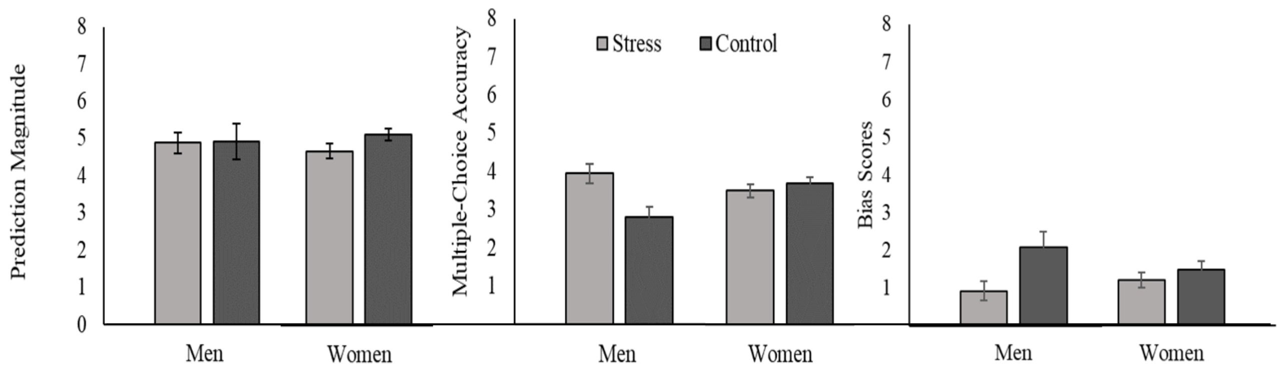
Controlling on trait anxiety, neither gender nor condition were related to prediction magnitude [$F(4, 124) = 1.13$, $p = .35$] or relative accuracy [$F(4, 124) = 0.26$, $p = .90$; see Figure 8]. These results suggest that gender did not influence prediction magnitude regardless of condition, nor did it affect relative accuracy.

The ANCOVA assessing absolute accuracy was found to be significant [$F(4, 124) = 3.86$, $p = .005$]. There is a main effect of condition, with bias scores being significantly lower in the stress condition ($F(1, 124) = 7.71$, $p = .01$). There is a non-significant effect of gender ($F(1, 124) = .42$, $p = .52$), and a marginal but non-significant interaction effect ($F(1, 124) = 3.02$, $p = .08$), with men in the control group demonstrating the greatest overconfidence. Because prediction magnitude did not differ between group or gender, any potential differences in bias scores are most likely driven by multiple-choice scores, as is reported in the next paragraph. Due to a low number of men in the sample and non-significant results, a replication is necessary before any conclusions can be drawn.

When testing multiple-choice performance, the ANCOVA revealed a significant effect of the overall model [$F(4, 124) = 3.11$, $p = .02$]. There was not a main effect of gender on multiple-choice accuracy ($F(1, 124) = 0.76$, $p = .39$), but there was a significant effect of condition, with those in the stress condition scoring significantly higher ($F(1, 124) = 4.51$, $p = .04$). Note that running the ANCOVA without gender, as was run in hypothesis 1, did not find a significant difference ($p = .14$); the significant main effect found in the gender analysis might be due to the inclusion of gender in the model, or the exclusion of the five non-binary individuals. There is a significant interaction ($F(1, 124) = 8.16$, $p = .005$), driven by men in the control condition, who scored lower on the multiple-choice test than men in the stress condition, and women in both conditions (See Figure 8). A difference in multiple-choice accuracy between conditions is not observed among women. It should be noted that men in the control condition had the fewest participants (*n* = 14) and the highest variance (*SE* = .41) compared to the women in the stress condition (*SE* = .18), women in the control condition (*SE* = .17) and men in the stress condition (*SE* = .26)

Figure 8

Means of Prediction Magnitude, Bias Scores, and Multiple-Choice Accuracy, separated by Gender and Condition.



Note. Error bars represent standard error.

In addition, a regression was used to assess the relationship of gender to each of the dependent variables of interest, controlling for trait anxiety. Gender was coded as a dummy variable for this analysis. There were no significant effects of gender on any of the dependent variables: prediction magnitude [R^2 = .04, $F(3, 125) = 1.89$, $p = .14$], gamma correlations [R^2 = .003, $F(3, 120) = 0.13$, $p = .94$], or multiple-choice [R^2 = .03, $F(3, 125) = 1.25$, $p = .29$]. Although the regression model assessing bias scores is significant [R^2 = .06, $F(3, 125) = 2.94$, p = .04], this is explained by trait anxiety (B = -.04, p = .03) rather than gender (B = -.001, p = .99).

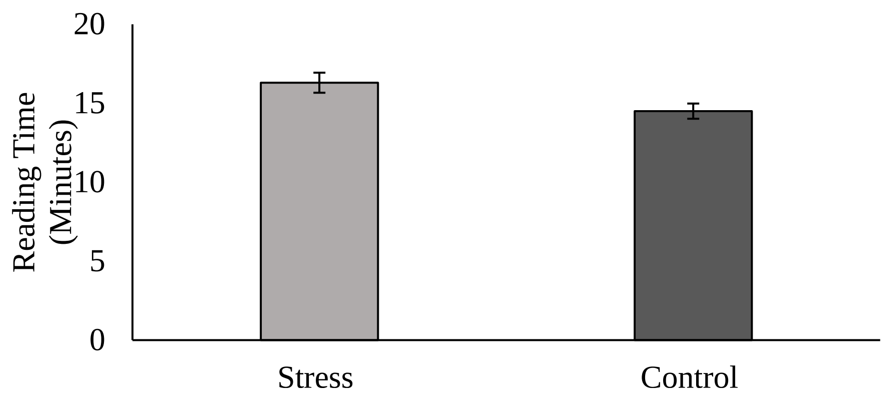
To conclude, there were no effects of gender on prediction magnitude or relative accuracy. Men in the control condition had significantly lower multiple-choice scores compared to men in the stress condition, or women in either condition. This likely drove the marginal interaction effect of men and condition on absolute accuracy, which suggests that men in the control condition are the most overconfident group.

Reading times

Reading times were calculated by finding the total time from when a person opened the screen with the first text, to their last prediction judgment, the slide before they reached the multiple-choice test instruction screen. Without removing outliers, there were no significant differences in reading time between the conditions [$t(130) = 1.50$, $p = .14$]. However, there was one outlier in the control condition, which for the purpose of this study was defined as a value three standard deviations above or below the mean. With the outlier removed, there was a significant difference in reading times between the two conditions, with the mean reading time in the stress condition ($M = 16.30$, $SE = .63$) being higher than the control condition [$M = 14.94$, $SE = .65$; $t(129) = 2.28$, $p = .02$; see Figure 8]. There was no significant relationship between reported stress at time two and reading speeds ($R^2 = .01$, $p = .39$). Removing the outlier did not alter this effect. To summarize, participants in the stress condition took longer to read, but reading time was not correlated with self-reported stress in the sample.

Figure 9

Average Reading Time between Stress and Control Condition.



Note. Error bars represent standard error

Chapter 4: DISCUSSION

This study demonstrates a general trend that higher stress is associated with lower prediction magnitude, which may reduce levels of overconfidence. Specifically, state anxiety was associated with lower prediction magnitude, while trait anxiety seemed to be associated with more accurate absolute accuracy. Relative accuracy was not impacted by stress in any capacity. The attentional control theory cannot explain the entirety of these effects unaided but has strong explanatory power when in conjunction with the Level-of-Disruption Theory (Dunlosky & Rawson, 2005; Soto, 2019). The Level-of-Disruption Theory, first described by Dunlosky and Rawson (2005), in part explains why individuals may have improved absolute accuracy when stressed. Alternative explanations for these effects may include level of arousal (Circia et al., 2021; Kemeny, 2003; Yerkes & Dodson, 1908), optimism (Golke et al., 2020), or potentially, familiarity with stress. This study builds evidence for stress acting as a state-based cue, though state-based cues must be defined more clearly before it can be considered a cue. This also has implications for the SRL process for students who experience differing levels of acute stress when studying and taking exams.

It was anticipated that stress would impair metacognitive accuracy based on the Attentional Control Hypothesis. This hypothesis suggests that stress produces distractions, like worrying about performance, which increases cognitive load (Eysenck et al., 2007; Miesner & Maki, 2007). This may decrease performance, or increase the time required to complete the task, especially for goal directed tasks like metacognitive monitoring (Eysenck et al., 2007). Indeed, there was a significant difference found in the object level reading task, with those in the stress condition taking on average about 1.5 minutes longer to read the six texts. However, when focusing on the metalevel task, some data in the current study show the opposite effect to what was anticipated: no facet of metacognitive monitoring was impaired by stress. Rather, relative accuracy was unaffected by the stress manipulation, and some metacognitive variables were improved. Namely, state anxiety led to lower prediction judgments while trait anxiety was predictive of improved absolute accuracy[1]. The prediction that monitoring ability would decline was incorrect, though there may be merit in the idea that stress is leading to more distractions as is predicted by the Attentional Control Hypothesis. Using a complimentary theory, the Level-of-Disruption Theory, these distractions may have benefited rather than impaired metacognitive monitoring.

This complementary theory, the Level-of-Disruption Theory, posits that when readers are disrupted, the disruption acts as a diagnostic cue for their metacomprehension monitoring

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[1] See section titled "A Disruptive Unplanned Analysis" beginning on page 52 for a more in-depth discussion, as this effect may be more nuanced than is reported here.

(Dunlosky & Rawson, 2005). For example, when students use a button to indicate every instance they are disrupted when they read, the number of disruptions correlates strongly with metacognitive judgments (Dunlosky & Rawson, 2005). Distractions would be considered a valid cue, as more distractions accurately indicates lower performance. For students with higher test anxiety, Meisner and Maki (2007) explain that these students likely had greater distractions based on their level of anxiety, which is predicted by the Attentional Control Hypothesis. Because of this increase in distractions, the authors believe that for anxious students, distractions were acting as a valid cue, therefore increasing their relative accuracy. In the current study, relative accuracy was not different, though likely because distractions were not able to act as a cue in the same way, which will be discussed shortly. Unlike the referenced study (Meisner & Maki, 2007), the frequency of disruptions during reading was not measured. However, participants in the stress condition had slower reading speeds on average, which may indicate more frequent distractions. Considering both evidence from prior studies and the current study, the Level-of-Disruption Theory is the most plausible explanation for why stress contributes to better absolute accuracy.

Authors Meisner and Maki (2007) found that test anxiety improved metacognitive monitoring, a finding that was conceptually replicated by the current study. However, there are crucial differences in the results of the two studies that must be explored to completely understand the nature of stress's effects on metacognitive monitoring. Meisner & Maki (2007) found that relative accuracy, measured by gamma correlations, improved with test anxiety. They explained that after certain texts, participants reported elevated anxiety, likely correlated to an increased frequency of distractions during reading. The texts that were associated with higher anxiety were associated with *lower* prediction magnitude for that text. This type of text specific cue relates to high relative accuracy. For example, if a student is reading a text called "Zoo Habitats" and they experienced several disruptions in their comprehension, they might correctly believe they will do worse on this test compared to the text called "Women in the Workplace", during which they experienced fewer disruptions. The current study conceptually replicated this effect, but there were discrepancies. The results from the current study show only absolute accuracy was affected, with participants showing lower overconfidence with higher stress. So how can these results, an increase in relative versus absolute accuracy, be reconciled? To answer this, one must consider the type of stress that the participants were experiencing. In the Meisner & Maki (2007) study, this stress was directly related to the reading material, as they found stress fluctuated with each text. The current study was not designed to produce differences in stress at the level of the text. Rather, we induced participants' stress before the main task, so presumably their stress was more uniform and did not necessarily fluctuate with each text. In other words, after completing the TSST, a student might experience high levels of disruption during both "Zoo Habitats" and "Women in the Workplace", but because their stress and disruptions are both extrinsic to the material, they cannot aptly tell which text they will do better on. More generally, when stress is intrinsic to the material, it may act as a cue to help predict which texts might be best understood. When stress is more general, it acts as an anchor, decreasing average prediction magnitude without discriminating between which information is comprehended best. With this explanation, it seems clear that in the current study it would be unlikely that relative accuracy would improve due to stress; however, it is a bit surprising that Meisner and Maki did not find a correlation between test anxiety and absolute accuracy. They found that predictions about performance were much lower in those with test anxiety, however, anxious test-takers also had lower multiple-choice scores on average. Students with test anxiety tend to score more poorly on exams due to poor attentional control (Cassady & Johnson, 2002; Wei et al., 2022). Therefore, despite the significantly lower prediction magnitude, those with test anxiety were about equal in their absolute accuracy compared to the control group (Miesner & Maki, 2007). In the current study, those in the stress condition did not score significantly different on the multiple-choice test from the control condition, indicating that stress did not impact their performance negatively; it is likely that if those in the stress condition performed more poorly on the multiple-choice questions, their absolutely accuracy would be equivalent to those in the control condition, as was the case in the Miesner and Maki (2007) study.

Though the current data conceptually replicates the findings of Meisner and Maki, the other heavily referenced study conducted by Reyes and colleagues (2018) was not supported by the current data, as Reyes and colleagues found stress impaired relative accuracy. As mentioned in the introduction, the authors were not completely transparent in some of their methods, and potentially experimenter biases may explain why the effect is opposite from the current study. Yet, if we assume that this prior study's methods are sound, there may be valid explanations for why they found worse metacognitive monitoring. Reyes used a perceptual task, not the reading tasks used in the Meisner and Maki and current studies. In this perceptual task, each stimulus was presented for 200 ms each. The Attentional Control Theory explains that individuals can compensate for poorer attentional control by increasing the time to complete the task (Eyseneck et al., 2007). It seems plausible that when a task is faster and more automatic, stressed participants may not have the cognitive resources to both complete the task and make accurate judgments on their performance. However, when participants can control the pace of the task, they can use the distractions from stress as a cue to make improved predictions. Therefore, if there was a time restriction during reading, perhaps the results of the current study might have revealed decreased metacognitive accuracy instead. Additionally, research suggests metacognition is domain specific (Morales et al., 2018; Scott & Berman, 2013; although see Bellon et al., 2020 for counter evidence). Specifically, Morales and colleagues (2018) found differences in accuracy between metamemory and meta-perception. It could be that stress improves one and impairs the other, regardless of the speed of the task.

The Attentional Control theory and Levels-of-Disruption theory in conjunction with each other may well explain the results of the current study, but are there other explanations? Arousal (Circia et al., 2021; Kemeny, 2003; Yerkes & Dodson, 1908), optimism (Golke et al., 2020), and familiarity with stress may alternatively explain the results. Participants in our control condition played a neutral computer game, while the stress condition experienced a situation (stressful interview and math task) that likely increased arousal. Stress often causes increased arousal due to the release of the hormone cortisol, along with neurotransmitters norepinephrine and epinephrine (Kemeny, 2003). Stress and arousal are distinct, as arousal has neither positive nor negative valance; rather, it may be indicative of intensity of experiences, with both physiological and psychological components (Shapiro et al., 2013). Physiological arousal refers to alertness or activation, and can be measured with physiological measures such as skin conductance or heart rate. Psychological arousal refers to self-reported awakeness or excitement (Singh & Hitchon, 1989). While arousal was not a measured construct in the current study, it seems plausible that arousal would increase in the stress condition, thereby potentially leading to improved metacomprehension accuracy compared to the control condition. This is explained by the Yerkes-Dodson principle, suggesting that there is an optimal level of arousal, with too much or too little arousal impairing performance, while a moderate level of arousal will improve performance (Yerkes & Dodson, 1908). However, although this principle has been demonstrated in both rats (Salehi et al., 2010) and humans (Circia et al., 2021), it has surprisingly limited evidence (Tsai et al., 2019). Moreover, one prior study assessed mood and metamemory, and found that of arousal did not relate to metacognitive judgments or accuracy (Prinz et al., 2017). Therefore, arousal may not be the best explanation for the improved metacognitive monitoring.

Optimism might be a better candidate for explaining the findings because it has been shown to positively correlate with overconfident judgments in some instances (Golke et al., 2020, although see de Bruin et al., 2017 for counterevidence). Specifically, stress may decrease optimism; optimism could act as a mediator, in turn decreasing overconfidence. There is some suggestion that stress negatively impacts optimism (Peterson, 2000), but stress more often is considered a protective factor against negative stress evaluations (Nes & Segerstrom, 2006); whether optimism would decrease after one session of the TSST would need to be studied at greater length.

Finally, students are often stressed throughout the semester, so there could be a practice effect/familiarity effect in which they learn to make accurate metacognitive judgments under stressful conditions. As mentioned, students experience high levels of stress during college (American College Health Association, 2019), which may peak around exams (Garett et al., 2017), so perhaps students learn to adjust judgments based on their experience with stressful exams. Alternatively, students might become habituated to the exam stress because they most frequently judge their memory and comprehension under stressful conditions. If this were the case, it may benefit students to practice metacognitive judgments in both high and low stress situations.

State Versus Trait Anxiety

There are some challenges associated with explaining the unique effects of state and trait anxiety given the current data. How can it be that state anxiety was the better predictor of prediction magnitude, and only trait anxiety influenced bias scores, given that bias scores are derived in part from prediction magnitude? Differences in multiple-choice accuracy cannot explain this effect, as neither trait nor state anxiety were statistically related to multiple-choice accuracy, the other component of bias score. First, it may be worth considering the marginal differences. Specifically, there was a marginal effect of state anxiety on bias scores. Because a medium effect was used to calculate power, it is possible that smaller effects were obscured. In other words, it is possible that absolute accuracy *is* related to both measures of stress.

Alternatively, a recent study found a similar pattern, revealing that trait and state anxiety were correlated with prediction magnitude, but only trait anxiety predicted absolute accuracy (Silaj et al., 2021), similar to what was found in the current study. This suggests that perhaps this pattern, that only trait anxiety is related to absolute accuracy, *is* logical. Students might be using how they feel immediately before a quiz to make their judgments, which is why state anxiety relates to prediction magnitude. However, it might be the case that adjustments that are made to prediction magnitude based on state anxiety are not enough to change their absolute accuracy. And both trait anxiety and absolute accuracy are stable over time, which might explain why trait anxiety relates to absolute accuracy, but why state anxiety does *not* predict absolute accuracy.

As an additional note, trait and state anxiety cannot be entirely separated. One study in particular found a very strong relationship between trait and state worry ($\beta = .51$, $p = .001$; Hong and Karstensson, 2002). This is corroborated by our own data, which shows there is a strong relationship between people's state and trait anxieties ($r = .57$). It is possible that the close relationship makes it particularly challenging to parse apart the effects, especially since there was only a modest increase in state anxiety due to the TSST. Finally, the possibility of statistical error must be considered. Because of the number of hypotheses and a multitude of significance tests, there is an increased risk of type 1 error. Running this number of statistical tests is justified because they test theoretically distinct concepts, but replicating this study would provide more insight on whether any of the found effects are due to error. Generally, it seems that a greater amount of trait and state anxiety leads to lower prediction magnitude and less overconfidence. But given the nature of the several marginal, non-significant results, it is important to interpret these findings cautiously. On the other hand, the power analysis conducted was designed to find medium effects, and thus small effect sizes are likely obscured. With a larger sample size, these effects could be better detected. While the results of this study are both exciting and novel, more evidence is required to fully understand the nature of this relationship.

State Based Cues

The literature available on state-based cues is sparse, and there is no exact definition on what constitutes a state-based cue. While there are several studies that assess the effect of states on metacognition, only one study labels these cues as state-based factors and, unfortunately, this study does not formally define a state-based factor (Hourihan & Benjamin, 2014). If the Levels-of-Disruption Theory is used to explain the results, it could be argued that stress is *not* a state-based cue. Rather, stress creates an environment where a person is more likely to experience disruptions, which Koriat (1997) would categorize as mnemonic cues, cues based on one's experience with and perceptions of the material. Perhaps the other state-based cues that are associated with differences in metacognitive monitoring (mood, time of day, alcohol, caffeine) all are similar, in that they create different experiences which influence mnemonic cues. For state-based cues to be considered distinct from mnemonic cues, the mechanism in which they influence judgments should also be distinct from mnemonic cues.

While the mechanism for state-based cues is currently unknown, it is possible that different states lead participants to interpret the same cues and experiences differently. If this is the mechanism, then state-based cues would be distinct from mnemonic cues. For example, mood was described as changing the level at which someone processes information (Prinz et al., 2018). If participants were to have the same number of distractions when they are happy and studying, compared to when they feel neutral while studying, those who feel happy may judge that they understand the readings better, despite having access to the same cues. Broadly, the current definition of cues that impact metacognitive judgments is limited to cues directly related to the material in some way. Many other factors potentially contribute to judgments or decisions about learning. One's state (i.e. stress level, arousal, time of day, caffeination status) may in part alter how they judge their ability to learn or succeed on an upcoming exam in ways that were not captured in the simple question "How many questions out of eight do you think you will get correct". Currently, there is not enough known about state-based cues to decide whether they are influencing the cues available to participants (therefore falling under the cues described by Koriat), or if they can be called cues in their own right. For state-based cues to be considered unique from Koriat's cues, research must focus on the mechanism. For instance, researchers might induce different states, then measure if the cues available to the participants are different in quality or quantity. If one's state does not change cue availability but still influences monitoring judgments, then state-based cues surely deserve to be considered distinct from the cues described in the Cue Utilization Hypothesis.

Gender Analysis

The gender analysis may be informative, but the readers should be reminded that due to the large imbalance in men and women in the current sample, these results should be interpreted with caution. There were no gender differences in prediction magnitude, however, men in the control condition performed slightly worse on the multiple-choice test compared to men in the stress condition or women. This likely explains the marginal gender difference in bias scores, as no differences were found for prediction magnitude. It is possible that men on average do better on tests of comprehension when stressed. This is supported by at least some of the research showing that men’s working memory performance improves slightly under stress (Lin et al., 2020; Schoofs et al., 2013), which might lead to better performance on the comprehension task that was used. If it is assumed that this is not a statistical artifact, it the intervention still has little effect on metacomprehension. For both men and women, there seem to be no differences in prediction judgments, whether in the stress or control condition. It should be emphasized that any improvements in comprehension or metacomprehension are at the object level rather than the meta-level. However, it does not explain why men scored poorly on the comprehension test in the control condition compared to women. For this effect to be valid, men must be slightly worse on average at this multiple-choice test, and when stressed, their average matches the average score of women. However, the simpler and therefore more likely explanation is that this was an error due to the small sample of men. Again, men in the control group had the fewest number of participants, so it seems likely that this low performance is due to chance rather than true differences between genders.

Going into the gender analysis, it was suggested that there may be a difference in outcomes, but no direction was predicted. This is because the research findings on gender, stress, and cognition are inconsistent. For example, some studies show that working memory performance decreases in response to stress more in women than men (Schoofs et al., 2013) while other studies show that women's working memory performance increases under stress (Zandara et al., 2016). One challenge with this research is that so many variables may impact these results; for instance, while both these studies used the TSST to induce stress, they used different working memory measures. In addition to the stress protocol and type of working memory task, individual differences such as current stress level and coping mechanisms might contribute to the inconsistencies in the data. Generally, while a meta-analysis shows that men's working memory is on average more impaired under stress (Shields et al., 2016), there is also a bias to exclude women in stress studies, even in more recent studies (Lin et al., 2020). Gender is not commonly analyzed in metacognitive research. The most common finding is that women tend to be more underconfident than men (Ackerman et al., 2010; Chiu & Klaasen, 2010; Sharma & Bewes, 2011), but an effect of gender is not always found (Gutierrez, 2017). Based on these preliminary findings, it seems necessary to include gender as a factor in this analysis when replicating this study.

While the current study did not reveal gender differences, gender is still relevant to consider due to potential gender differences in anxiety, especially in an academic context. For example, a recent study found that female high school students report higher levels of general anxiety, test anxiety, and science anxiety, despite there not being a difference in performance outcomes (Megreyal et al., 2021). And while high overconfidence is generally unfavorable, a small amount of overconfidence may be beneficial, as it allows for some students to enthusiastically engage with the material without giving up (Bi et al., 2016). For example, as mentioned earlier, optimism and overconfidence are correlated, but optimism is also positively correlated with academic performance (Icekson et al., 2020; Popa-Velea et al., 2021). Underconfidence can lead to giving up, and disengaging from the material. Many have explored the gender gap in STEM careers, and this higher anxiety in the absence of worse performance, indicating more underconfident metacognitive judgments, might have a small but significant role in the problem (Megreyal et al., 2021).

A Disruptive Unplanned Analysis

In order to assist the readers with the interpretation of the results, it was suggested to the author to separate the correlation matrix (Table 3) by condition (see Table 5). While this analysis was unplanned, it was not meant to add new information, only to clarify and support the information already written. Instead, separating the correlation matrix by condition led to an observation partially inconsistent with the interpretation of the data. It was difficult to decide whether or not to include this section, as this was an unplanned analysis; yet, this author prefers to be completely transparent, and did not feel like this dissertation could be defended in good faith without including all of the information, even though this new information is not fully explained by the discussion. It does not mean that the information in the discussion is incorrect; the full story is likely either more nuanced than the discussion suggests, or possibly only true for the control condition.

Table 5

Correlation Matrix for Metacognitive and Stress Variables, by Condition

Stress Condition

	1. Prediction Magnitude	2. Bias Score	3. Gamma Correlation	4. Multiple-Choice Accuracy	5. STAI-1	6. STAI-2
1. Prediction magnitude	-	-	-	-	-	-
2. Bias score	.54**	-				
3. Gamma correlation	.02	-.02	-			
4. Multiple-choice accuracy	.49**	-.47**	<.001	-		
5. STAI-1	-.14	-.25*	.06	.11	-	
6. STAI-2	-.03	.001	.03	-.03	.58**	-
7. Trait anxiety	-.04	-.26*	-.07	.22	.47**	.22

Control Condition

	1. Prediction Magnitude	2. Bias Score	3. Gamma Correlation	4. Multiple-Choice Accuracy	5. STAI-1	6. STAI-2
1. Prediction magnitude	-	-	-	-	-	-
2. Bias score	.69**	-				
3. Gamma correlation	.09	-.01	-			
4. Multiple-choice accuracy	.22	-.55**	.11	-		
5. STAI-1	-.39**	-.38*	.06	.06	-	
6. STAI-2	-.35*	-.31*	-.01	.01	.68**	-
7. Trait anxiety	-.29*	-.34*	.02	.12	.64**	.46**

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

As a summary, when the correlation matrix was run separately by condition, it was observed that in the stress condition, there was not a correlation between prediction magnitude and trait or state-2 anxiety, nor was there a relationship between bias scores and state-2 anxiety. All of these correlations were significant in the aggregate, and these relationships were each driven by the significant correlations in the control condition (Table 5). This was confirmed by running regressions independently for condition. In the stress condition, neither state-2 nor trait anxiety related to prediction magnitude [R^2 = .002, F(2, 60) = .07, p = .94; see Table 6], and there was a non-significant regression for state-2 and trait anxiety on bias scores [R^2 = .07, F(2, 60) = 2.25, p = .11; see Table 6], but in the expected direction. The control condition had significant regressions for state-2 and trait anxiety on both prediction magnitude [R^2 = .15, F(2, 66) = 5.61, p = .006; see Table 6] and bias scores [R^2 = .14, F(2, 66) = 5.50, p = .006; see Table 6]. It is recognized that correlations, regressions, and p-values cannot be compared directly. However, this author is confident that in addition to comparing significant to non-significant relationships, that looking at such large differences in effect sizes builds evidence that these effects are present for the control but not stress condition.

Table 6

Regression Coefficients for Stress Variables on Prediction Magnitude and Bias Scores, Separated by Condition

Stress		**B (SE)**	***p*-value**
	Prediction Magnitude		
	Trait Anxiety	-.006 (.02)	.77
	State-2	-.004 (.03)	.89
	Bias Scores		
	Trait Anxiety	-.04 (.02)	.03
	State-2	-.01 (.03)	.64
Control			
	Prediction Magnitude		
	Trait Anxiety	-.03 (.02)	.22
	State-2	-.06 (.02)	.03
	Bias Scores		
	Trait Anxiety	-.05 (.03)	.06
	State-2	-.05 (.03)	.13

The most substantial discrepancy revealed by the analysis is that state-2 anxiety relates to prediction magnitude in the control condition, but not in the stress condition. The reason this is so disruptive to the central thesis of this paper is due to the implication that when stress is actively induced in participants, it is not related to prediction magnitude, so how can stress be considered a cue for metacognitive judgements? There are several explanations, though all of these explanations are speculative. This is the first instance of stress being manipulated in the context of metacognitive judgments, so there are not necessarily references to support or dispute these findings. The three explanations are that there are null effects, that there are non-linear effects of stress, or that the scale used to measure stress was not sensitive enough to parse out effects.

The first explanation is the most conservative explanation; there were technically no differences in conditions for any of the variables, so perhaps, the stress manipulation had no effects on metacognitive judgments or accuracy. Stress did increase in the stress condition, yet the lack of differences in prediction magnitude and bias scores between groups, as well as the utter lack of relationship between any type of stress and prediction magnitude in the stress condition does provide evidence that stressing the participants did not lead to differences in metacognitive ability. Yet, this idea is not consistent with other evidence, which is that both types of stress impacted metacognitive judgments in the control condition. Trait and state-2 anxiety correlate to prediction magnitude in the control condition, with both with medium effect sizes. Trait anxiety also relates to bias scores in the control condition. It seems counterintuitive that the effects of state-2 and trait anxiety disappear when stress is induced; indeed, this change between conditions also suggests that stress *is* affecting metacognitive judgments, just not in the way that was assumed. If induced stressed truly did not change the cognitive experience of the participants, participants in the stress condition would show a similar pattern between the trait anxiety and metacognitive variables. Additionally, if stress did not relate to metacognitive variables, then we would not see this pattern of relationships at all in the control condition. Finally, other evidence suggests that stress does impact conditions. For Hypothesis 1(a), which predicted that condition would affect prediction magnitude, there was a marginal difference where prediction magnitude was lower in the stress condition. While marginal, the *p*-value was .0501, almost directly on the threshold of what is considered significant. This marginal effect, especially in conjunction with the evidence that those in the stress condition are showing a very different relationship between state-2 stress and prediction magnitude, indicate that the stress manipulation does seem to change metacognitive judgments in a subtle way.

This leads to the second rationale, that this induced stress does affect metacognitive judgments; the reason a correlation is not observed is because the increase in stress is not proportionate to the reduction in prediction magnitude. This rationale does require the interpretation of several marginal results, and thus is not as conservative as the first rationale. To explain, participants are not adjusting their predictions from their anchor in a linear way. As a reminder, it is proposed that bias scores tend to be stable due to anchors (Kwon & Linderholm, 2014; Linderholm et al., 2008; Zhao & Linderholm, 2008). Individuals seem to base their metacognitive judgments on information like how they tend to do on similar tasks (Foster et al., 2017; Kwon & Linderholm, 2014; Linderholm et al., 2008), or perhaps trait anxiety, as was explored in the current study. As was discussed, a participant's trait anxiety, or how anxious they tend to feel, affects how over or underconfident they tend to be. This is supported by the correlation between trait anxiety and bias scores in the aggregated data (r = -.29). When the aggregated data is separated by conditions, the control condition demonstrates this effect (r = -

.34). This is further supported by the regression run for the control condition; when trait and state-2 anxiety are included in the model, trait anxiety is a marginally significant predictor of bias scores (p = .06), and state-2 anxiety is not uniquely significant. Generally, this suggests those in the control condition may have used trait anxiety as an anchor. This idea is more ambiguous in the stress condition. The regression, which includes both trait and state-2 anxiety, is not significant, showing no relationship between the stress variables and bias scores in the stress condition (p = .11). While the full model is not significant, it shows a similar pattern as the control condition, with state-2 anxiety showing virtually no relationship, but with trait anxiety being significant in this model (p = .03). The pattern of the results seems quite odd: trait anxiety seems to relate to bias scores in both conditions, state anxiety is the best predictor of prediction magnitude in the control condition, and no stress measure relates to prediction magnitude in the stress condition. All of these effects can be explained succinctly with the idea that participants are using an anchor to make predictions, but when they experience the stress manipulation, the adjustment from the anchor is not proportionate to the stress that is reported.

As participants likely use an anchor to make prediction judgments, when subjected to some irregular stressor (the TSST), they seemed to know they should account for this scenario, but each participant may have adjusted differently. In the control condition, it seems feasible that trait anxiety was used as an anchor, considering there is a medium strength correlation between both trait anxiety and prediction judgments, and trait anxiety and bias score. Participants (potentially unconsciously) seem to consider that because they tend to have a certain level of anxiety, they tend to perform a certain way. This also explains why state-2 anxiety accounts for more variance than trait anxiety for prediction magnitude in the control condition. They may take their current state into consideration when making judgments. But, due to the limited range of judgments, and that people tend to under-adjust from their anchor (Tversky & Kahneman, 1974), the changes in prediction magnitude due to state anxiety are not enough to change their average bias scores. This potentially explains why bias scores tend to be consistent over time. In the stress condition, it seems likely that they use the same anchors, but that the stress manipulation leads participants to adjust from their anchors differently compared to the control condition. Participants likely have the metacognitive knowledge, or understanding of how their mind functions (Flavell, 1979), and that the consequences of stress can change their cognitive performance due to past experiences. Again, this may or may not be conscious. Due to this knowledge, experiencing the stress manipulation would motivate participants to deflate their prediction judgments; in other words, they are adjusting further from the anchor than the control condition. This is evidenced by the marginally significant difference (p = .0501) in prediction magnitude between the stress and control condition. However, for there to be a significant correlation between state-2 stress and prediction magnitude, participants with the highest stress should adjust the most from their anchor. Thus, it may be that the increase in stress was not consistent with the amount adjusted from the anchor. Perhaps, some people did not adjust at all, and some people over-adjusted; however, the amount that they adjusted did not relate to how much stress they reported due to the TSST. As an example, envision two people. Participant A normally would predict that they would score 6 out of 8 on a multiple-choice test, but because they are feeling more stressed due to the TSST, they state that they will probably score 5 out of 8. Participant B might adjust the same amount in response to the TSST, which explains why on average, the stress condition has lower average prediction judgments. However, say Participant B had a much larger increase in stress due to the TSST. If both participants adjusted from the anchor the same amount, a correlation between stress and prediction magnitude would not emerge. It would only emerge if those who reported higher stress adjusted their predictions to a greater extent. This scenario illustrates that participants might still be using state stress as a cue by decreasing prediction magnitude, but this would not lead to a linear relationship between stress and prediction magnitude. Still, it is acknowledged that this interpretation is presented as speculation and requires more data to support it.

Another variable that appears to play a large role, but was hereto all but ignored, is state-1 anxiety. State-1 anxiety was never meant to be analyzed outside of the context of a baseline. However, in the correlation matrix for each condition, it had a stronger relationship with prediction magnitude than state-2 or trait anxiety. Some of these correlations are similar in strength, and so one cannot truly state that state-1 anxiety had a significantly larger relationship than state-2 or trait anxiety, yet it does demonstrate that other factors may be influencing prediction judgments. Perhaps, participants did not use trait anxiety or state-2 anxiety specifically as an anchor. Rather, state-1 anxiety may be the anchor that participants were more likely to use. It may best capture the stress that a person is experiencing on the day they are participating in this study. For state-2, either they had their state anxiety inflated by the manipulation, or they had a calm but relatively boring task in the control, so in either condition, their state-2 anxiety is not necessarily an accurate indicator of how a person is generally feeling that day. It seems intuitive that someone’s real life stressors (college course work, job stress, social relationships, etc.) would play a more impactful role in a person’s metacognitive judgments, as these stressors hold deeper meaning to the participants. And while the TSST is validated to increase psychological and physiological stress (Birkett, 2011), supported by the increase in the STAI in the current study, this manipulation might not feel as meaningful to participants as the other stressors they are experiencing, and therefore have less of an impact on their metacognitive judgments.

Returning to the theme of a non-proportionate relationships, a final explanation might be that the STAI is not capturing nuances of the increase of stress for the current sample. The STAI is the best stress self-report scale that could have been used, as it is often the subjective stress measure used in studies that invoke the TSST protocol (Birkett, 2011; Human et al., 2018). While the STAI is validated for both healthy and clinical populations, it should be noted that the upper end of the scale represents a quite extreme level of stress, most of the participants scored in the low stress range, even after the stress manipulation. There are two ways in which this measure could have affected the current results. First, even though there was an increase in stress, average stress levels were considered low in both conditions; perhaps the change in stress was not large enough to influence their cognitive performance. However, this cannot explain all of the results. First, the average stress before and after the TSST is similar to Birkett's (2011) TSST protocol; while there was not a biological measure included, past protocols demonstrate increases in biological measures of stress due to the TSST (Allen et al., 2014; Birkett, 2011). Additionally, state-2 anxiety was a correlate of prediction magnitude in the control condition, so if the problem was only with the stress measure, then it is odd to observe a correlation here. A more convincing explanation is that the scale was not sensitive enough to measure the increase in stress that was experienced. As it was designed to measure extremes, perhaps it is not detecting small changes accurately. For example, a person might feel greatly stressed by the TSST experience, but due to low sensitivity of the STAI, this feeling of stress is not reflected in their state-2 anxiety. Therefore, a participant might be feeling quite distraught due to this manipulation, which is reflected in their predictions, but not necessarily their state-2 anxiety.

This illustrates the possibility that stress is acting as a cue, but is not reflected by the current data. A final possibility is that maybe there was an expectation effect. Because the STAI was administered directly before and after the TSST, maybe the numbers were inflated due to the expectation that participants *should* feel more stress, but that their stress levels were not actually different. Again, this is not likely because this method was validated with biological measures of stress, but it is certainly possible.

To summarize, this author was quite surprised to discover that the stress condition did not drive the effects of state and trait anxiety on metacognitive variables found for the current study. But this opens the door to new questions about the ways that stress affects judgments of cognition. There are many avenues to explore to parse out these effects, such as assessing how different types of stress affect different types of metacognitive tasks. These new insights may lead to exciting future replications, particularly using a within-subjects design. In the current study, it is impossible to observe how much participants are potentially adjusting from their usual judgements, and so much of the discussion surrounding anchors is based in speculation. Using a within-subjects design, baseline metacognitive judgments and accuracy will be recorded, so researchers would be able to observe the amount that people adjust from their norm after a stressor such as the TSST. This design could provide additional evidence for anchoring as a mechanism. This would allow for a more concrete explanation for how acute stress affects judgments, and whether stress acts as a metacognitive cue.

Limitations

A general concern for this study is the stress reactivity of the participants due to the Covid-19 global pandemic. This is because students report feeling very high levels of stress after the pandemic was declared, with about 88% reporting moderate or severe stress (Lee et al., 2021). This could be exacerbated by the use of masks in this study, reminding participants that being in the presence of others could be a risk to the individuals health and well-being. Another concern would be high rates of burnout and undiagnosed depression and anxiety in this sample. This can affect how participants react to stress, with either a response that is inappropriately small, or inappropriately large (Roth et al., 2012). For example, at least one participant shed tears during the TSST protocol due to overwhelming stress. At this point, research assistants reminded her that she could leave the study at any time, but she expressed a desire to continue. She did receive a special debriefing from me, and I assured she knew appropriate stress relieving techniques. In any case, due to the stresses of the global pandemic, I feel that this data collection occurred in an environment that is unique to this time in history. Additionally, something not examined in this study was the effect of chronically high stress and psychological disorders, which for many was quite high during this stage of the pandemic. Chronic stress may be tapped by the measure of trait anxiety, but they are not completely analogous. Chronic stress has a greater impact on cognitive functions than acute stress; specifically, chronic stress can impact memory and attention, having potential consequences for both comprehension and metacomprehension (Wolff et al., 2020; Sandi, 2013).

There also are clear differences between the lab context of the current study and real-world context that might have influenced the results. Motivation might be a huge factor, as there are no rewards or consequences for the performance for the TSST or multiple-choice test for the current study. That may have reduced effort, or lower anxiety knowing that their performance did not affect their college grade point average. A recent study (Sijas et al., 2021) looked at trait anxiety in a classroom setting, and found that trait anxiety lead to greater underconfidence, showing similar results to the current study. However, this effect was only shown for repeated quizzes and not exams. Thus, it is likely that stress leads to less overconfidence in at least some real-world contexts, though more research is needed. It is even less clear whether this would apply to non-academic contexts, or higher stress contexts. For instance, a person who recently was diagnosed with a life altering condition may read medical related information to learn more about their condition. Would their metacognitive accuracy of that text still be improved, even though the stressor has a much greater consequence? In this scenario, metacognition accuracy can impact health, and more basic and applied research is necessary for understanding such phenomenon.

Another consideration is the type of stressor that was used, especially considering that acute social stress might affect judgments differently than stress from the pressure of a big exam. It is possible but unlikely that a student has a stressful interview immediately before an exam. Because this protocol specifically invokes acute social stress, there are other analogous scenarios. Between conflicts within platonic, romantic, roommate, or family relationships, and class presentations that might occur on the same day, there are many reasons that a student may be experiencing a form of social stress while studying or before an exam. Future studies may assess the difference between stress intrinsic or extrinsic to the cognitive event. In this case, intrinsic stress refers to stress related to the cognitive task, and extrinsic stress referring to stress unrelated to the cognitive task; for example, comparing differences between social stress (extrinsic) and test anxiety (intrinsic). One interesting study might expand on this current study, comparing the TSST as an extrinsic way to increase stress, to intrinsic methods, by telling the participants, for example, that an expert panel of judges will be assessing essays written about the articles they read.

Implications

Due to the novel nature of this study, the results contribute to both our understanding of stress and state-based cues on metacognition, as well as useful knowledge for current college students. Considering the prevalence of stress on college campuses, this study is relevant for most students. Perhaps it may be relieving to anxious students to learn they are accurate in their metacognitive judgments. However, this does not mean that students should cultivate greater stress levels for the metacognitive benefit, as this can negatively impact their performance in different ways. Rather, it is more insightful to look toward those who are not anxious, and suggest that they adjust their judgments to accommodate their mood. Another interesting avenue of research is to assess students with high anxiety and underconfidence in their work. This can open up research questions such as whether anxiety reduction techniques would increase prediction magnitude and overconfidence levels. Additionally, future research should assess the tradeoffs of anxiety. Is the metacognitive benefit enough to counterbalance the degradation in performance due to anxiety? If so, at what point is anxiety beneficial, and at what point is it impairing? In general, it is important that students know that chronically high stress is not normal. We should teach students when stress levels are acceptable, and when stress becomes abnormal or pathological, which is important not only for academic performance, but also for student health and wellness.

Further, this article explores state-based cues, which have received very little attention in the literature, and can potentially breed a wealth of research. For example, the current study found that stress may act as a state-based cue, or alternatively, change the cues available for the participants, therefore acting through mnemonic cues. Regardless, state-based cues deserve more attention in the literature. Future research may confirm and expand upon the few state-based cues that have been identified and further understand their mechanisms, or identify new state-based cues that might influence metacomprehension.

In a more general sense, future studies can explore a variety of real-world scenarios and differing populations that might experience comparatively high rates of stress, and how that may impact their metacognitive accuracy and study habits. For example, the significance of an exam or perceived difficulty of a class are both scenarios that may intensify the level of stress that a student might experience. A longitudinal study in which researchers assess study techniques, metacognitive judgments, and performance can help researchers explain how stress surrounding an exam can influence study behaviors. Furthermore, because stress seems to influence judgments, a logical next step would be to assess metacognitive judgements in marginalized populations that tend to experience higher levels of stress. For example, in stem classes, female students tend to have more underconfident predictions compared to their male counterparts, which may in part contribute to lower participation in stem fields (Megeryal et al., 2021). Additionally, some research has shown some marginalized populations experience greater markers of distress in academic settings, which include Asian and Biracial ethnicities, as well as those who are disabled, immigrants, and those who identify as a sexual minority. More generally, distress is higher when reported discrimination is higher (Nurius et al., 2023). Those who are experiencing greater distress, especially due to discrimination, may experience a tax on working memory. This may in turn affect their metacognitive abilities. In addition to systematic inequalities, it is possible that due to higher average stress levels for marginalized groups, that vulnerable groups may have more underconfident predictions, which may lead to lower engagement in the material. If stress explains an additional contributor to academic inequalities for marginalized students, perhaps additional metacognitive training or support can help to assure these students feel supported, and have the confidence in themselves to succeed in a stressful collegiate environment.

References

Allen, A. P., Kennedy, P. J., Cryan, J. F. Dinan, T. G., & Clarke, G. (2014). Biological and psychological markers of stress in humans: Focus on the Trier Social Stress Test. *Neuroscience and Biobehavioral Reviews, 38*, 94-124. http://dx.doi.org/10.1016/j.neubiorev.2013.11.005

American College Health Association. (2019). *American College Health Association-National College Health Assessment II: Undergraduate Student Executive Summary.* Silver Spring, MD: American College Health Association.

Anderson, M. C. M., & Thiede, K. W. (2008). Why do delayed summaries improve metacomprehension accuracy? *Acta Pyschologica, 128,* 110-118. doi: 10.1016/j.actpsy.2007.10.006

Baumeister, R. F. (1984) Choking under pressure: Self-consciousness and paradoxical effects on incentives on skillful performance. *Journal of Personality and Social Psychology, 46*(3), 610–620. http://dx.doi.org.collegeofidaho.idm.oclc.org/10.1037/0022-3514.46.3.610

Beilock, S. L., & Carr, T. H. (2005). When high-powered people fail. *Psychological Science, 16,* 101–105. doi:10.1111/j.0956-7976.2005 .00789.x

Bellon, E., Fias, W., & de Smedt, B. (2020) Metacognition across domains: Is the association between arithmetic and metacognitive monitoring domain-specific? *PLoS ONE, 15*(3): e0229932. https://doi.org/10.1371/journal.pone.0229932

Bi, Y., Dang, Q., Li, S., Guo, J., & Zhang, B. (2016). The Effect of Overconfidence on Persistent Behavior: The Mediation Effect of “I Think I Can Do It” Rather Than “I’m Attracted To It”. *Psychological Reports, 118*(1), 138-153. doi: 10.1177/0033294115627524

Birkett, M.A. (2011). The Trier Social Stress Test Protocol for Inducing Psychological Stress. *Journal of Visualized Experiments, 56,* e3238. doi: 10.3791/3238

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: beliefs, techniques, and illusions. *Annual Review of Psychology, 64,* 417–444. doi: 10.1146/annurev-psych113011-143823

Board, T. C. (1997). 10 real SATs. New York: College Entrance Examination Board.

Brouwer, A.-M., & Hogervorst, M. A. (2014). A new paradigm to induce mental stress: the Sing a-Song Stress Test (SSST). *Frontiers in neuroscience, 8*(224), 1-8. doi: 10.3389/fnins.2014.00224

de Bruin, A. B. H., Kok, E. M., Lobbestael, J., & de Grip, A. (2017). The impact of an online tool for monitoring and regulating learning at university: overconfidence, learning strategy, and personality. *Metacognition and Learning, 12,* 21-43. doi: I 10.1007/s11409-016-9159-5

Calvo, M. G., & Castillo, M. D. (1995). Phonological coding in reading comprehension: The importance of individual differences. *European Journal of Cognitive Psychology, 7,* 365–382.

Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology, 27,* 270–295. doi:10.1006/ceps.2001.1094

Circia, L. F., Suárez-Pinilla, M., Williams, A. G., Jagannathan, S. R., Sanabria, D., & Bekinschtein, T. A. (2021). Different underlying mechanisms for high and low arousal in probabilistic learning in humans. *Cortex, 143,* 180-194. https://doi.org/10.1016/j.cortex.2021.07.002

Dunlosky, J., Hertzog, C., Kennedy, M. R. T., & Thiede, K. W. (2005). The self-monitoring approach for effective learning. *Cognitive Technology, 10*(1), 4-11.

Dunlosky, J., & Lipko, A. R. (2007). Metacomprehension: a brief history and how to improve its accuracy. *Current Directions in Psychological Science, 16(4)*, 228-223.

Dunlosky, J., & Rawson, K. A. (2005). Why does rereading improve metacomprehension accuracy? Evaluating the Levels-of-Disruption Hypothesis for the rereading effect. Discourse Processes, 40(1), 37–55. https://doi.org/10.1207/s15326950dp4001_2

Efklides, A. (2014). How does metacognition contribute to the regulation of learning? An integrative approach. *Psihologijske teme, 23*(1), 1-30. https://hrcak.srce.hr/120492

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion, 7*(2), 336-353.

Ferreira, S. O. (2019). Emotional activation in human beings: procedures for experimental stress induction. *Psicologia USP, 30,* e180176. https://dx.doi.org/10.1590/0103-6564e20180176

Foster, N. L., Was, C. A., Dunlosky, J., & Isaacson, R. M. (2017). Even after thirteen class exams, students are still overconfident: The role of memory for past exam performance. *Metacognition and Learning, 12,* 1-19.

Fukaya, T. (2013). Explanation generation, not explanation expectancy, improves metacomprehension accuracy. *Metacognition Learning*, *8*, 1-18. doi: 10.1007/s11409-012-9093-0

Garett, R., Liu, S., & Young, S. D. (2017). A longitudinal analysis of stress among incoming college freshmen. *Journal of American College Health*, *65*(5), 331-338. https://doi.org/10.1080/07448481.2017.1312413

Griffin, T. D., Wiley, J., & Thiede, K. W. (2008). Individual differences, rereading, and self-explanation: Concurrent processing and cue validity as constraints on metacomprehension accuracy. *Memory & Cognition, 36(1),* 93-103. doi: 10.3758/MC.361.93

Gutierrez, A. P. (2017). Calibration Between Undergraduate Students' Prediction of and Actual Performance: The Role of Gender and Performance Attributions. *Journal of Experimental Education, 85*(3), 486-500. doi: 10.1080/00220973.2016.1180278

Hacker, D. J., Bol, L., Horgan, D. D., & Rakow, E. A. (2000). Test prediction and performance in a classroom context. *Journal of Educational Psychology*, *92(1)*, 160-170. doi: 10.1037//0022-0663.92.1.160

Hawn, S. E., Paul., L., Thomas, S., Miller, S., & Amstadter, A. B. (2015). Stress reactivity to an electronic version of the Trier Social Stress Test: a pilot study. *Frontiers in Psychology*, *6*, 724. doi: 10.3758/s13428-015-0565-4

Herbison, C.E., Henley, D., Marsh, J., Atkinson, H., Newnham, J.P., Matthews, S.G., Lye, S. J., & Pennell, C.E., (2016). Characterization and novel analyses of acute stress response patterns in a population-based cohort of young adults: influence of gender, smoking, and BMI. *Stress, 19*(2), 139e150. doi: 10.3109/10253890.2016.1146672

Hodge, M.A., Sutherland, R., Jeng, K., Bale, G., Batta, P., Cambridge, A., Detheridge, J., Drevensek, S., Edwards, L., Everett, M., Ganesalingam, K., Geier, P., Kass, C., Mathieson, S., McCabe, M., Micallef, K., Molomby, K., Ong, N., Pfeiffer, S., … Silove, N. (2019). Agreement between telehealth and face-to-face assessment of intellectual ability in children with specific learning disorder. *Journal of Telemedicine and Telecare, 25*(7), 421-437. doi: 10.1177/1357633X18776095

Hong, E., & Karstensson, L. (2002). Antecedents of state anxiety. *Contemporary Educational Psychology, 27,* 348-367. doi:10.1006/ceps.2001.1095

Hong, J-C., Hwang, M-Y., Tai, K-H., & Lin, P-H. (2019). Improving cognitive certitude with calibration mediated by cognitive anxiety, online learning self-efficacy and interest in learning Chinese pronunciation. *Educational Technology Research and Development, 67,* 596-615. https://doi.org/10.1007/s11423-018-9628-4

Hourihan, K. L., & Benjamin, A. S. (2014). State-based metacognition: How time of day affects the accuracy of metamemory. *Memory, 22*(5), 553-558. http://dx.doi.org/10.1080/09658211.2013.804091

Human, R., Henry, M., Jacobs, W. J., & Thomas, K. G. F. (2018). Elevated cortisol leaves working memory unaffected in both men and women. *Frontiers in Neuroscience, 12*(299). doi: 10.3389/fnhum.2018.00299

Icekson, T., Kaplan, O., & Slobodin, O. (2020). Does optimism predict academic performance? Exploring the moderating roles of conscientiousness and gender. *Studies in Higher Education, 45*(3), 635-647. https://doi.org/10.1080/03075079.2018.1564257

Jamieson, J. P., Nock, M. K., & Mendes, W. B. (2013). Improving acute stress responses: The power of reappraisal. *Current Directions in Psychological Science, 22*, 51–56.

Jamieson, J. P., Peters, B. J., Greenwood, E. J., & Altose, A. J. (2016). Reappraising stress arousal improves performance and reduces evaluation anxiety in classroom exam situations. *Social Psychology and Personality Science, 7*(6), 1-9. doi: 10.1177/1948550616644656

Katz, L., & Epstein, S. (1991). Constructive thinking and coping with laboratory-induced stress. *Journal of Personality and Social Psychology, 61*(5), 789-800. https://doi.org/10.1037/0022-3514.61.5.789

Kelemen, W. L., & Creeley, C. E. (2003). State-dependent memory effects using caffeine and placebo do not extend to metamemory. *The Journal of General Psychology, 130*(1), 70–86. doi: 10.1080/00221300309601276

Kelemen, W. L., Frost, P. J., & Weaver, C. A. (2000). Individual differences in metacognition: Evidence against a general metacognitive ability. *Memory & Cognition, 28*(1), 92-107.

Kemeny, M. E. (2003). The psychobiology of stress. *Current Directions in Psychological Science, 12*(4), 124–129.

Kim, J. J., & Diamond, D. M. (2002). The stressed hippocampus, synaptic plasticity and lost memories. *Nature Reviews Neuroscience, 3,* 453–462.

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,* 76-81. https://doi.org/10.1159/000119004

Kirschbaum, C., Wust, S., & Hellhammer, D. H. (1992). Consistent sex differences in cortisol responses to psychological stress. *Psychosomatic Medicine, 54*(6), 648–657.

Kintsch, W., & van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85*(5), 363-394. doi: 10.1037/0033- 295x.85.5.363

Koriat, A. (1993). How do we know that we know? The accessibility model of the feeling of knowing. *Psychology Review, 100*(4), 609-639. doi: 10.1037/0033-295X.100.4.609

Koriat, A. (1997). Monitoring one’s own knowledge during study: A cue-utilization approach to judgements of learning. *Journal of Experimental Psychology: General, 126*(4), 349-370. https://doi.org/10.1037/0096-3445.126.4.349

Kwon, H., & Linderholm, T. (2014). Effects of self-perception of reading skill on absolute accuracy of metacomprehension judgements. *Current Psychology, 33,* 73-88.

Lee, H. W., Lim, K. Y., & Grabowski, B. L. (2010). Improving self-regulation, learning strategy use, and achievement with metacognitive feedback. *Education Technology Research Development, 58,* 629-648. doi: 10.1007/s11423-010-9153-6

Lin, L., Leung, A. W. S., Wu, J., & Zhang, L. (2020). Individual differences under acute stress: Higher cortisol responders performs better on N-back task in young men. *International Journal of Psychophysiology, 150,* 20-28. https://doi.org/10.1016/j.ijpsycho.2020.01.006

Linderholm, T., & van den Broek, P. (2002). The effects of reading purpose and working memory capacity on the processing of expository text. *Journal of Educational Psychology, 94*(4), 778-784. doi: 10.1037//0022-0663.94.4.778

Linderholm, T., Zhao, Q., Therriault, D.J., & Cordell-McNulty, K. (2008). Metacomprehension effects situated within an anchoring and adjustment framework. *Metacognition Learning, 3*(3), 175-188. https://doi.org/10.1007/s11409-008-9025-1

Luethi, M., Meier, B., & Sandi, C. (2009). Stress effects on working memory, explicit memory, and implicit memory for neutral and emotional stimuli in healthy men. *Frontiers in Behavioral Neuroscience, 2*(5), 1-9. doi: 10.3389/neuro.08.005.2008

Lukasik, K. M., Waris, O., Soveri, A., Lehtonen, M., & Laine, M. (2019). The relationship of anxiety and stress with working memory performance in a large non-depressed sample. *Frontiers in Psychology, 10*(4). doi: 10.3389/fpsyg.2019.00004

Lusk, S. L. (1981). Test anxiety, level and accuracy of predicted performance. *Psychological Reports, 49,* 527-532. doi: 10.2466/pr0.1981.49.2.527

Madison, E. M., Fulton, E. K., & Huber, B. N. (2021). Relationship between generalized metacomprehension and personality traits. *Reading Psychology*. doi: 10.1080/02702711.2021.1888347

Maki, R. H. (1998). Predicting performance on text: Delayed versus immediate predictions and tests. *Memory & Cognition, 26(5),* 959-964.

Maki, R. H., & Berry, S. L. (1984). Metacomprehension of Text Material. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*(4), 663-679.

Maki, R. H., Shields, M., Wheeler, A. E., & Zacchilli, T. L. (2005). Individual differences in absolute and relative metacomprehension accuracy. *Journal of Education Psychology, 97(4),* 723-731.

Megeryal, A. M., Szucs, D., & Moustafa, A. A. (2021). The Abbreviated Science Anxiety Scale: Psychometric properties, gender differences and associations with test anxiety, general anxiety and science achievement. *PLoS ONE, 16*(2): e0245200. https://doi.org/10.1371/journal.pone.0245200

Miesner, M. T., & Maki, R. H. (2007). The role of test anxiety in absolute and relative metacomprehension accuracy. *European Journal of Cognitive Psychology, 19*(4-5), 650-670, doi: 10.1080/09541440701326196

Montero- Lopez, E., Santos-Ruiz, A., Farcia-Rios, M. C., Rodriguez-Blazquez, R. Perez-Gacia, M., & Peralta-Ramirez, M. I. (2016). A virtual reality approach to the Trier Social Stress Test: Contrasting two distinct protocols. *Behavior Research Methods, 48,* 223-232. doi: 10.3758/s13428-015-0565-4

Morales, J., Lau, H., & Fleming, S. M. (2018). Domain-General and Domain-Specific Patterns of Activity Supporting Metacognition in Human Prefrontal Cortex. *Journal of Neuroscience*, *38*(14), 3534-3546. doi: 10.1523/JNEUROSCI.2360-17.2018

Nelson, T. O. (1984). A comparison of current measures of the accuracy of feeling-of-knowing predictions. *Psychological Bulletin, 95*(1), 109–133. https://doi.org/10.1037/0033-2909.95.1.109

Nelson, T. O., McSpadden, M., Fromme, K., & Marlatt, G. A. (1986). Effects of alcohol intoxication on metamemory and on retrieval from long-term memory. *Journal of Experimental Psychology: General, 115*, 247-254. http://dx.doi.org.libpublic3.library.isu.edu/10.1037/0096-3445.115.3.247

Nes, L. S., & Segerstrom, S. C. (2006). Dispositional Optimism and Coping: A Meta-Analytic Review. *Personality and Social Psychology Review*, *10*(3), 235–251. https://doi.org/10.1207/s15327957pspr1003_3

Nurius, P. S., Sefidgar, Y. S., Kuehn, K., Jung, J., Zhang, H., Figueira, O., Riskin, E. A., Dey, A, K., & Mankoff, J., C. (2023). Distress among undergraduates: Marginality, stressors and resilience resources. *Journal of American College Health,* 1-9. https://doi.org/10.1080/07448481.2021.1935969

Oei, N. Y. L., Everaerd, W. T. A. M., Elzinga, B. M., van Well, S., & Bermond, B. (2006). Psychosocial stress impairs working memory at high loads: n association with cortisol levels and memory retrieval. *Stress, 9*(3), 133-141. doi: 10.1080/10253890600965773

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

Peng, P. Wang, C., Li, S., Dardick, W., Barnes, M., Wang, W., Swanson, H. L., & Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychological Bulletin, 144*(1), 48-76. http://dx.doi.org/10.1037/bul0000124

Perrig, W., & Kintsch, W. (1985). Propositional and situational representations of text. *Journal of Memory and Language, 24,* 503-518.

Peterson, C. (2000). The future of optimism. *American Psychologist, 55*(1), 44-55. doi: 10.1037//0003-066X.55.1.44

Peyman, S. & Sadighi, F. (2011). The relationship between Iranian EFL learners' stress and their reading comprehension. *Journal of Pan-Pacific Association of Applied Linguistics, 15*(1), 67-90.

Ping, L, T., Subramaniam, K., Krishnaswamy, S. (2008), Test anxiety: state, trait, and relationship with exam satisfaction. *The Malaysian Journal of Medical Sciences, 15*(2), 18-23.

Popa-Velea, O., Pirvan, I., & Diaconescu, L. V. (2021). The Impact of self-efficacy, optimism, resilience and perceived stress on academic performance and its subjective evaluation: A cross-sectional study. *International Journal of Environmental Research and Public Health, 18*(17), 8911. https://doi.org/10.3390/ijerph18178911

Prinz, A., Bergmann, V. & Wittwer, J. (2018). Happy but overconfident: Positive affect leads to inaccurate metacomprehension. *Cognition and Emotion, 33*(3), 606-615. doi: 10.1080/02699931.2018.1472553

Rabasco, A. N., & Sheets, E. S. (2016). The effects of face-to-face and online social stress on emotional identification. *Modern Psychological Studies, 22*(1), 53-63.

Radvansky, G. A., & Copeland, D. E. (2004). Working memory span and situation model processing. *The American Journal of Psychology, 117*(2), 191-213. doi: 10.2307/4149022

Rai, M. K., Loschky, L. C., & Harris, R. J. (2011). The effects of stress on reading: A comparison of first-language versus intermediate second-language reading comprehension. *Journal of Educational Psychology*, *107*(2), 248-363. http://dx.doi.org/10.1037/a0037591

Reyes, G., Silva, J. R. Jaramillo, K., Rehbelm, L., & Sakur, J. (2015). Self-knowledge dim-out: Stress impairs metacognitive accuracy. *PLoS ONE, 10*(8): e0132320. doi:10.1371/journal.pone.0132320

Reber, R. & Greifeneder, R. (2017). Processing fluency in education: How metacognitive feelings shape learning, belief formation, and affect. *Educational Psychologist, 52*(2), 84-103. https://doi.org/10.1080/00461520.2016.1258173

Roth, M. K., Bingham, B., Shah, A., Joshi, A., Frazer, A., Strong, R., & Morilak, D. A. (2012). Effects of chronic plus acute prolonged stress on measures of coping style, anxiety, and evoked HPA-axis reactivity. *Neuropharmacology, 63*(6), 1118-1126. https://doi.org/10.1016/j.neuropharm.2012.07.034

Salehi, B. Cordero, M, I., & Sandi, C. (2010). Learning under stress: The inverted-U-shape function revisited. *Learning & Memory, 17,* 522-530. doi: 10.1101/lm.1914110

Sandi, C. (2013). Stress and cognition. W*iley Interdisciplinary Reviews: Cognitive Science, 4,* 245-261. doi: 10.1002/wcs.1222

Scott, B. M., & Berman, A. F. (2013). Examining the domain-specificity of metacognition using academic domains and task-specific individual differences. *Australian Journal of Educational & Developmental Psychology, 13,* 28-43.

Schoofs, D., Pabst, S., Brand, M., & Wolf, O. T. (2013). Working memory is differentially affected by stress in men and women. *Behavioural Brain Research, 241,* 144-153. http://dx.doi.org/10.1016/j.bbr.2012.12.004

Schunk, D. H., & Zimmerman, B. J. (1998). *Self-regulated learning: From teaching to self-reflective practice.* New York: Guilford.

Sharpiro, S., MacInnis, D. J., & Park, C. W. (2002). Understanding program-induced mood effects: Decoupling arousal from valence. *Journal of Advertising, 31*(4), 15-26. https://doi.org/10.1080/00913367.2002.10673682

Shields, G. S., Sazma, M. A., & Yonelinas, A. P. (2016). The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience and Biobehavioral Reviews, 68,* 651-668. http://dx.doi.org/10.1016/j.neubiorev.2016.06.038

Silaj, K. M., Schwartz, S. T., Siegel, A. L., & Castel, A. D. (2021). Test anxiety and metacognitive performance in the classroom. *Educational Psychology Review, 33,* 1809-1834. https://doi.org/10.1007/s10648-021-09598-6

Singer, M., Andrusiak, P., Reisdorf, P., & Black, N. L. (1992). Individual differences in bridging inference processes. *Memory & Cognition, 20*, 539–548. https://doi.org/10.3758/BF03199586

Singh, S. N., & Hitchon, J. C. (1989). The intensifying effects of exciting television programs on the reception of subsequent commercials. *Psychology and Marketing, 6*(1), 1-31. doi: 10.1002/mar.4220060102

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Steele. C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69*(5), 797-811. https://doi.org/10.1037/0022-3514.69.5.797

Stober, J., & Esser, K. B. (2001). Test anxiety and metamemory: general preference for external over internal information storage. *Personality and Individual Differences, 30*, 775-781. doi: 10.1016/S0191-8869(00)00069-6

Thiede, K. W., & Anderson, M. C. M. (2003). Summarizing can improve metacomprehension accuracy. *Contemporary Educational Psychology, 28*, 129-160. doi: 10.1016/S0361-476X(02)00011-5

Thiede, K. W., Anderson, M. C. M., & Therriault, D. (2003). Accuracy of metacognitive monitoring affects learning of texts. *Journal of Educational Psychology, 95*(1), 66-73. doi: 10.1037/0022-0663.95.1.66

Thiede, K. W., Griffin, T. D., Wiley, J., & Anderson, M. C. M. (2010). Poor metacomprehension accuracy as a result of inappropriate cue use. *Discourse Processes*, *47*(4), 331-362. doi: 10.1080/01638530902959927

Toth, J. P., Daniels, K. A., & Solinger, L. A. (2011). What you know can hurt you: Effects of age and prior knowledge on the accuracy of judgments of learning. *Psychology and Aging, 26*(4), 919-931. doi: 10.1037/a0023379

Tsai, N., Eccles, J. S., & Jaeggi, S. M. (2019). Stress and executive control: Mechanisms, moderators, and malleability. *Brain & Cognition, 133*, 54-59. https://doi.org/10.1016/j.bandc.2018.10.004

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*, 1124–1131. doi:10.1126/science.185.4157.1124.

Undorf, M. Sollner, A., & Broder, A. (2018). Simultaneous utilization of multiple cues in judgments of learning. *Memory & Cognition, 46*(4), 507-519.

Wei, H., Oei, T. P., & Zhou, R. (2022). Test anxiety impairs inhibitory control processes in a performance evaluation threat situation: Evidence from ERP. *Biological Psychology, 168*, 108241. https://doi.org/10.1016/j.biopsycho.2021.108241

Wiley, J., Griffin, T. D., Jaeger, A. J., Jarosz, A. F., Cushen, P. J., & Thiede, K. W. (2016). Improving metacomprehension accuracy in an undergraduate course context. *Journal of Experimental Psychology: Applied, 22*(4), 393-405. doi:10.1037/xap0000096

Winne, P. H. (1996). A metacognitive view of individual differences in self-regulated learning. *Learning and Individual Differences*, *8*(4), 327-353. doi: 10.1016/S1041-6080(96)90022-9

Wolff, M., Soren, E., Krapllin, A., Kronke, K-M., Burhringer, G., Smolka, M.N., & Goschke, T. (2020). Chronic stress, executive functioning, and real-life self-control: An experience sampling study. *Journal of Personality, 89,* 402-421. doi: 10.1111/jopy.12587

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

Zandara, M., Garcia-Lluch, M., Pulopulos, M. M., Hidalgo, V., Villada, C., & Salvador, A. (2016). Acute stress and working memory: The role of sex and cognitive stress appraisal. *Physiology & Behavior, 164,* 336-344. http://dx.doi.org/10.1016/j.physbeh.2016.06.022

Zeidner, M., & Stoeger, H. (2019). Self-regulated learning (SRL): A guide for the perplexed. *High Ability Studies*, *20*(1-2), 9-51. https://doi.org/10.1080/13598139.2019.1589369

Zhao, Q., & Linderholm, T. (2008). Adult metacomprehension: Judgment processes and accuracy constraints. *Educational Psychology Review, 20,* 191-206.

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). San Diego, CA: Academic Press. Zimmerman,

Appendix A: Demographic Questionnaire

Age

____

Gender

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary (3)
- ○ Other (4)
- ○ Prefer not to answer (5)

Do you identify as transgender?

- ○ Yes (1)
- ○ No (2)
- ○ Unsure (3)

Are you currently taking hormonal birth control?

- ○ Yes (1)
- ○ Yes, but it is localized (2)
- ○ No (4)
- ○ Unsure (3)
- ○ Not applicable (5)

When was your last period?

- ○ Within the month (please enter days since last period) (1) ____
- ○ Longer than one month (3)
- ○ Not applicable (2)

Race (select all that apply):

- ▢ White (1)
- ▢ Black or African American (2)
- ▢ American Indian or Alaska Native (3)
- ▢ Asian (4)
- ▢ Native Hawaiian or Pacific Islander (5)
- ▢ Other (6) ____

Are you Hispanic or Latino?

- ○ Yes (1)
- ○ No (2)

Year in university

- ○ 1 (1)
- ○ 2 (2)
- ○ 3 (3)
- ○ 4 or more (4)

Is English your first language?

- ○ Yes (1)
- ○ No (2)

What age did you learn English?

____

Check all that apply:

- ☐ Depression diagnosis (1)
- ☐ Anxiety diagnosis (2)
- ☐ Other mood/anxiety disorder diagnosis (4)
- ☐ Probable diagnosis in one of these areas (3)

Check all that apply:

- ▢ ADHD Diagnosis (1)
- ▢ Autism Diagnosis (2)
- ▢ Individualized Education Program (IEP) while in school (3)
- ▢ Specific Learning Disability (please describe) (4) ____

Do you have a chronic or life threatening medical diagnosis?

- ○ Yes (1)
- ○ No (2)
- ○ Unsure (3)

Do you take prescription medication (excluding birth control)?

- ○ Yes (1)
- ○ No (2)
- ○ Unsure (3)

Do you consider yourself a caffeine user?

- ○ Yes (2)
- ○ No (3)
- ○ Occasionally (4)

When was the last time you consumed caffeine?

- ○ Within the week (1)
- ○ Yesterday (2)
- ○ Today (please specify the time) (3) ________________
- ○ More than a week (4)

Do you smoke cigarettes or use tobacco products?

- ○ Yes (1)
- ○ No (2)
- ○ Occasionally (3)

When was the last time you used cigarettes or tobacco?

- ○ Within the month (1)
- ○ Within the week (2)
- ○ Yesterday (3)
- ○ Today (please specify the time) (4) ________________
- ○ More than a month (5)

Have you used marijuana or other illicit drugs within the past week? This information will be kept confidential.

- ◯ Yes (1)
- ◯ No (2)

Appendix B: State and Trait Anxiety Inventory

A number of statements which people have used to describe themselves are given below. Read each statement and then click the appropriate circle 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 (1)	Somewhat (2)	Moderately so (3)	Very much so (4)
I feel calm (1)	○	○	○	○
I feel secure (2)	○	○	○	○
I am tense (3)	○	○	○	○
I feel strained (4)	○	○	○	○
I feel at ease (5)	○	○	○	○
I feel upset (6)	○	○	○	○
I am presently worrying over possible misfortunes (7)	○	○	○	○
I feel satisfied (8)	○	○	○	○
I feel frightened (9)	○	○	○	○
I feel comfortable (10)	○	○	○	○
I feel self-confident (11)	○	○	○	○
I feel nervous (12)	○	○	○	○
I am jittery (13)	○	○	○	○
I feel indecisive (14)	○	○	○	○
I am relaxed (15)	○	○	○	○

A number of statements which people have used to describe themselves are given below. Read each statement and then click the appropriate circle to the right of the statement to indicate you *generally* feel.

	Almost Never (1)	Sometimes (2)	Often (3)	Almost Always (4)
I feel pleasant (1)	○	○	○	○
I feel nervous and restless (2)	○	○	○	○
I feel satisfied with myself (9)	○	○	○	○
I wish I could be as happy as others seem to be (3)	○	○	○	○
I feel like a failure (10)	○	○	○	○
I feel rested (11)	○	○	○	○
I am "calm, cool, and collected" (12)	○	○	○	○
I feel that difficulties are piling up so that I cannot overcome them (13)	○	○	○	○
I worry too much over something that doesn't matter (14)	○	○	○	○
I am happy (15)	○	○	○	○
I have disturbing thoughts (16)	○	○	○	○
I lack self-confidence (17)	○	○	○	○

Appendix C: Sample Passage and Questions

Television Newscasts

Relaying information and images instantly, television newscasts have allowed viewers to form their own opinions about various political events and political leaders. In many instances, television newscasts have even fostered active dissent from established government policies. It is no coincidence that, in the 1960's, the civil rights movement took hold in the United States with the advent of television, which was able to convey both factual information and such visceral elements as outrage and determination. Only when all of America could see, on the nightly newscasts, the civil disobedience occurring in places like Selma and Montgomery did the issue of civil rights become a national concern rather than a series of isolated local events. By relaying reports from cities involved to an entire nation of watchers, television showed viewers the scope of the discontent and informed the disenfranchised that they were not alone. The ability of television news to foster dissent has also been affected by increasingly widespread access to video cameras, so that the news presented on television now comes from the bottom up as well as from the top down. Across the world, dissidents have used video equipment to gather visual evidence of human rights abuses. Uncensored images and information have then been transmitted across otherwise closed borders by television newscasts. One professor of popular culture, Jack Nachbar, views the personal video camera as a "truth- telling device that can cut through lies." That claim presumes, though, that the television viewer can believe what he or she sees. But the motivation of the photographer must be taken into account, and the videotape that appears on television can, like still photography, be staged and even faked. When and if propagandists for some government utilize computer-generated effects, viewers will have more trouble believing what they see. However, even if seeing is not automatically believing, at least seeing is seeing--and in some repressive regimes, seeing is the fastest road to freedom

1. The passage is primarily concerned with ways in which

   a) television newscasts deliberately distort information

   b) television affects viewers by its presentation of news

   c) truth frustrates efforts by the media to constrain it

   d) viewers of television newscasts cannot sort out fact from fiction

   e) governments manage to control television newscasts

2. Which of the following, if true, would most strengthen the assertion about television and the American civil rights movement?

   a) Many filmed reports of civil disobedience were censored by television executives during the 1960s
   b) Recent studies have questioned the objectivity with which television newscasts presented reports of civil disobedience during the 1960s
   c) A biography of a major civil rights leader describes in detail the occasions on which the leader was featured in television newscasts in the 1960s
   d) A 1960s poll shows that those Americans who considered civil rights a national priority had seen television newscasts of civil disobedience
   e) Many of the reporting techniques used today originated in newscasts covering the 1960s civil rights movement

3. It can be inferred from the passage that television newscasts would be better at informing public opinion if

   a) newscasts presented only competing views and not one-sided views
   b) personal videos were banned from television newscasts
   c) technology was developed to detect when videos had been tampered with
   d) highly visceral information were not presented during television newscasts
   e) only factual information were presented during television newscasts

4. The author suggests a major reason why television newscasts are effective at influencing public opinion. Based on this argument, which medium below would be the most effective at influencing public opinion?

   a) daily newspapers

   b) radio broadcasts

   c) classroom instruction

   d) grassroots movements based on word of mouth

   e) witnessing newsworthy events first hand

5. According to the passage, television coverage of the civil rights movement did all of the following EXCEPT

a) inform dissenters that they were not alone

b) convey factual information

c) present emotional elements such as anger

d) portray the scope of the dissent

e) express opinions of the political leaders

6. Jack Nachbar, who is quoted in the passage, is

a) a popular culture professor

b) a government propagandist

c) a reporter for a professional news agency

d) a civil rights activist

e) a prominent political figure

7. The author explicitly states that the believability of television news may be compromised by

a) effects produced by computers

b) videos from personal cameras

c) photographers for professional news agencies

d) established government policies

e) reports that are transmitted across closed borders

8. The passage states that when nightly newscasts portrayed civil dissent in the 1960s,

a) it incited dissent in places like Selma and Montgomery

b) it created a national concern for civil rights

c) it started a series of isolated local events

d) viewers formed opinions about political leaders

e) interest in personal video cameras increased