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FROM DISTRESS TO "EUSTRESS": CONTEXTUAL AND COGNITIVE FACTORS IN THE AROUSAL-PERFORMANCE RELATIONSHIP

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I am ready to face any challenges that
are foolish enough to face me.
– Dwight Schrute, *The Office*

TABLE OF CONTENTS

ACKNOWLEDGEMENTS v

LIST OF TABLES vi

LIST OF FIGURES viii

ABSTRACT ix

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1. INTRODUCTION 1
2. REVIEW OF LITERATURE 3
3. DISSERTATION OVERVIEW 16

CHAPTER TWO: PRESSURE AS INCENTIVE AND PRESSURE AS THREAT: PERFORMANCE PRESSURE FACILITATES UNDERGRADUATES' COGNITIVE PERFORMANCE VIA INCREASED EFFORT

1. INTRODUCTION 18
2. METHODS 27
3. RESULTS 33
4. DISCUSSION 41

CHAPTER THREE: PRESSURE AS INCENTIVE AND PRESSURE AS THREAT: DOES HEIGHTENING UNCERTAINTY CHANGE THE EFFECTS OF PRESSURE?

1. INTRODUCTION 42
2. METHODS 43
3. RESULTS 44
4. DISCUSSION 49

CHAPTER FOUR: DISTRESSED TO DISTRACTED: COVID-19 DISTRESS THREATENS UNDERGRADUATES' LEARNING BY INCREASING THEIR MIND WANDERING DURING INSTRUCTION

1. INTRODUCTION 54
2. METHODS 59
3. RESULTS 62
4. DISCUSSION 64

CHAPTER FIVE: DISTRESSED TO DISTRACTED: CAN MINDFULNESS OR REAPPRAISAL INSTRUCTION MITIGATE THE EFFECTS OF COVID-19 DISTRESS ON DISTRACTION AND LEARNING?

1. INTRODUCTION 66
2. METHODS 68
3. RESULTS 73
4. DISCUSSION 79

CHAPTER SIX: GENERAL CONCLUSION

1. SUMMARY 83
2. LIMITATIONS 84
3. FINAL SUMMARY AND IMPLICATIONS 87

SUPPLEMENTAL MATERIALS 91

REFERENCES 96

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List of Tables

Table 2.1. Full condition manipulations and reminder prompts 29

Table 2.2. Chapter 2 participants' average affective response, working memory performance and response time (RT), verbal reasoning performance, and confidence at Blocks 1 and 2 35

Table 2.3. Correlations between Chapter 2 participants' changes in affect and performance on the Block 2 tasks 40

Table 3.1. Chapter 3 participants' average affective response, working memory performance and response time (RT), verbal reasoning performance, and confidence at Blocks 1 and 2 46

Table 3.2. Correlations between Chapter 3 participants' changes in affect and performance on the Block 2 tasks 49

Table 4.1. Descriptive statistics for all measures in Chapter 4 62

Table 5.1. Domains of pandemic-related concerns and example quotes 70

Table 5.2. Descriptive statistics for all measures in Chapter 5, by condition 74

Table 5.3. Frequency of worry about pandemic-related domains by student identity 77

Table S.1. Full prompts and reminders for the reappraisal manipulation 91

Table S.2. Results from regression analysis of learning from the lesson on COVID-19 distress in Chapter 4 93

Table S.3. Results from regression analysis of mind wandering during the lesson on COVID-19 distress in Chapter 4 93

Table S.4. Results from regression analysis of learning from the lesson on mind wandering in Chapter 4 94

Table S.5. Results from regression analysis of learning from the lesson on COVID-19 distress in Chapter 5 94

Table S.6. Results from regression analysis of mind wandering during the lesson on COVID-19 distress in Chapter 5 94

Table S.7. Results from regression analysis of learning from the lesson on mind wandering in Chapter 5 95

Table S.8. Results from regression analysis of learning from the lesson on condition in Chapter 5 95

Table S.9. Results from regression analysis of mind wandering during the lesson on condition in Chapter 5 95

List of Figures

Figure 2.1. Chapter 2 participants' average Block 2 working memory capacity at each set size of the working memory task, conditional on school and Block 1 performance 36

Figure 2.2. Chapter 2 participants' average accuracy for the easy, medium, hard, and very hard verbal reasoning items, conditional on school and Block 1 performance 38

Figure 2.3. Chapter 2 participants' average change in affect from Block 1 to Block 2, conditional on school 39

Figure 3.1. Chapter 3 participants' average Block 2 working memory capacity at each set size of the working memory task, conditional on school and Block 1 performance 48

Figure 3.2. Chapter 3 participants' average change in affect from Block 1 to Block 2, conditional on school 48

Figure 4.1. Histogram of Chapter 4 COVID-19 distress scores, categorized by severity of distress 63

Figure 5.1. Histogram of Chapter 5 COVID-19 distress scores, categorized by severity of distress 74

Figure 5.2. Students' composite worry index by self-reported student identity 76

Abstract

How can we strike a balance between motivating individuals to perform their best without unduly stressing them? In other words, how can we shift our experiences of stress from bad (distress) to good (eustress; Selye, 1956)? One approach is to optimize, rather than simply reduce, the amount of arousal one experiences while performing. Arousal subsumes psychological states of pressure, stress, and anxiety. Using the inverted-U model of arousal and performance as a guide, whereby moderate arousal facilitates performance more so than low or high arousal, this dissertation examines how features of the performance context (including the severity, relevancy, and controllability of a stressor, the uncertainty while performing, and the motivation to perform) can in turn influence cognitive task engagement (task-directed attention and effort). As I show, these contextual and cognitive factors can inform 1) when and how heightened states of psychological arousal may optimize or threaten individuals' cognitive performance, and 2) the utility and efficacy of emotion regulation strategies to help downregulate arousal. Importantly, across four studies, I show that there is no uniform effect of context, cognitive engagement, or emotion regulation on performance in heightened arousal states. Rather, each factor interacts to determine whether arousal threatens or optimizes performance.

Specifically, in Chapters 2 and 3, I examined the arousal-performance relationship by manipulating a performance pressure prior to undergraduates' completing two cognitive tasks in the laboratory with some (Chapter 2) and no certainty (Chapter 3) in their performance. I show that this transient, task-relevant, low severity, and controllable stressor facilitated performance on a working memory task by increasing participants' task-directed effort, suggesting that the pressure induced a moderate, optimal amount of arousal. For those in the pressure condition, I also manipulated instructions to reappraise feelings of arousal, but found no difference between

reappraisal and no reappraisal groups in any performance or affective outcomes. Because arousal was already optimized, there likely was no need for downregulation of arousal, hence rendering reappraisal unnecessary.

In Chapters 4 and 5, I examined the arousal-performance relationship during learning versus performance and with a different stressor: distress about the COVID-19 pandemic. In contrast to the experimental pressure induction paradigm in Chapters 2 and 3, the COVID-19 pandemic is an enduring, task-irrelevant, higher severity, and uncontrollable stressor. I show that higher distress threatened performance by decreasing task-directed attention. Furthermore, in Chapter 5, I show that mindfulness instructions protected individuals from becoming too distracted, though this did not necessarily translate to gains in learning. Thus, these findings suggest that COVID-19 distress pushed individuals to the rightmost side of the inverted-U, where heightened arousal was overwhelming and no longer adaptive. In contrast to Chapters 2 and 3, where pressure optimized performance, here I show that emotion regulation strategies have greater potential utility when arousal is experienced in excess. Thus, in order to optimize arousal and performance, this dissertation highlights the importance of simultaneously considering performance context, its consequences for cognitive engagement, and how these in turn influence the utility and efficacy of emotion regulation.

Chapter 1

Introduction and Literature Review

1. Introduction

Be it performance on a standardized college entrance exam, a cognitive task, or a speech, optimizing individuals' cognitive performance is an important endeavor for individuals, educators, policy makers, and researchers alike. Much research has attempted to uncover how best to optimize arousal and motivate individuals to perform without unduly stressing them. To this end, researchers interested in stress, anxiety, and pressure while performing have attempted to modify the performance context by heightening or optimizing arousal while performing (e.g., incentives for performance, raising the stakes) and/or equip students with strategies to manage their debilitating emotions while performing. Much of this work reveals conflicting findings. Moreover, these theoretical approaches differ in their proposed cognitive mechanisms, with some showing that heightening pressure and stress during performance may increase cognitive resource availability and deployment (e.g., Bonner & Sprinkle, 2002), while others show that these same factors may consume cognitive resources and distract one from the task at hand (e.g., Beilock, 2008). Even in cases where individuals are relatively uniformly impacted by their performance context, research finds conflicting evidence to support the efficacy of emotion regulation strategies to downregulate negative emotions and improve performance (see Camerer et al., 2018; Ganley et al., 2021; Mesghina & Richland, 2020).

Prevailing theories in stress, performance pressure, and anxiety each suggest important contextual and mediating cognitive factors that explain how heightened arousal may impact performance, and in what ways emotion regulation might change any arousal-performance relations. Importantly, though these theoretical perspectives all center on arousal and performance, they are rarely put in conversation together. This dissertation utilizes the inverted-U model of arousal and performance (Yerkes & Dodson, 1908) to integrate similar, yet, to the best of my knowledge, unlinked theories of performance. As I will show, doing so can clarify when and how heightened arousal translates to improvements in performance.

Across four studies, this dissertation aims to clarify under what conditions and by what means heightened arousal during performance may threaten or facilitate cognitive performance (Chapters 3 and 4) and learning (Chapters 4 and 5). Moreover, I test whether emotion regulation strategies might improve cognitive performance across studies. Critically, I show that heightened arousal in the form of increased stress, pressure, or anxiety does not uniformly affect individuals' cognitive engagement with a task (i.e., their attention and effort on a task). Rather, the extent to which these states of heightened arousal influence cognitive engagement, and in turn, performance, depends on elements of the performance context—specifically, the type of stressor, motivation to perform, and uncertainty while performing.

The remainder of this chapter reviews and integrates relevant literatures expounding on theories of stress, trait anxiety, and performance pressure. Though differing in their phenomenological foci, all three literatures detail the cognitive mechanisms by which psychological states corresponding to heightened arousal can compromise or promote performance and/or learning. In this chapter, I aim to integrate key elements of these theories to better understand how features of the performance context translate to differences in cognitive engagement on the task, which in turn have consequences for performance and for the utility and efficacy of emotion regulation strategies. This chapter concludes with an outline of the dissertation.

2. Review of Literature

2.1. Arousal and Performance: An Inverted Relationship

Arousal is defined as physiological activation in response to a stimulus (American Psychological Association, n.d.). Everyday, folk conceptions of heightened arousal—including states of high pressure, anxiety, or stress—are depicted as something to be avoided (e.g., Liu et al., 2017). Oftentimes, experiencing stress or anxiety in excess predicts negative outcomes, such as poorer academic performance (Heissel et al., 2017) and greater rates of disease and mortality (Schneiderman et al., 2004). Yet, in reality, the relationship between heightened psychological arousal states and performance is not as straightforward. Much work shows that cognitive performance outcomes (e.g., Cheng et al., 2020), academic outcomes (e.g., Keech et al., 2018), and physiological reactions to stress (e.g., Liu et al., 2017) are improved when individuals experience or believe they can experience a “sweet spot” of moderate stress, anxiety, or pressure.

In their renowned inverted-U model of arousal and performance, psychologists Robert Yerkes and John Dodson (1908) illustrated a curvilinear relationship between arousal and performance, where very low or very high arousal (right and left most sides of the inverted-U) yields poorer performance relative to medium arousal (top of the inverted-U), which facilitates performance across a wide array of performance domains (Yerkes & Dodson, 1908; also see Sapolsky, 2015). Much foundational research examining stress, anxiety, and pressure posit that the relationship between these psychological states and performance follow a similar curvilinear relationship. For example, physician and researcher Hans Selye characterized stress in a similar manner to Yerkes and Dodson (1908), but with different terminology. Selye believed stress, like arousal, is a nonspecific and nonvalenced bodily response to a stimulus (1956). He posited that different types of stress can be categorized in terms of their impacts on cognitive and physiological functioning and performance—distress, which signals the bad stress, and eustress, good stress. Mapped onto the inverted-U model, eustress would be experienced at the peak of the parabola, whereas distress would be at the rightmost tail and no stress at the left.

It follows then that to optimize performance, one must know how to move about the inverted-U. In other words, how can we nudge individuals who are over-aroused (e.g., distressed and anxious; right side of the curve) or under-aroused (e.g., bored and disinterested; left side of the curve) to the optimal arousal zone (e.g., eustress; middle of curve)? Since the latter half of the twentieth century, researchers investigating human behavior in cognitive and educational psychology, behavioral economics, and social, cognitive, and affective neuroscience have considered this question. More specifically, researchers interested in heightened arousal—as measured via states of increased pressure, stress, and anxiety—have been interested in determining 1) the conditions that must be met to ensure an individual is operating within the optimal zone of arousal, and 2) how emotion regulation strategies might assist individuals in moving from over-arousal to optimal arousal.

For the former, these conditions involve features of the performance context, including motivation to perform, uncertainty while performing, and type of stressor, which in turn influence individual-level cognitive engagement, including task-directed attention and effort. In the following sections, I summarize key arousal-performance theories in the fields of stress, anxiety, and pressure. I highlight the theoretical components and empirical evidence revealing key contextual factors and subsequent individual-level cognitive engagement factors that correspond to optimal and suboptimal arousal and performance. Then, I integrate across these theories, revealing important contextual features and their significance for cognitive task engagement—specifically, the importance of attention and the facilitative role of effort for performance.

As for the latter, I review the literature on emotion regulation in performance contexts, narrowing in on two highly endorsed, research-backed emotion regulation strategies—reappraisal and mindfulness—that may assist in optimizing performance by changing how one imagines and engages with feelings of heightened arousal. Following the literature review, I conclude with an outline of the dissertation and the studies herein.

2.2. Theories of Stress and Performance

Using the inverted-U theory as a guide, the following three sections review theories of stress, anxiety, and pressure**,** all of which center on the facilitative and threatening role of arousal on performance, yet differ in the assumptions about the performance context and proposed cognitive mechanisms. I conclude these sections by showing that these contextual and cognitive factors likely interact to determine whether arousal threatens or optimizes performance, emphasizing the unique insights gleaned from this novel integration across typically separated stress, anxiety, and pressure literatures.

Prevailing theories of stress and performance include the Transactional Theory of Stress and Coping (TT; Lazarus & Folkman, 1984) and the Biopsychosocial Model (BPS; Blascovich & Tomaka, 1996; Blascovich & Mendes, 2000), an extension of the former. Lazarus and Folkman's (1984) TT underscores the importance of cognitive interpretations of stressors to determine when stressors give rise to a stress response and to different coping strategies. When facing a stressor, Lazarus and Folkman (1984) argue that individuals simultaneously make two series of appraisals that determine their stress response: a primary appraisal, in which the individual determines whether the stressor is a threat or a challenge, and a secondary appraisal, in which the individual determines whether or not they have sufficient resources to avoid the threat (i.e., cope). Primary appraisals of a stressor can be benign-positive, irrelevant, or stressful. Critically, only stressful appraisals will bring about secondary appraisals of coping potential. If a stressor is appraised as benign-positive or irrelevant, then no stress response will come about, and no coping is required. Only if something is appraised as stressful does one next make a secondary appraisal of their perceived coping resources to manage the stressful experience (e.g. prior coping success and experience, controllability of the stressor). If one's secondary appraisal leads them to believe they have sufficient resources to cope, then the stressful situation may be appraised as a challenge. Conversely, if one believes they are insufficiently equipped to cope with the stressor, then they appraise the situation as a threat (Lazarus & Folkman, 1984).

The TT contributes to literature on stress and performance by focusing on individuals' cognitive appraisals of stressors. Yet, as Blascovich and colleagues (Blascovich & Tomaka, 1996; Blascovich & Mendes, 2000) observe, stress responses manifest through social and physiological means as well. In their extension of the TT, Blascovich and Tomaka (1996) propose the BPS model of challenge and threat, combining cognitive, physiological, and social dimensions of arousal-based phenomena, including stress. The primary process of the BPS model assumes an individual is in a motivated performance context, meaning they are in a situation that is relevant to their personal goals, in which they are able to act towards said goal, and where their performance outcome is uncertain. From here, and similar to the TT, individuals cognitively appraise the situation via primary appraisals (perceived demand of stressor) and secondary appraisals (perceived coping resources). Notably, whereas the TT posits that challenge and threat are primary appraisals of a stressor, the BPS conceptualizes challenge and threat as consequences of primary and secondary appraisals of stressor demand (i.e., severity) and perceived coping resources (i.e., controllability). Specifically, perceiving low stressor demand and high coping resources (a low severity, high controllability stressor) invokes a challenge evaluation of the situation, whereas perceiving high stressor demand and low coping resources (a high severity, low controllability stressor) invokes a threat evaluation. Accordingly, these psychological evaluations of severity and controllability translate to distinct physiological activation patterns whereby the body recruits biological resources to promote performance.

Core to both theories of stress is an assumption that individuals are in an uncertain, motivated performance context. If individuals are not motivated—either because the situation is not goal-relevant, the outcome is certain and therefore does not invoke psychological responses, or they have no agency in achieving said goal—then cognitive appraisals of the stressor are not made (Blascovich & Tomaka, 1996; Seery, 2011). Moreover, if the individual is in a motivated context, yet appraisals of the stressor are benign-positive or irrelevant, indicating no need to recruit coping resources, then one would not expect a stress response (Lazarus & Folkman, 1984). In sum, determining the context in which one performs is critical to understanding whether and to what extent stress responses manifest after stressor exposure and affect performance outcomes downstream. However, though these theories expound upon how challenge and threat appraisals can change performance via physiological mechanisms, relatively less attention is devoted to explanations of the precise cognitive processes that may change performance independent of physiological responses. Research in trait anxiety and performance pressure focus more specifically on the cognitive mechanisms (e.g., task-directed attention and effort) and outcomes (e.g., test scores and learning) through which heightened arousal can threaten and facilitate performance.

2.3. Theories of Trait Anxiety and Performance

Trait anxiety is a theoretical construct that derives from a different mode of considering the role of stressors on individuals, and is characterized by a stable, context-independent heightening of arousal in response to one's real or imagined environment (Gaudry et al., 1975). Trait anxiety subsumes more context-specific phenomena, like math anxiety and test anxiety, that are characterized by apprehension and heightened arousal in real or imagined math and test performance contexts, respectively (Ashcraft, 2002; Suinn & Edwards, 1982; Wine, 1971). Individuals tend to maintain their status as higher or lower trait-anxious individuals throughout their lifespan, with consequences for performance (e.g., lower mathematics test performance for the highly math-anxious; Ashcraft & Kirk, 2001). Theories of trait anxiety and performance underscore the cognitive mechanisms underlying performance decrements when anxious. Distraction theory (Wine, 1971) suggests that while taking a test, a test-anxious individual's attention is split between self-relevant and task-relevant features. As she argues, attending to self-relevant features, including worry and rumination about one's performance, is quite cognitively demanding. With less attention devoted to the task, performance suffers (Wine, 1971). Similar works by Sarason (1984, 1988) argue that the anxiety-induced splitting of attention consumes cognitive resources necessary for performance.

Ashcraft and Kirk (2001) expand upon this notion of distraction as cognitively demanding in their investigations of highly math-anxious individuals. In a series of experiments, the authors show that feeling highly math-anxious during math performance temporarily reduces available working memory capacity, a resource that is important for math performance, resulting in lower performance. They propose two potential explanations for the reduction in available working memory: either math-anxious individuals cannot redirect their attention and put forth maximal effort when performing, or they are doing so, but they struggle to inhibit the intrusive, self-relevant thoughts and worries that arise in working memory (Ashcraft & Kirk, 2001).

In their review of trait anxiety and cognitive performance, Eysenck et al. (2007) propose an Attentional Control Theory that addresses much of the remaining questions in Ashcraft and Kirk's (2001) conceptualization. Specifically, Attentional Control Theory posits that anxiety threatens performance via biased attention to threat-related stimuli and impaired attentional control more generally, resulting in increased distractibility in highly anxious individuals (Eysenck et al., 2007). Importantly, though anxious individuals do tend to underperform relative to their non-anxious counterparts, Eysenck et al. (2007) propose that increased effort might mitigate the effect of anxiety on performance. Specifically, highly anxious individuals might be motivated to put forth more effort in a compensatory manner. Thus, a core facet of the Attentional Control Theory is that anxiety often does not jeopardize performance effectiveness broadly, but rather compromises individuals' performance efficiency specifically.

2.4. Theories of Performance Pressure

Theories of trait anxiety emphasize the cognitive mechanisms, including fluctuations in working memory and task-directed attention and effort, that underlie arousal-induced changes in cognitive and academic performance. Critically, by the very nature of their operationalization of anxiety, trait-anxious, math-anxious, and test-anxious individuals perform within a motivated performance context. To be anxious about one's performance, the performance context must be self-relevant and appraised as threatening, and the outcome must be uncertain (Blascovich & Tomaka, 1996; Blascovich & Mendes, 2000). Though these elements are evident in investigations of trait anxiety, they are less so in state anxiety. State anxiety is a transient state of heightened arousal in response to an environmental stimulus (Gaudry et al., 1975). Experimental manipulations of state anxiety, often taking the form of imposing performance pressure, find conflicting evidence for whether or not pressure boosts or hinders performance.

Research in cognitive, social, and educational psychology has documented how feeling pressure prior to a demanding task can harm performance, a phenomenon commonly referred to as “choking under pressure.” Either by imposing a social-evaluative, performance-contingent pressure (e.g., you must attain a certain test score in order to determine another’s receipt of a prize; Beilock et al., 2004) or by reminding individuals of their stereotyped identity in a relevant performance context (e.g., priming women to think about their gender before completing a difficult math test; Spencer et al., 1999), this research shows that individuals tend to appraise these pressures as threatening, and consequently show lower performance than those who were not under imposed pressure. In line with Ashcraft and Kirk’s (2001) findings, it is believed that these pressure-induced decrements occur due to compromised working memory capacity under pressure, whereby individuals direct their attention internally towards intrusive thoughts and worries and away from the task at hand (see Beilock, 2008; Schmader et al., 2008).

At the same time, researchers in the fields of cognitive neuroscience and behavioral economics find that performance pressure incentivizes performance by motivating individuals to exert more effort (see Bonner & Sprinkle, 2002; Botvinick & Braver, 2015). When under pressure, individuals put forth more effort (as measured by pupil dilation, time on task, or neural network activation), which in turn results in improved test performance (e.g., Attali, 2016; Schlosser et al., 2019) and working memory capacity (e.g., Heitz et al., 2008; Jimura et al., 2010).

Additionally, more recent work has encouraged the use of performance pressure to “gamify” learning and performance contexts (Howard-Jones & Jay, 2016; Luria et al., 2020).

Researchers studying declarative and episodic memory have found that learning and memory improve when individuals perform with the potential for performance-contingent rewards (see Miendlarzewska et al., 2016). For example, undergraduate engineering students learned more from an educational game when there was anticipation for reward (rolling dice after correct answers) than when reward values were guaranteed (constant point values for correct answers; Ozcelik et al., 2013). They argue that anticipation of random rewards is particularly arousing (Miendlarzewska et al., 2016), which can heighten individuals' motivation, dopaminergic activation, and goal-directed attention, leading to improved memory and learning (see Howard-Jones & Jay, 2016; Miendlarzewska et al., 2016). This anticipation of reward can promote further emotional engagement with the content (Howard-Jones & Demetriou, 2009) and yield improvements in memory and cognitive performance in an inverted-U fashion (Cheng et al., 2020).

To summarize, proposed theories for pressure-as-threat and pressure-as-incentive all expound upon quite similar mechanisms: Specifically, heightened arousal changes the direction of attention and quality of attention (i.e., effort) one puts towards a task. As I review below, the direction of such effects—in other words, whether or not they promote or co-opt attention and effort—may be determined by elements of the performance context.

2.5. Integrating Perspectives: Context and Cognitive Engagement Matter

Bridging across the aforementioned theories of stress, anxiety, and performance pressure elucidate key contextual and cognitive elements that inform when heightened arousal may optimize or threaten individuals' cognitive performance. Specifically, conditions of the performance context include the type of stressor (how severe, task-relevant, and controllable it is), uncertainty while performing, and motivation to perform. Cognitive elements include individual-level differences in task-directed attention and effort.

Feeling heightened arousal via increased feelings of pressure, stress, or anxiety while performing may be optimal for performance (i.e., move individuals to the top of the inverted-U) if individuals were not originally motivated or if they were certain of their ability to perform, both of which signal little to no need for the individual to put forth much effort. So long as the stressor or pressure used to heighten arousal is not too severe, within the individual's control, and relevant to the task, then the heightened state of arousal may serve to facilitate performance by motivating the individual to exert more effort.

At the same time, heightened arousal while performing may threaten performance (i.e., move individuals to the right of the inverted-U) if the individuals were already motivated or quite uncertain about their ability to perform, in which case they may have already put forth maximal effort. Moreover, if the stressor or pressure is too severe, outside of the individual's control, or irrelevant to the task, then the heightened state of arousal may threaten performance by generating worries that direct limited attentional resources internally.

2.6. Emotion Regulation

As reviewed above, changing the context in which one performs is one way to optimize arousal levels and improve performance. Another way to optimize the arousal-performance relationship is to change how one relates to the arousing stimulus by regulating their emotions. Broadly, emotion regulation refers to cognitive and behavioral processes individuals use to change the "valence, intensity, or duration of an activated emotion" (Cole et al., 2004, p. 320).

There are many ways one may attempt to regulate their emotional experiences, with some ways being more adaptive than others (see Gross, 1998, 2002). Emotion regulation can be deliberate (e.g., diverting eye gaze from a horror film) or automatic (e.g., ruminating about a sick relative's health) and can manifest cognitively (e.g., telling oneself an intense interview is actually an opportunity to practice public speaking) or behaviorally (e.g., leaving a room after an upsetting confrontation). Here, I focus on deliberate, cognitive emotion regulation strategies, which are most adaptive in performance contexts and academic settings (Harley et al., 2019).

2.6.1. Reappraisal. Research in emotion regulation has focused primarily on reappraisal, a form of emotion regulation aimed at changing one's appraisal of a stimulus in order to reduce its emotional impact (Gross, 2002; Gross & John, 2003). In particular, stress reappraisal has received growing attention in recent years. Stress reappraisal paradigms encourage individuals to adopt a positive perspective on their stress and stress response, by reframing commonly held beliefs about physiological experiences related to stress and arousal (see Crum et al., 2020). Unlike reappraisal paradigms that instruct individuals to adopt a neutral perspective on stressful situations (e.g., this test is no big deal), stress reappraisal (e.g., I'm feeling stressed, but stress signals that my body is recruiting all the necessary resources to tackle this stressor) maintains arousal congruency (Brooks, 2013). In other words, priming oneself to think of the motivating, energizing, and excitatory aspects of stress does not contradict their original physiological experience of the arousal (e.g., sweating, heart beating, "butterflies").

Much work shows that stress reappraisal can improve performance across a wide array of performance domains (e.g., Brooks, 2013; Crum et al., 2013; Jamieson et al., 2010, 2016; Strack et al., 2017). In accordance with prevailing theories of stress (Blascovich & Tomaka, 1996; Lazarus & Folkman, 1984), stress reappraisal does not reduce the extent to which one is aroused, but rather changes one's appraisal of a stressor from threatening to challenging, as evidenced by greater perceived coping resources after reappraisal (see Jamieson et al., 2018).

2.6.2. Mindfulness. Another emotion regulation strategy that has received growing attention for reducing maladaptive or unpleasant states of heightened arousal is mindfulness (see Roemer et al., 2015 for discussions). Whereas reappraisal instructs an individual to change the meaning they place on an arousing stimulus, mindfulness practices instruct individuals to accept their default appraisals and nonjudgmentally let go of these thoughts and feelings (Kabat-Zinn, 2003; Bishop et al., 2004). Short-term interventions (e.g., Mrazek et al., 2012) and longer-term (e.g., Jha et al., 2010) mindfulness practices can reduce the impact of stress on a variety of behavioral, affective, and cognitive indices (see Brown, 2007 for a review), including reducing the extent to which negative emotional experiences divert attention and harm performance (Brunyé et al., 2013; Mrazek et al., 2012).

2.6.3. Selecting Between Emotion Regulation Strategies in Arousing Contexts. To summarize, there is evidence to suggest that both reappraisal and mindfulness strategies may optimize the arousal-performance relationship and promote performance in stressful or otherwise arousing contexts. However, they achieve this by different cognitive means: Whereas reappraisal emphasizes reimagining one's appraisal of a stressor, mindfulness encourages one to divert attention away from the stressor. Again, the performance context—specifically, the controllability, relevancy, and severity of a stressor—may elucidate the conditions under which each strategy is most useful and effective. Take, for example, research that finds that reappraising one's negative emotions is not always adaptive for performance outcomes, particularly when the ability to resolve the emotional situation is already within one's control (see Ford & Troy, 2019).

Another example centers on the severity of emotional experience, which may determine whether reappraisal is effective. First, if a stressor is not appraised as threatening—either because it is relatively low severity or because the individual believes they have sufficient coping resources—then reappraisal would not be necessary. Second, across lifespans, individuals tend to prefer using strategies other than reappraisal in everyday emotion regulation contexts (Brans et al., 2013; Ford & Troy, 2019; Levine et al., 2013; Suri et al., 2015; Troy et al., 2018), particularly when the emotion becomes more severe (Ford & Troy, 2019; Sheppes et al., 2014). Individuals may not rely on reappraisal because they perceive it as more difficult or costly to implement than other strategies (Ford & Troy, 2019), including acceptance of emotional experience (Troy et al., 2018), a core tenant of mindfulness practices (Lindsay & Creswell, 2019; Rahl et al., 2017). Indeed, those instructed to reappraise their negative emotions initially experience heightened arousal and increased negativity immediately following reappraisal (e.g., Troy et al., 2010; 2012), suggesting that reappraisal may not be an effective strategy for quickly downregulating severe emotions in performance contexts.

Evidence from the laboratory corroborates individuals' perceptions of reappraisal as a cognitively demanding endeavor. Insofar as individuals must simultaneously maintain two contradictory appraisals of an emotional stimulus, inhibit the negative appraisal, and constantly monitor the extent to which they are successfully reappraising, reappraisal may tax cognitive resources like working memory (Schmeichel & Tang, 2015). Studies in support of this hypothesis show that reappraisal relies on and develops alongside the same neural networks involved in working memory and cognitive resources broadly (see Buhle et al., 2013 for a review; though see Lee & Xue, 2018) and that individuals higher in baseline cognitive resources have greater success with reappraisal (Hofmann et al., 2012; Schmeichel & Tang, 2015). Thus, reappraising one's emotions while performing may paradoxically decrease the amount of task-directed attention and effort, with ramifications for emotional experience and performance. On the other hand, mindfulness practices encourage nonjudgmental acceptance of and detachment from one's thoughts and feelings, and therefore may not require the same amount of engagement with and manipulation of emotional content. This means that mindfulness may preserve task-directed attention and effort while performing. For example, Keng and colleagues (2013; 2017) found that using mindfulness, rather than reappraisal, to downregulate negative emotional experiences consumes fewer cognitive resources with similar or greater efficacy.

3. Dissertation Overview

In short, this dissertation considers the critical role of context when performing under presumably arousing situations, and importantly, how different contextual factors (here, type of stressor, amount of uncertainty, and baseline motivation to perform) in turn can bring about differences in cognitive engagement—specifically, task-directed attention and effort. Moreover, this dissertation examines under what conditions and by what cognitive mechanisms certain emotion regulation strategies can alter the impact of heightened arousal on performance.

In Chapters 2 and 3, I consider this in a manipulation of performance pressure while adults complete a working memory task and a verbal reasoning test. This was a transient, task-relevant, controllable, and mildly severe pressure induction in which I asked participants to attain a certain performance threshold in order for them and another participant to receive additional compensation. Across both chapters, I show that the pressure manipulation increased participants' effort and, as a result, improved their working memory performance. In both chapters, I also manipulated reappraisal instructions for some students in an attempt to mitigate any threatening effects of pressure on performance. In Chapter 3 specifically, I attempt to increase uncertainty in the performance context by removing all feedback participants received while performing. Chapters 2 and 3 are under review for publication as a combined manuscript.

In Chapters 4 and 5, I examine arousal and performance in a different context. Specifically, I examine how distress about the COVID-19 pandemic—a stressor that is quite severe, enduring, task-irrelevant, and outside of individuals' control—may impact another cognitive engagement marker: task-directed attention. I show a distressed-to-distracted pathway, whereby individuals higher in COVID-19 distress reported greater distraction while watching a brief neuroscience lesson, which in turn harmed their learning. In Chapter 5, I manipulated reappraisal and mindfulness emotion regulation strategies in an attempt to mitigate the link between distress and distraction. Chapters 4 and 5 are also under review for publication as a combined manuscript.

Chapter 2

Pressure as incentive and pressure as threat: Performance pressure facilitates undergraduates' cognitive performance via increased effort[1]

1. Introduction

Performance pressure, in the form of performance-contingent incentives or rewards, is often applied in settings where individuals must perform well, but may not be motivated to show their full potential. For example, teachers may provide prizes to students who achieve certain test performance thresholds. Some argue that performance pressure improves test performance and cognitive processing ability by incentivizing individuals to exert greater effort (see Botvinick & Braver, 2015), but others argue that this pressure threatens test performance by increasing verbally-rehearsed worries and depleting requisite cognitive resources (see Beilock, 2008).

Could it be that pressure can have both incentivizing and threatening effects? If so, which translates to changes in performance? We seek to contribute to the literature on pressure and performance by manipulating performance pressure in adults prior to completing two tasks: a working memory task and a verbal reasoning task. We focus on working memory capacity as a mechanism since it has been shown to be consumed by pressure under threat (e.g., Beilock et al., 2004; see Schmader et al., 2008), yet has also been shown to be facilitated under pressure (e.g., Heitz et al., 2008). Our primary objective, in line with pressure-as-incentive views, is to explore whether increased effort mediates the relation between pressure and improved performance. A secondary goal, in line with pressure-as-threat views, asks in what ways performance pressure changes adults' emotions, motivation, and confidence in their performance. Across Chapters 2 and 3, we also manipulate uncertainty while performing.

[1] A version of Chapters 2 and 3 is currently under review for publication.

1.1. Pressure as Incentive

Placing pressure on individuals can promote performance on a variety of tasks. In educational contexts, these pressure manipulations often take the form of performance-contingent incentive programs, where students are made aware that they can receive money for meeting certain performance criteria (e.g., Levitt et al., 2016). Other forms of performance pressure operate by raising the stakes of the assessment (e.g., taking a practice exam vs. an official exam; Attali, 2016). When performance pressure is applied prior to exams, performance improves for students of all ages, though the focus here is on adults (Attali, 2016; Castro et al., 2018; Schlosser et al., 2019).

In the laboratory, performance-contingent pressure has been shown to improve adults' cognitive processing abilities, including working memory (see Pessoa, 2009). In the most common experimental paradigm, participants complete working memory tasks under two conditions. First, participants complete tasks with no instructions. Later, participants are instructed that they can earn money on certain trials of the task for quick and accurate responses (e.g., Jimura et al., 2010). Studies consistently show that, compared to baseline performance, receiving these performance-contingent incentives reliably improves accuracy and efficiency on working memory tasks. This is true regardless of baseline working memory capacity (Heitz et al., 2008) or emotional valence of the pressure (positively framed vs. negatively framed rewards; Krawczyk & D'Esposito, 2013; Savine et al., 2010), and occurs primarily on the most working memory-demanding trials (Pochon et al., 2002; Savine et al., 2010).

1.2. Pressure Incentivizes Performance by Increasing Effort

As elaborated in more detail below, theorists across disciplinary perspectives show that pressure improves performance by increasing effort (Bonner & Sprinkle, 2002; Botvinick &

Braker, 2015; Wise & DeMars, 2005). For example, evolutionary perspectives of cognitive control posit that all goal-oriented behaviors require both cognitive and motivational inputs; the former addressing how a behavior will happen, and the latter addressing why one should recruit limited cognitive resources, like working memory, and exert effort towards the behavior (Botvinick & Braver, 2015). Pressure, in the form of performance-contingent rewards, motivates individuals to devote limited resources to a task (i.e., exert more effort). According to Bonner and Sprinkle (2002), this can occur in four ways: Pressure determines whether or not someone will devote cognitive resources to a task (effort direction), how much time they will devote cognitive resources (effort duration), the extent of their cognitive resources they will deploy for a task (effort intensity), and how much trial-and-error, practice, and problem solving one will devote to improving performance on the task (i.e., learning). When the stakes are raised, or when reward is promised, it is more likely that an individual deploys these limited cognitive resources (see Botvinick & Braver, 2015), including working memory (Jimura et al., 2010).

1.3. Evidence of the Mediating Role of Effort

1.3.1. On Working Memory Capacity. Empirical work highlights the important role of effort in explaining the pressure-performance relation. Neuroimaging studies reveal that the addition of performance-contingent rewards during a working memory task increased activation in prefrontal regions already implicated in working memory processes (Gilbert & Fiez, 2004; Pochon et al., 2002; Krawczyk & D'Esposito, 2013; Jimura et al., 2010; Taylor et al., 2004). Moreover, there is some evidence to suggest that pressure facilitates working memory performance by activating more effortful—yet more effective—preparatory neural networks (e.g., Jimura et al., 2010). Performance-contingent rewards seem to have the greatest impact on performance (Zedelius et al., 2011) and prefrontal cortex activation (Gilbert & Fiez, 2004;

Pochon et al., 2002; Zedelius et al., 2011; Taylor et al., 2004) during earlier maintenance phases of working memory tasks where participants must actively hold and manipulate things in mind. Here, participants have sufficient time to adopt and utilize more effortful preparatory processes prior to recall.

Lastly, performance pressure can mitigate deleterious impacts of mental fatigue on cognitive ability. Boksem and Tops (2008) argued that mental fatigue is the result of a subconscious cost-benefit analysis where the cost of expending effort is deemed greater than any benefit, but performance-contingent rewards could tip the scale. To test this, the authors asked adults to complete a monitoring task for two hours, during which they steadily declined in their attention and accuracy. When participants were informed that they could receive additional compensation if they performed better than all other participants, who would see their scores, participants' performance markedly improved (Boksem et al., 2006). Performance-contingent pressure could improve scores in similar contexts where participants experience mental fatigue or low motivation (e.g., volunteer research participation; Sharp et al., 2006).

1.3.2. On Test Performance. The mediating role of effort on performance extends beyond the laboratory. Researchers in education assessment express concern that low-stakes, ungraded assessments, like standardized exams, do not sufficiently motivate students to put forth their best effort, jeopardizing assessment validity (see Wise & DeMars, 2005). For example, when adolescents received performance pressure in the form of $1 for every correct response on a standardized mathematics exam, they self-reported exerting more effort on the exam, which positively correlated with their accuracy (O'Neil et al., 1996). Similarly, students saw significant improvements on the same mathematics items when they were embedded in a high-stakes exam compared to their original low-stakes administration (Kiplinger & Linn, 1996). For both studies, improvements were concentrated on the easier items, as these are responsive to changes in cognitive resource expenditure, whereas improving performance on difficult items requires more than effort (see Bonner & Sprinkle, 2002 for a discussion on task difficulty). For adults invited to complete a low-stakes, voluntary Graduate Record Exam (GRE), effort moderated the discrepancy between performance on the high- and low-stakes exams: Those who exerted more effort on the low-stakes exam, as measured by completion time, had similar performance to their high-stakes, official GRE (Attali, 2016; Schlosser et al., 2019).

Even in cases where pressure does not change performance, students still exert greater effort, as assessed through self-report (Baumert & Demmrich, 2001; O'Neil et al., 1996; 2005) or pupil dilation (Castro et al., 2018). This suggests that though there may be unexplored moderators of the impact of pressure on performance (e.g., skill; Bonner & Sprinkle, 2002), the impact of pressure on effort is relatively constant. Moreover, there is little evidence to suggest that pressure, a form of extrinsic motivation, "crowds out" individuals' intrinsic motivation (Baumert & Demmrich, 2001; List et al., 2018). In sum, performance pressure in test and working memory performance contexts can increase individuals' exerted effort and, consequently, their performance, particularly in cases where individuals would not otherwise be motivated to exert effort to their fullest extent.

1.4. Pressure as Threat

At the same time, other research has documented that feeling pressure prior to a demanding task can harm performance, a phenomenon commonly referred to as "choking under pressure." In a common paradigm used to raise the pressure on participants through a social-evaluative manipulation (e.g., Beilock et al., 2004), participants are invited to the laboratory to perform a working memory-demanding mathematics task. First, they complete a non-pressured pre-test. Then, they are told that they were randomly paired with another person completing the tasks, and that they both would receive an additional $5 if they improve their pre-test score. These social-evaluative pressure paradigms have reliably shown to increase self-reported anxiety and other indices of negative affect (see Dickerson & Kemeny, 2004). Moreover, these forms of pressure have serious implications for performance: Adults show decreased performance on this working memory-demanding task (Beilock et al., 2004; Beilock & Carr, 2005), and lower confidence in their performance (Beilock et al., 2004) when under pressure, compared to control groups instructed to try their best.

Choking under pressure operates by consuming limited working memory resources (Ashcraft & Kirk, 2001). When pressure is perceived as a threat, it can generate intrusive thoughts and worries that are verbally rehearsed and take up limited working memory resources (Beilock, 2008; Schmader et al., 2008). Thus, when one experiences pressure as threatening, they have less working memory capacity to devote to difficult tasks, compromising performance. Empirical work lends evidence to this, showing that working memory capacity can both moderate (Beilock & Carr, 2005) and mediate (Owens et al., 2008) the relation between pressure and performance. When under high pressure, individuals perform worse on higher working memory-demanding problems (Beilock & Carr, 2005), further supporting the working memory depletion account of pressure-as-threat.

1.5. Pressure as Incentive, Despite Threat

Performance-contingent pressures can incentivize performance in a variety of contexts, including working memory tasks, by increasing effort. Yet, these same pressures can consume working memory resources and threaten performance by inducing intrusive worries. Importantly, some research suggests that pressure can promote working memory capacity when in heightened emotional states by reducing the negative impact of said emotional distractors. For example, during maintenance periods of rewarded working memory trials, researchers find considerable deactivation in reward-processing and emotion areas in the brain, suggesting that participants are turning off or down-regulating their intrusive thoughts and worries when performing working memory trials for reward (Gilbert & Fiez, 2004; Zedelius et al., 2011), a term Pochon and colleagues coined “emotional gating” (2002, p. 5674). Moreover, Castro et al. (2018) find that, despite increased expressions of fear and anger, adults completing math problems under pressure also increased the quality and quantity of their effort on the task.

In sum, performance-contingent rewards offer sufficient motivation to exert effort which can trump deleterious effects of distracting emotions on cognitive tasks. Put another way, though pressure can induce distracting emotions like anxiety, it can also increase effortful cognitive processes that could mitigate the impacts of such distractions. This suggests that pressure could potentially operate as both a threat and an incentive simultaneously, depending on the outcome measured.

In a test of the role of effort on adults’ working memory, Hayes et al. (2009) manipulated the degree to which a categorization task required working memory resources and the degree to which adults could exert effort on the task. Informed by Eysenck et al.’s (2007) Attentional Control Theory, the authors theorized that opportunities for increased effort might moderate the effect of trait anxiety on participants’ performance on the working memory-demanding versions of the task. Accordingly, they found that highly anxious adults had worse category learning on the working memory-demanding task versions, but only if there was no opportunity to increase goal-related effort. High and low anxious adults learned equally from the working memory-demanding version of the task when provided an opportunity to exert more effort (Hayes et al., 2009), suggesting that increased effort can eliminate harmful effects of anxiety on task performance. Importantly, however, opportunities for effort were manipulated—it remains to be addressed to what extent individuals under pressure exert effort. Moreover, the authors examined changes in effort and performance in adults who differed in baseline trait anxiety. Does an exogenous source of pressure similarly facilitate adults' effort and performance on working memory-demanding tasks? We address these questions below.

1.6. Present Study

To the best of our knowledge, no work has concurrently examined changes in effort, working memory capacity, and anxiety in response to a social-evaluative performance pressure. Therefore, in Chapters 2 and 3, we manipulated performance pressure prior to adults' completing two tasks: the Operation Span Task (OSPAN; Unsworth et al., 2005), which is a dual-span working memory task, and a verbal reasoning task. We manipulated performance pressure using a performance-contingent social-evaluative pressure induction, such that one's performance determined another's receipt of a prize (e.g., Beilock et al., 2004). Specifically, participants in the pressure condition were told that they must perform at or above a certain percentile on both tasks in order for them and another participant to receive additional compensation. In an attempt to reduce any harmful effects of pressure, a reappraisal prompt was also manipulated for some in the pressure condition. However, it is not the focus of this analysis, since the pressure did not reduce performance enough for any reappraisal effects to be measured.

Before and after the pressure manipulation, we assessed participants' performance on the two tasks and their self-reported stress, anxiety, and motivation. In addition to measuring the impact of pressure on demonstrated ability, we examined differences in perceived ability—here operationalized as participants' confidence in their performance upon conclusion of the tasks

(Beilock et al., 2004). Lastly, our mediator of interest was participants' exerted effort on the working memory task. Congruent with prior work that uses time on task as a measure of exerted effort under pressure (e.g., Attali, 2016; Castro et al., 2018), we assessed effort using a measure of response time during the working memory task.

We used the same procedure, manipulations, and measures in the experiments reported in Chapters 2 and 3, with one critical difference. In Chapter 2, we report on a standard administration of the OSPAN. This included performance feedback after every test trial. Feedback might have alleviated any anxiety-inducing impacts of pressure insofar as participants were provided insight into their performance. Performance pressure may be incentivizing in cases when one knows they can attain the goal, either because they are certain in their ability, or because they receive feedback that indicates as much. Conversely, pressure might be threatening when one is less certain. Given that some research finds that demonstrated working memory capacity increases with the provision of feedback (e.g., Adam & Vogel, 2016), we removed the feedback from the OSPAN in Chapter 3 so that participants could not predict their accuracy. We believed this uncertainty might make the pressure manipulation more threatening, as theoretical work underscores the importance of uncertainty in anxiety (see Grupe & Nitschke, 2013; Hirsh et al., 2012).

In Chapter 2, we narrow in on the mechanisms that might explain when pressure threatens or incentivizes performance. We examine the impacts of a performance-contingent, social-evaluative pressure induction on participants' affective and performance outcomes. In particular, we assessed adults' performance on a working memory task and a verbal reasoning task, their confidence in their performance on the tasks, and changes in self-reported stress, anxiety, and motivation after pressure. Furthermore, we examined changes in effort on the working memory task under pressure, and whether effort mediated the effect of pressure on performance.

2. Methods

2.1. Participants

157 participants were recruited from online research study databases or flyers across two data collection sites: universities in Chicago, IL and Irvine, CA. Recruitment materials advertised a cover story stating that the purpose of the study was to validate new thinking and reasoning tasks. We conducted a power analysis to determine the minimum sample size required. We used Johns et al. (2008; Study 3; $d = 0.26$) as a guide, as our original study design had a similar repeated measures design with three conditions (see Procedure for detail on omitted condition). At alpha = 0.05 and power = 0.80, we estimated the minimum sample size to be 126. With a larger sample and fewer conditions, we believe we are sufficiently powered to explore the intended main effects while also controlling for additional factors like baseline performance.

Participants were dropped from analyses for misunderstanding the task instructions (n = 2), experimenter error (n = 1), computer malfunction (n = 5), guessing the confederate (n = 3), or failing to complete the task due to too much stress (n= 1), for a total of 145 participants (n_{Chicago} = 95; n_{Irvine} = 50; M_{age} = 21.60 years, SD_{age} = 4.39 years; 89 women). Participants were randomized within-site to either pressure (n = 96) or control (n = 49) conditions. Half of the pressure participants (n = 48) were randomly assigned to receive a positive reappraisal message, prompting them to positively reframe any feelings of stress or anxiety as advantageous for performance. The other half (n = 48) did not receive an additional prompt. Though similar positive reappraisal prompts have been shown to improve performance and reduce negative emotions under pressure (Johns et al., 2008), we did not find this to be the case[2] (see Supplemental Materials for full reappraisal prompts). Therefore, we collapsed across reappraisal and no reappraisal conditions to create one pressure condition (n = 96). Informed consent was obtained for all participants.

2.2. Procedure

The study procedure was comprised of two blocks. In Block 1, we assessed participants' baseline performance on the two tasks and their baseline affect during the tasks. Then, in Block 2, participants received pressure or control manipulations and again completed the two tasks and reported their affect. Study materials were presented using E-prime 3.0 for Windows. Afterwards, participants provided demographic information and reported their confidence in their performance.

2.2.1. Pressure Protocol. Modeled after prior research (e.g., Beilock et al., 2004; see Dickerson & Kemeny, 2004), the pressure manipulation was comprised of a social component (peer pressure due to shared consequences) and two evaluative components (progress tracking by an authority and peer evaluation). Upon entering the lab, participants in the pressure condition were greeted by an experimenter and escorted to a waiting area, where a confederate was seated. The two remained seated in the waiting area for three minutes while the experimenter prepared the study materials. Then, the experimenter returned and provided instructions verbally to both confederate and participant. To bolster the later pressure manipulation, the experimenter told

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[2] The pressure and reappraisal conditions had no differences in their changes in self-reported anxiety ($t(94) = -0.66$, $p = .51$), stress ($t(94) = -0.76$, $p = .45$), or motivation ($t(94) = 0.22$, $p = .82$). Moreover, there were no differences in their overall average performance on the working memory task ($F(1,93) = 0.69$, $p = .41$) or the verbal reasoning test ($F(1,93) = 1.14$, $p = .29$) conditional on Block 1 performance. The conditions had equal confidence in their performance on the tasks, conditional on their actual performance ($F(1,93) = 1.25$, $p = .27$).

both individuals that they would collaborate on the second half of the task. Then, the confederate and participant were escorted to different testing rooms for the remainder of the study.

Participants first completed a 13-item "Partner Questionnaire" created by the researchers and intended only to bolster the confederate's role in the experiment (e.g., "When working with others, I tend to take the lead on projects"). Then, the researcher introduced the tasks to the participant and informed them that the researcher would monitor their progress and accuracy via an iPad application, which was shown to the participant (the "application" was, in fact, a spreadsheet). Afterwards, the participant began Block 1, during which they completed an abbreviated version of the working memory task and a verbal reasoning test. They were prompted to report their affective state periodically. Both tasks and all instructions were presented on a computer. Student responses for surveys and the verbal reasoning test were obtained via a packet. Task order was counterbalanced across participants.

Table 2.1.

Full condition manipulations and reminder prompts.

	Pressure	Control
Prompt	You have been randomly paired with another participant who is completing the same tasks. If you both score above 90% on the two reasoning tasks, you will both receive an additional $5 for participating in our study. However, if even one of you scores below 90% on either task, neither of you will receive the $5. Thus, it is important that you make as few mistakes as possible on the following two reasoning tasks.	Please pay close attention to the instructions provided on the screen and on your response packet. Remember, when you are done reading the instructions on the screen, you must click the mouse to continue to the next screen.
Reminder	Remember, you must keep a score of 90% or higher in order to ensure that you and the other participant receive the additional $5.	Remember, when you are done reading the instructions on the screen, you must click the mouse to continue to the next screen.

Note. Full prompts are provided at the beginning of Block 2. Reminders are provided immediately before each of the two tasks in Block 2.

In Block 2, participants received pressure prompts followed by the tasks (see Table 2.1 for full condition manipulations). Pressure participants read a prompt stating that they had been paired with another participant (presumably the confederate) who was also completing the tasks, and that they must perform above 90% on the tasks, otherwise they and the other participant would not receive an additional $5. Participants were reminded that the researchers could monitor their task progress and accuracy. Social-evaluative threats like these have reliably been shown to both incentivize performance (e.g., Boksem et al., 2006) and induce choking under pressure (e.g., Beilock et al., 2004; see Dickerson & Kemeny, 2004). This prompt was followed by a 190 second pause, during which the screen read “Please wait a few minutes while the task configures.” This pause was intended to provide adequate time for the participants to reflect on the pressure prompt and for any feelings to intensify prior to completing the tasks (Sheppes & Meiran, 2008). After the pause, participants completed the full-length working memory task and another verbal reasoning test. Task order was again counterbalanced. To prevent forgetting, brief reminders of the pressure prompt were provided twice, each time occurring after the instructions of a task but before the test trials began.

Upon completion of Block 2, the experimenter returned, provided the participant with a demographic questionnaire, and assessed their confidence in their performance overall. Afterwards, all participants were debriefed and received the additional $5.

2.2.2. Control Protocol. We used an identical procedure for the control group, with three exceptions. First**,** there was no confederate in the waiting area. Second, the control group was not administered the Partner Questionnaire. Lastly, participants in the control were not informed of a performance criterion, nor were they informed that the researchers would monitor their progress and accuracy. Rather, they were simply asked to continue paying attention (see Table 2.1).

2.3. Measures

2.3.1. Working Memory. Working memory capacity was assessed twice for each participant. In Block 1, we used an abbreviated version of the Operation Span Task (OSPAN) to assess baseline working memory capacity (Foster et al., 2015). The working memory test trials are comprised of a maintenance period, in which participants must maintain letters in memory while attending to distracting information (whether an arithmetic solution is true or false), and a recall period, in which participants must recall the order of the presented letters. Participants completed five test trials which varied in length from three to seven letters to be memorized, for a total possible score of 25 letters correctly memorized in order. Test trials of differing set sizes were presented in random order, and all participants completed all set sizes. In Block 2, we assessed working memory capacity with the full-length version of the OSPAN (Unsworth et al., 2005), which is three times longer than the abbreviated OSPAN, for a total possible score of 75 letters correctly memorized in order. Working memory capacity was measured as the proportion correct out of 25 (Block 1) or 75 (Block 2). Performance feedback was provided for all test trials. Importantly, participants were unaware as to which parts of the task were distracting. As far as those under pressure knew, performance on both the maintenance and recall periods were evaluated as part of the 90% criteria for reward.

2.3.2. Effort. Response time is a commonly used measure of exerted effort under pressure (e.g., Attali, 2016; Castro et al., 2018). The reaction times during maintenance periods of the OSPAN test trials—when participants held letters in mind while performing arithmetic calculations—were extracted and averaged as a measure of participants' effort. Prior work has shown that the facilitative effects of pressure on working memory are greatest during these maintenance periods of working memory tasks (e.g., Zedelius et al., 2011). Effort on the working memory task during Blocks 1 and 2 was measured as the average amount of time (in seconds) participants spent evaluating each arithmetic solution, from the onset of the solution display to the time the participant advanced to the next screen.

2.3.3. Verbal Reasoning Test. Performance on a verbal reasoning test was also assessed at Block 1 and Block 2. We used sentence equivalence questions from the verbal reasoning section of a Graduate Record Exam practice software (Magoosh: https://gre.magoosh.com) to contrast changes in available working memory capacity specifically with performance changes on tasks assessing multiple facets of cognition under pressure. For each forced-choice verbal reasoning question, participants were provided a sentence containing two blanks and were asked to choose the two appropriate words (of six possible choices) to fill the blank. These verbal reasoning questions consist of recall and inferencing processes: The test requires participants to draw from their vocabulary to select the most appropriate words, interpret the context of the sentence with and without the chosen words, and align and integrate the chosen words into the sentence. Thus, these questions are not working memory-independent, yet their reliance on prior knowledge means that performance is less reliant on working memory capacity than the OSPAN, allowing us to contrast changes in working memory with changes in test performance.

We made two sets of verbal reasoning questions for Block 1 and 2, and counterbalanced the order across participants. Order was unrelated to performance at Block 1 ($t(143) = -1.58$, $p = .11$) and Block 2 ($t(143) = -1.21$, $p = .23$). For each set, we chose four questions labeled as easy, four medium, five hard, and five very hard for a total of 18 questions per set. Participants received 1 point for every question, for a total possible score of 18. Partial credit (0.5 points) was provided. Verbal reasoning performance at Blocks 1 and 2 was measured as the proportion correct out of 18. Performance feedback was not provided. We did not assess response time for the verbal reasoning test.

2.3.4. Affect. Eleven times across Blocks 1 and 2, participants were prompted to report on the extent to which they were experiencing each of three affective states: stressed, anxious, and motivated. For each state, they were asked to use a 9-point Likert scale (1: *Not at all anxious*; 5: *Moderately anxious*; 9: *Highly anxious*; Sheppes & Meiran, 2008) to "please circle the value corresponding to the extent to which you are experiencing the word right now, in this moment." Baseline anxiety, stress, and motivation are measured as the average value the participant reported for the six affect items in Block 1 before the condition manipulations, and post-manipulation scores are the average value for the five affect items occurring after the pressure manipulation. In analyses, we report change in affect as the difference between Block 2 and Block 1 averages.

2.3.5. Confidence. After Block 2, we assessed participants' confidence using the same 9-point Likert Scale as above (1: *Not at all confident*; 5: *Moderately confident*; 9: *Highly confident)*. Participants were asked to reflect on their performance across both blocks and use the scale to report the extent to which they agreed with the statement: "I think I did well on the tasks."

3. Results

3.1. Analytic Plan

Our research questions center on the impacts of pressure on performance, affective, and metacognitive outcomes. First, we test main effects of the pressure manipulation on demonstrated working memory capacity, and we test whether increased effort mediates the impact of pressure on working memory performance. Second, we explore the effect of pressure on verbal reasoning performance. For analyses of task performance, we control for participants' Block 1 performance when analyzing Block 2 performance. Third, we test the impact of pressure on participants' changes in self-reported affect, followed by their confidence judgments. We use regressions to explore our primary analyses of the impact of our pressure manipulation (binary coded: 0 if control, 1 if pressure) on all outcomes. School is included as a covariate in all regressions, as differences in baseline performance and affect emerged across sites[3]. Standardized beta coefficients and standard errors are reported for all regressions.

3.2. Working Memory Performance

3.2.1. Working Memory Capacity. Descriptive statistics for participants' working memory capacity are provided in Table 2.2. Overall, participants performed fairly well on the working memory task: They recalled 84% (*SD* = 0.14; range = 0.28, 1.00) of the items in the correct order at baseline, and this score increased to 87% (*SD* = 0.12; range = 0.24, 1.00) at Block 2. A regression revealed a main effect of condition on participants' overall working memory capacity (β = 0.49, *SE* = 0.15, *p* = .001). Those in the pressure condition (*M* = 0.89, *SE* = 0.01) had significantly higher working memory capacity scores at Block 2 than the control (*M* = 0.83, *SE* = 0.01).

We next explored whether the effects of pressure varied across the level of trial difficulty. Working memory task trials varied in length from three to seven items to remember. We ran regressions for each of the set sizes, conditioning on their Block 1 performance at each set size.

[3] We examined differences between schools in their performance and affective responses, as one school is an elite private institution and the other a public state institution. At baseline, participants at Chicago had lower stress (β = -0.20, *SE* = 0.08, *p* = .01), higher working memory (β = 0.18, *SE* = 0.08, *p* = .03), and higher verbal reasoning (β = 0.50, *SE* = 0.07, *p* < .001) compared to Irvine participants. Thus, we control for school in all analyses. When split by school, the relationship between pressure and performance on both tasks remained consistent with the overall analysis, though we lose power due to the smaller sample sizes.

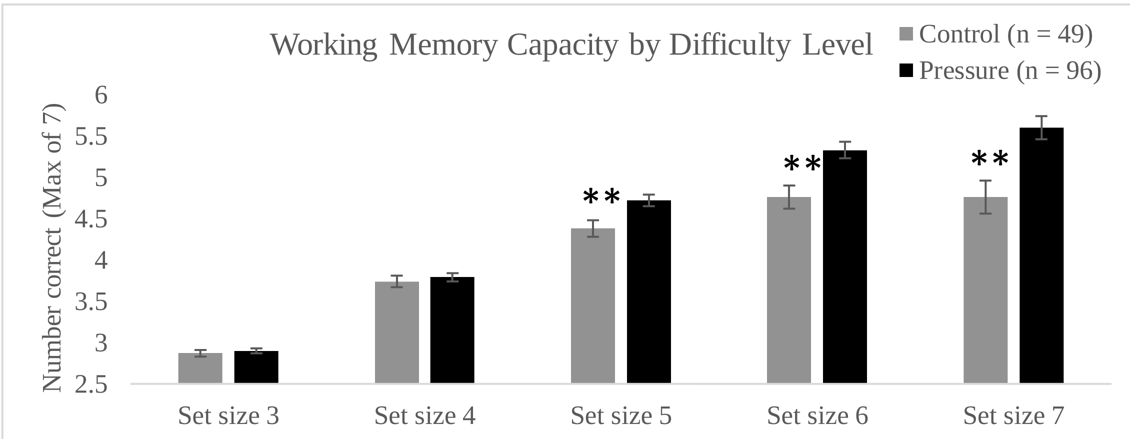
Table 2.2.

Chapter 2 participants' average affective response, working memory performance and response time (RT), verbal reasoning performance, and confidence at Blocks 1 and 2.

M (SD)	Control (*n* = 49)		Pressure (*n* = 96)		Overall (*N* = 145)	
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
Affect Self-Report (out of 9)						
Anxiety	3.43 (1.83)	3.25 (2.00)	3.53 (1.67)	3.82 (1.87)	3.49 (1.72)	3.63 (1.93)
Stress	3.63 (1.80)	3.40 (1.93)	4.07 (1.86)	4.28 (1.91)	3.92 (1.84)	3.98 (1.96)
Motivation	4.89 (2.00)	4.28 (2.09)	4.86 (1.75)	4.84 (1.93)	4.87 (1.83)	4.65 (2.00)
Working Memory						
RT during maintenance (Effort, in seconds)	2.19 (0.89)	1.70 (0.76)	2.17 (0.83)	1.88 (0.78)	2.18 (0.85)	1.82 (0.78)
Accuracy during maintenance (% correct)	0.92 (0.08)	0.91 (0.08)	0.93 (0.06)	0.94 (0.05)	0.93 (0.07)	0.93 (0.06)
Working Memory Capacity						
Set size 3	2.84 (0.56)	2.86 (0.36)	2.91 (0.42)	2.90 (0.25)	2.89 (0.47)	2.89 (0.29)
Set size 4	3.58 (0.97)	3.73 (0.53)	3.83 (0.48)	3.80 (0.46)	3.75 (0.69)	3.78 (0.48)
Set size 5	4.42 (1.25)	4.34 (0.92)	4.38 (1.31)	4.73 (0.52)	4.40 (1.29)	4.60 (0.70)
Set size 6	4.09 (2.16)	4.66 (1.34)	4.90 (1.62)	5.36 (0.71)	4.63 (1.85)	5.13 (1.02)
Set size 7	4.82 (2.12)	4.67 (1.65)	5.36 (1.88)	5.63 (1.18)	5.18 (1.98)	5.31 (1.42)
Overall % Correct	0.81 (0.17)	0.82 (0.16)	0.85 (0.13)	0.90 (0.09)	0.84 (0.14)	0.87 (0.12)
Verbal Reasoning Performance						
Easy (out of 4)	3.15 (0.89)	3.04 (0.95)	3.34 (0.88)	3.50 (0.70)	3.28 (0.88)	3.34 (0.82)
Medium (out of 4)	2.48 (1.10)	2.35 (1.08)	2.55 (0.95)	2.82 (0.86)	2.52 (1.00)	2.66 (0.97)
Hard (out of 5)	2.42 (1.17)	2.32 (1.13)	2.74 (1.02)	2.78 (1.02)	2.63 (1.08)	2.62 (1.08)
Very Hard (out of 5)	1.94 (0.93)	2.07 (0.99)	2.10 (0.93)	2.07 (0.89)	2.04 (0.93)	2.07 (0.92)
Overall % correct	0.56 (0.18)	0.54 (0.19)	0.60 (0.16)	0.62 (0.15)	0.59 (0.17)	0.59 (0.17)
Confidence Self-Report (out of 9)	--	4.63 (1.93)	--	4.57 (1.93)	--	4.59 (1.92)

Figure 2.1.

*Chapter 2 participants' average Block 2 working memory capacity at each set size of the working memory task, conditional on school and Block 1 performance. Error bars are ± 1 standard error. ** p < .01*



The impacts of pressure were focused on the higher difficulty items (see Figure 2.1). There were no effects of pressure on trials of set size 3 (β = 0.09, *SE* = 0.18, *p* = .62) or set size 4 (β = 0.10, *SE* = 0.19, *p* = .58). Conversely, the pressure group had significantly better performance than the control group on trials of set size 5 (β = 0.50, *SE* = 0.18, *p* = .006), set size 6 (β = 0.56, *SE* = 0.18, *p* = .002), and set size 7 (β = 0.59, *SE* = 0.18, *p* = .001).

3.2.2. Effort. We use participants' average response time during the maintenance periods of the working memory task to assess exerted effort. Participants performed well on this component of the working memory task, correctly evaluating 93% (*SD* = 6%) of the arithmetic solutions at Block 1. Pressure and control conditions did not differ in their arithmetic accuracy (β = 0.23, *SE* = 0.18, *p* = .19), nor did they differ in their average response time on these items at Block 1 (β = 0.001, *SE* = 0.17, *p* = .99; see Table 2.2 for means). Moreover, response time did not predict arithmetic accuracy (β = 0.05, *SE* = 0.09, *p* = .58), though it did predict working memory capacity (β = -0.24, *SE* = 0.08, *p* = .004). Those who were faster at evaluating the arithmetic solution had lower recall performance at Block 1.

In Block 2, effects of pressure emerged. The pressure group had higher accuracy (β = 0.33, *SE* = 0.16, *p* = .04) and had a slower average response time (β = 0.24, *SE* = 0.10, *p* = .02) on the arithmetic items compared to the control group. In Block 2, response time predicted higher accuracy on the arithmetic items (β = 0.62, *SE* = 0.12, $p < .001$) and higher working memory capacity (β = 0.37, *SE* = 0.12, *p* = .003). Those who spent more time evaluating the arithmetic items had higher accuracy on all parts of the working memory task.

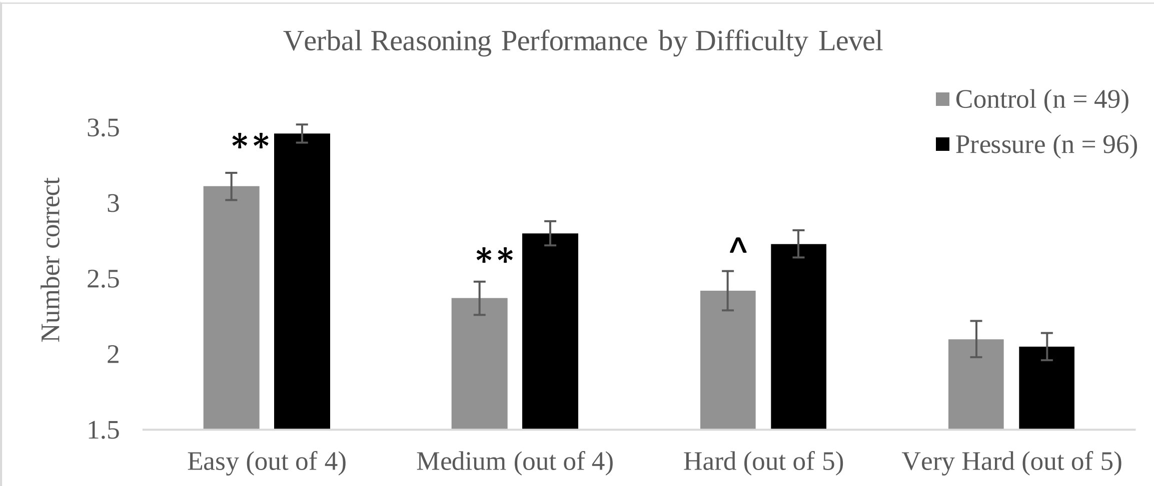
It could be the case that faster reaction times came at a cost to participants' accuracy. To address this, we re-ran this analysis using average response time on only the arithmetic items for which the participants were accurate. All results held[4], suggesting the pressure condition's gains were not due to a speed-accuracy tradeoff. Rather, pressure seemed to motivate participants to take their time, which was related to better performance on the working memory task.

3.2.3. Mediation. Given the relations between pressure, effort, and working memory performance, in conjunction with theory linking performance pressure gains to effort, we next explored the mediational role of increased effort on working memory capacity gains. Using Hayes' (2013) PROCESS model (Model 4; 5,000 bootstrapped samples), we tested whether pressure (independent variable) increased working memory capacity (dependent variable) through increased effort (response time; mediator). We conditioned our mediation analysis on subjects' school and their Block 1 working memory capacity and effort. We found a direct effect of pressure on subjects' working memory capacity (*b* = 0.05, *SE* = 0.02, *p* = .007), and critically,

[4] We re-ran the analyses of effort after reducing the response time measure to include only the trials on which the participant was accurate ($M_{Block\ 1}$ = 2.37; $SD_{Block\ 1}$ = 0.97; $M_{Block\ 2}$ = 1.96, $SD_{Block\ 2}$ = 0.82). The pressure group had longer response time on Block 2, conditional on their Block 1 response time (β = 0.25, *SE* = 0.10, *p* = .02). Block 2 response time predicted higher accuracy on the arithmetic items (β = 0.39, *SE* = 0.14, *p* = .005) and on the working memory task (β = 0.30, *SE* = 0.14, *p* = .03) conditional on their Block 1 performance and response time. All results were consistent with the original measure of effort across both studies.

Figure 2.2.

*Chapter 2 participants' average accuracy for the easy, medium, hard, and very hard verbal reasoning items, conditional on school and Block 1 performance. Error bars are ± 1 standard error. ^ $p < .10$ ** $p < .01$*



a significant indirect effect of effort (b = 0.009, SE = 0.006, 95% confidence interval = [0.0005, 0.0227])[5]. Pressure increased participants' working memory capacity via increased effort on the task.

3.3. Verbal Reasoning Performance

We next examined participants' performance on a relatively less working memory-demanding, yet academically challenging, verbal reasoning test. Descriptive statistics are provided in Table 2.2. No effects of condition emerged in Block 1 performance (β = 0.22, SE = 0.15, p = .16). However, in Block 2, the pressure group had higher accuracy than control (β = 0.29, SE = 0.12, p = .01). We ran separate regressions at each difficulty level. Unlike the working memory patterns, verbal reasoning gains from pressure were focused on the easier items

[5] In the PROCESS model, the indirect effect estimate is obtained as the product of two estimated coefficients that do not have an asymptotic sampling distribution, which means that the central limit theorem does not apply to this estimation of the mediation model. The PROCESS model utilizes bootstrapping methods to obtain the confidence interval, which is asymmetric. This means that the estimation of the confidence interval obtained from the PROCESS model is quite similar, but not mathematically equivalent to, the standard calculation of a confidence interval under the assumptions of the central limit theorem.

(Figure 2.2). The pressure group had significantly higher accuracy on the easy (β = 0.43, *SE* = 0.13, *p* = .001), medium (β = 0.45, *SE* = 0.15, *p* = .003), and hard (β = 0.28, *SE* = 0.14, *p* = .05) items. There were no effects of pressure for very hard items (β = -0.06, *SE* = 0.16, *p* = .72).

3.4. Affect

Descriptive statistics for participants' self-reported affective experience are provided in Table 2.2. Regressions revealed a significant effect of condition on participants' average change in anxiety (β = 0.56, *SE* = 0.16, *p* = .001), stress (β = 0.45, *SE* = 0.17, *p* = .01), and motivation (β = 0.65, *SE* = 0.17, *p* < .001) from Block 1 to Block 2. On average, participants in the pressure condition saw increases in self-reported anxiety and stress, whereas those in the control condition saw decreases in these experiences (see Figure 2.3). Conversely, the control group saw a drastic, significant decrease in their motivation over the course of the study. Pressure seemed to buffer from this loss in motivation, as the pressure group had changes in motivation that were not different from zero.

Figure 2.3.

*Chapter 2 participants' average change in affect from Block 1 to Block 2, conditional on school. Error bars are ± 1 standard error. * p < .05   ** p < .01   *** p < .001*

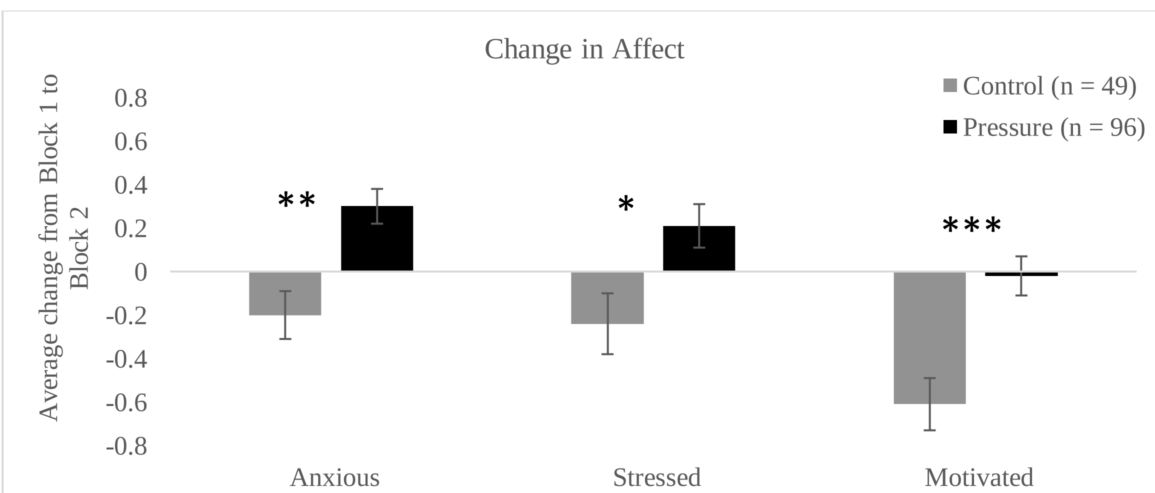


Table 2.3.

Correlations between Chapter 2 participants' changes in affect and performance on the Block 2 tasks.

	1	2	3	4	5
1. Change anxiety	1				
2. Change stress	0.54***	1			
3. Change motivation	0.06	0.24**	1		
4. Working memory – Overall	-0.02	-0.04	0.18*	1	
5. Verbal reasoning – Overall	-0.14^	0.10	0.33***	0.27***	1

Note. ^$p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

3.4.1. Relations Between Affect and Performance. Overall, changes in affect were positively correlated with each other, with the exception of changes in anxiety and motivation (see Table 2.3). Changes in motivation were positively correlated with participants' overall performance on both the working memory task ($r(143) = 0.18$, $p = .03$) and the verbal reasoning test ($r(143) = 0.33$, $p < .001$). Changes in anxiety and stress had comparably smaller and nonsignificant relations to task performance, suggesting the changes in motivation are particularly important to performance.

3.5. Confidence

Lastly, we asked whether participants' confidence in their performance, like their actual performance, was also influenced by pressure. We compared participants' response to the item "I think I did well on the tasks," while controlling for their overall performance in Block 2. Overall performance here was calculated as the average of their Block 2 working memory capacity and verbal reasoning performance ($M = 0.73$, $SD = 0.12$; range = 0.34, 0.93). We found no difference between pressure ($M = 4.72$) and control ($M = 4.53$) in their confidence ($\beta = -0.11$, $SE = 0.19$, $p = .55$), despite the fact that the pressure group actually outperformed the control on both tasks. In fact, conditional on their Block 1 overall performance ($M = 0.72$, $SD = 0.13$; range = 0.31, 0.97), there was a moderate, positive correlation between confidence and Block 2 performance for the control group ($r(46) = 0.29$, $p = .04$), yet performance and confidence were unrelated for those under pressure ($r(93) = 0.06$, $p = .60$). Pressure compromised metacognitive judgements.

4. Discussion

Across two different, yet cognitively challenging tasks, we found that pressure promoted adults' performance. Specifically, we found that a social-evaluative, performance-contingent pressure improved performance on the most demanding trials of a working memory task (Heitz et al., 2008; Jimura et al., 2010; Pochon et al., 2002; Savine et al., 2010). These performance gains were mediated by increased effort, consistent with theories of pressure as an incentive to deploy cognitive resources (Bonner & Sprinkle, 2002; Botvinick & Braver, 2015) and countering pressure-as-threat views (e.g., Beilock, 2008) arguing that pressure generates worries that consume working memory resources. We also found that pressure improved performance on the easier items of the verbal reasoning tasks (Kiplinger & Linn, 1996; O'Neil et al., 1996; 2005).

Combined, the performance and effort patterns suggest that the pressure manipulation was experienced as an incentive that optimized participants' performance. Participants' self-reported motivation to perform further confirmed this: those who received pressure were guarded against the significant loss in motivation experienced by those in the control. Critically, this change in motivation was most predictive of performance gains on both tasks. However, we also found evidence to suggest that pressure was experienced as a threat. Self-reported anxiety and stress increased among pressure participants, though these changes were comparably smaller and not predictive of their performance on the tasks. Moreover, confidence data suggests participants under pressure had undermined their performance, again in line with pressure-as-threat views (Beilock et al., 2004). Thus, there may be affective consequences for performance pressure that are not evidenced in test performance and may not move through a working memory pathway.

Chapter 3

Pressure as incentive and pressure as threat: Does heightening uncertainty change the effects of pressure?

1. Introduction

In Chapter 2, we find evidence to suggest pressure can both pose a threat to participants yet still increase their effort and performance. In Chapter 3, we explore whether manipulating levels of uncertainty while performing may influence the extent to which pressure changes affect and facilitates performance through effort.

Feedback signals the discrepancy between one's goal and one's current performance (see Hattie & Timperley, 2007). If one receives negative or no feedback, signaling a potential gap between current and desired performance, then it may induce uncertainty and subsequent worries about one's ability to perform. Indeed, uncertainty has received growing attention as core to anxiety (see Grupe & Nitschke, 2013; Hirsh et al., 2012), and we theorize that this may impact the extent to which a pressure manipulation is threatening or incentivizing. Conversely, receiving positive feedback may assuage feelings of uncertainty, indicating a more achievable goal. The extent to which feedback catalyzes effort expenditure may depend on whether the feedback leads one to believe success is achievable (Hattie & Timperley, 2007; Kluger & DeNisi, 1996). Informative feedback can alter working memory performance (Acklin, 2012; Adam & Vogel, 2016, 2018) and metacognitive awareness of one's performance (Adam & Vogel, 2018). For example, after participants completed one working memory task, but prior to the next, Acklin (2012) provided them with falsified negative or positive performance feedback. Receiving negative feedback harmed performance and positive feedback boosted performance (also see

Hodges & Spielberger, 1969). Receiving feedback during tests or working memory tasks can drastically change one's demonstrated performance and confidence.

In Chapter 2, we assumed that participants under pressure were uncertain about their ability to perform above 90% on the tasks. However, given that 39% of participants in Chapter 2 received a score above 90% on the Block 1 working memory task, and received trial-by-trial feedback indicating as much, perhaps many felt certain in their ability to achieve the 90% goal on Block 2. Put differently, pressure may have improved performance because participants knew there was little discrepancy between their current and goal performance, which could be quite motivating. Anecdotal insight from debriefing conversations suggested Chapter 2 participants were more certain of their working memory performance, because it provided trial-by-trial feedback, than they were of their verbal reasoning performance, which provided no feedback.

To better elucidate the conditions under which participants best perform, we ran an experiment identical to Chapter 2 with one key modification: We heightened uncertainty in the performance context by removing the trial-by-trial feedback participants received during the working memory task. Participants would receive no performance feedback during the experiment reported in Chapter 3.

2. Methods

2.1. Participants

In accordance with the power analysis conducted in Chapter 2, 230 participants were recruited from Chicago and Irvine sites. We recruited from the same online research study databases and flyers, and under the same cover story, as Chapter 2. Participants were dropped from analyses for misunderstanding the task instructions (n = 2), experimenter error (n = 2), computer malfunction (n = 4), or guessing the confederate (n = 5), for a total of 217 participants

($n_{\text{Chicago}} = 101$; $n_{\text{Irvine}} = 116$; $M_{\text{age}} = 22.29$ years, $SD_{\text{age}} = 5.29$ years; 168 women). Again, we had originally assigned participants to one of three conditions. However, we again found no differences between the reappraisal and pressure conditions on any of our measures[1], so we collapsed across these conditions. Participants were randomized within-site to either pressure ($n = 137$) or control ($n = 80$). All participants provided informed consent.

2.2. Procedure

Procedures and measures were identical to Chapter 2, with one exception. For both the abbreviated OSPAN (Block 1) and full-length OSPAN (Block 2) working memory tasks, we removed the feedback provided during the test trials. Typically, after each test trial, the task provides accuracy feedback (e.g., "You got 6 out of 7 letters correct. You made 1 math error(s) for this set of trials.") We removed these feedback statements. Instead, after each test trial in Blocks 1 and 2, participants would see a blank screen displayed for the same duration. Feedback provided during the practice trials was not removed. No other changes were made to the tasks. As in Chapter 2, feedback was not provided on the verbal reasoning test.

3. Results

3.1. Working Memory Performance

3.1.1. Working Memory Capacity. The analytical plan is identical to that used in Chapter 2, including the use of school as a covariate in all subsequent analyses[2]. Descriptive

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[1] The pressure and reappraisal conditions had no differences in their changes in self-reported anxiety ($t(135) = 0.17$, $p = .87$), stress ($t(135) = 0.65$, $p = .52$), or motivation ($t(135) = 1.62$, $p = .11$). Moreover, there were no difference in their overall average performance on the working memory task ($F(1,134) = 1.23$, $p = .27$) or the verbal reasoning test ($F(1,134) = 0.34$, $p = .56$) conditional on Block 1 performance. The conditions had equal confidence in their performance on the tasks, conditional on their actual performance ($F(1,134) = 0.51$, $p = .48$). In Chapter 3, we also administered a manipulation check, asking participants to report how often they tried to "Think about how your stress could actually help your performance" during the tasks (1: *Never,* 5: *Sometimes,* 9: *Always*). There was no difference between pressure and reappraisal conditions ($t(104) = 1.30$, $p = .20$).

[2] Chicago participants also had higher motivation ($\beta = 0.18$, $SE = 0.06$, $p = .007$), higher working memory ($\beta = 0.27$, $SE = 0.13$, $p = .05$), and higher verbal reasoning ($\beta = 0.97$, $SE = 0.12$, $p < .001$) compared to Irvine at baseline.

statistics for working memory performance are provided in Table 3.1. We found that the pressure condition had higher Block 2 working memory capacity compared to control (β = 0.22, *SE* = 0.11, *p* = .05). There was no effect of pressure on performance on the easiest trials (three: β = 0.17, *SE* = 0.13, *p* = .21), but effects of pressure emerged on the more demanding ones (four: β = 0.31, *SE* = 0.14, *p* = .02; five: β = 0.26, *SE* = 0.14, *p* = .06; six: β = 0.24, *SE* = 0.14, *p* = .08; seven: β = 0.28, *SE* = 0.14, *p* = .04; Figure 3.1).

3.1.2. Effort. We again used average response time on the arithmetic items to examine exerted effort. In Block 1, there were no differences in average response time (β = -0.09, *SE* = 0.14, *p* = .56) between pressure and control, though the pressure group had higher accuracy on the arithmetic items at Block 1 (β = 0.32, *SE* = 0.14, *p* = .03). Response time did not predict arithmetic accuracy (β = 0.11, *SE* = 0.07, *p* = .12), but it did predict overall working memory performance (β = -0.23, *SE* = 0.07, *p* = .001). Again, those with slower arithmetic speed performed better on the working memory task.

At Block 2, we found effects of pressure: The pressure group responded slower on average than control (β = 0.18, *SE* = 0.09, *p* = .05), though this did not correspond to group differences in arithmetic accuracy at Block 2 (β = 0.23, *SE* = 0.14, *p* = .11). Response time at Block 2 predicted arithmetic accuracy (β = 0.69, *SE* = 0.09, $p < .001$) and overall working memory capacity (β = 0.26, *SE* = 0.08, *p* = .001). There was no evidence for a speed-accuracy trade-off.[3]

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[3] We re-ran the analyses of effort after reducing the response time measure to include only the trials on which the participant was accurate ($M_{Block\ 1}$ = 2.69; $SD_{Block\ 1}$ = 1.22; $M_{Block\ 2}$ = 2.31, $SD_{Block\ 2}$ = 1.22). The pressure group had longer response time on Block 2, conditional on their Block 1 response time (β = 0.19, *SE* = 0.19, *p* = .02). Block 2 response time predicted higher accuracy on the arithmetic items (β = 0.34, *SE* = 0.11, *p* = .002) and on the working memory task (β = 0.26, *SE* = 0.09, *p* = .003) conditional on their Block 1 performance and response time. All results were consistent with the original measure of effort across both studies.

Table 3.1.

Chapter 3 participants' average affective response, working memory performance and response time (RT), verbal reasoning performance, and confidence at Blocks 1 and 2.

M (SD)	Control (*n* = 80)		Pressure (*n* = 137)		Overall (*N* = 217)	
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2
Affect Self-Report (out of 9)						
Anxiety	3.63 (1.90)	3.61 (2.13)	3.54 (1.73)	3.96 (1.98)	3.57 (1.79)	3.82 (2.04)
Stress	3.94 (2.11)	3.93 (2.18)	3.71 (2.02)	4.30 (2.07)	3.80 (2.05)	4.16 (2.11)
Motivation	5.28 (1.83)	4.63 (2.05)	5.01 (1.77)	4.90 (1.98)	5.11 (1.80)	4.80 (2.01)
Working Memory						
RT during maintenance (Effort, in seconds)	2.52 (1.11)	2.00 (1.01)	2.48 (1.18)	2.20 (1.21)	2.50 (1.15)	2.13 (1.14)
Accuracy during maintenance (% correct)	0.91 (0.09)	0.90 (0.09)	0.93 (0.06)	0.92 (0.09)	0.92 (0.07)	0.91 (0.09)
Working Memory Capacity						
Set size 3	2.85 (0.51)	2.83 (0.48)	2.88 (0.44)	2.88 (0.34)	2.87 (0.46)	2.86 (0.40)
Set size 4	3.65 (0.89)	3.68 (0.63)	3.73 (0.76)	3.82 (0.45)	3.70 (0.81)	3.77 (0.53)
Set size 5	4.33 (1.39)	4.26 (1.11)	4.46 (1.31)	4.49 (0.82)	4.41 (1.34)	4.40 (0.94)
Set size 6	4.39 (1.95)	4.78 (1.40)	4.83 (1.65)	5.07 (1.00)	4.67 (1.77)	4.97 (1.17)
Set size 7	4.74 (2.02)	4.62 (1.66)	4.93 (2.01)	4.97 (1.55)	4.86 (2.01)	4.84 (1.60)
Overall % Correct	0.80 (0.18)	0.81 (0.17)	0.83 (0.16)	0.85 (0.11)	0.82 (0.16)	0.84 (0.14)
Verbal Reasoning Performance						
Easy (out of 4)	3.27 (0.92)	3.22 (0.94)	3.32 (0.80)	3.27 (0.92)	3.30 (0.84)	3.25 (0.93)
Medium (out of 4)	2.65 (0.99)	2.63 (0.96)	2.42 (0.90)	2.55 (0.83)	2.51 (0.94)	2.58 (0.88)
Hard (out of 5)	2.43 (1.10)	2.62 (1.02)	2.61 (1.40)	2.52 (1.07)	2.54 (1.30)	2.56 (1.05)
Very Hard (out of 5)	2.12 (1.08)	2.22 (0.96)	1.93 (0.88)	2.08 (1.08)	2.00 (0.96)	2.13 (1.04)
Overall % correct	0.59 (0.18)	0.59 (0.17)	0.57 (0.15)	0.58 (0.16)	0.58 (0.16)	0.58 (0.17)
Confidence Self-Report (out of 9)	--	4.98 (1.84)	--	4.26 (1.72)	--	4.52 (1.80)

3.1.3. Mediation. We again tested the mediating role of effort on working memory capacity under pressure conditional on participants' school and Block 1 working memory performance and effort. Though there was no direct effect of pressure on performance (b = 0.02, SE = 0.01, p = .11), we found a significant indirect effect of effort (b = .006, SE = 0.005, 95% confidence interval = [0.0000, 0.0176])[4]. Again, working memory performance gains under pressure were due to increasing participants' effort on the task.

3.2. Verbal Reasoning Performance

Descriptive statistics for participants' verbal reasoning performance are provided in Table 3.1. Pressure and control participants performed equally well (β = 0.05, SE = 0.09, p = .60). Split by problem difficulty, we found no relation between pressure and performance (easy: β = 0.11, SE = 0.12, p = .36; medium: β = 0.15, SE = 0.12, p = .20; hard: β = 0.02, SE = 0.12, p = .87; very hard: β = 0.04, SE = 0.13, p = .78). The pressure group performed equally to the control at all difficulty levels (see Table 3.1).

3.3. Affect

Descriptive statistics for participants' average affect, performance, effort, and confidence are provided in Table 3.1. Regressions revealed a significant effect of condition on participants' average change in anxiety (β = 0.35, SE = 0.14, p = .01), stress (β = 0.46, SE = 0.14, p = .001), and motivation (β = 0.56, SE = 0.14, p < .001) from Block 1 to Block 2. Again, pressure increased participants' stress and anxiety on average, and buffered participants from a substantial loss in motivation experienced by those in control (see Figure 3.2).

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[4] Again, the PROCESS model utilizes bootstrapping methods to obtain the confidence interval, which is asymmetric, meaning that the estimation of the confidence interval obtained from the PROCESS model is quite similar, but not mathematically equivalent to, the standard calculation of a confidence interval.

Figure 3.1.

Chapter 3 participants' average Block 2 working memory capacity at each set size of the working memory task, conditional on school and Block 1 performance. Error bars are ± 1 standard error. ^ $p < .10$ * $p < .05$

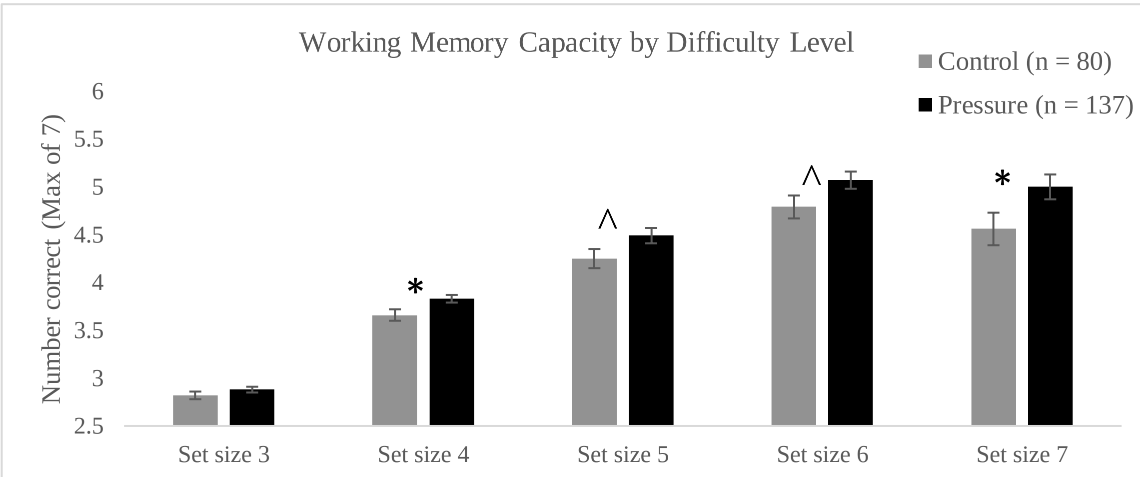
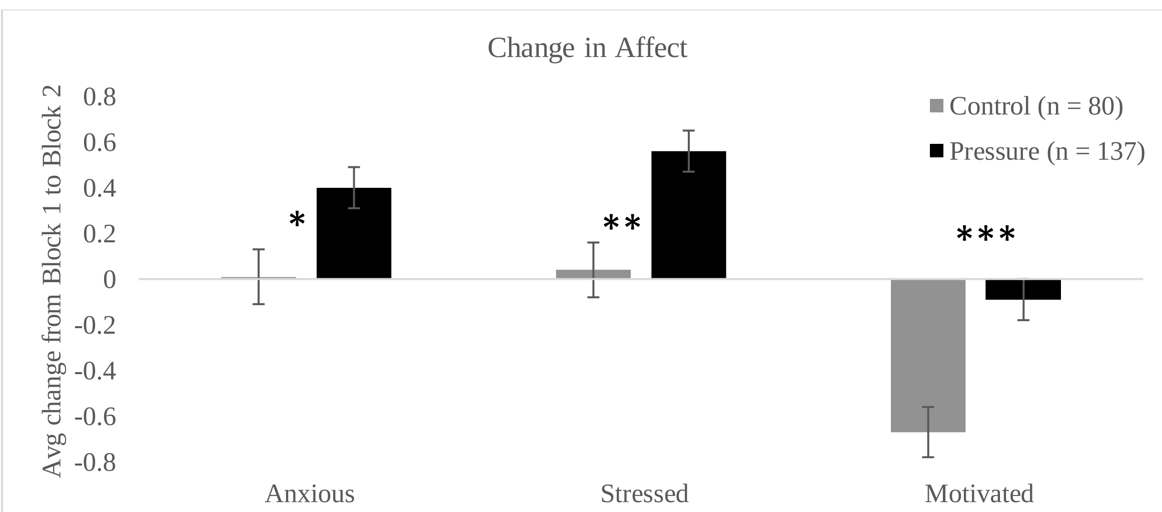


Figure 3.2.

Chapter 3 participants' average change in affect from Block 1 to Block 2, conditional on school. Error bars are ± 1 standard error. * $p < .05$ ** $p < .01$ *** $p < .001$



3.3.1. Relations Between Affect and Performance. Table 3.2 displays correlation matrices of affective responses and Block 2 working memory and verbal reasoning performance. Only changes in anxiety and stress were positively related to each other ($r(215) = 0.74$, $p < .001$).

Table 3.2.

Correlations between Chapter 3 participants' changes in affect and performance on the Block 2 tasks.

	1	2	3	4	5
1. Change anxiety	1				
2. Change stress	0.74***	1			
3. Change motivation	0.07	0.10	1		
4. Working memory – Overall	-0.001	-0.02	0.12^	1	
5. Verbal reasoning – Overall	-0.14*	-0.11^	0.20**	0.33***	1

Note. ^$p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Changes in motivation were not related to anxiety or stress, but they were significantly positively correlated with participants' performance on the verbal reasoning task ($r(215) = 0.18$, $p = .03$) and, to a lesser degree, their performance on the working memory task ($r(215) = 0.12$, $p = .08$). There were no significant relations to anxiety and stress on working memory performance.

3.4. Confidence

Conditional on their overall performance on both tasks in Block 2 ($M = 0.71$, $SD = 0.12$; range = 0.25, 0.96), the pressure group had lower self-reported confidence in their performance than control ($\beta = -0.39$, $SE = 0.13$, $p = .005$). This again was despite the fact that the pressure group performed at or above the control group on both tasks and at both timepoints. Partial correlations controlling for overall performance at Block 1 ($M = 0.70$, $SD = 0.13$; range = 0.32, 0.97) reveal that confidence for the control group ($r(77) = 0.31$, $p = .005$), but not the pressure group ($r(134) = 0.08$, $p = .34$), positively predicted performance. Again, pressure seemed to influence metacognitive judgements.

4. Discussion

In Chapter 3, we heightened uncertainty during performance by removing all feedback, replicating most Chapter 2 results and yielding larger magnitudes in affective changes. Like Chapter 2, pressure compromised metacognitive judgments, increased anxiety and stress, and maintained levels of motivation throughout the experiment relative to control, the latter of which again predicted performance on both tasks. Again, pressure improved performance on the working memory task, particularly on the higher-demand items, and the indirect effect of effort on working memory performance remained. However, without feedback on the working memory task, there was no direct effect of pressure on verbal reasoning performance, which was surprising given that feedback was never provided on that test.

4.1. Pressure and Effort

Our data highlight the important mediating role of effort in working memory capacity under pressure (Botvinick & Braver, 2015). Using a pre-post design, we add to this literature by showing that pressure can increase effort while simultaneously increasing stress and anxiety and compromising metacognitive judgements. Pressure improves performance by determining whether, how long, and to what extent individuals will recruit limited cognitive resources (Bonner & Sprinkle, 2002). Accordingly, participants under pressure had higher demonstrated working memory capacity compared to controls, particularly on the higher working memory-demanding items, and gains on the verbal reasoning test were concentrated on the easier items, where additional effort can facilitate performance without acquiring new vocabulary (see Bonner & Sprinkle, 2002). However, we are cautious without a direct measure of effort on the verbal reasoning test. Still, in the absence of pressure in laboratory research settings, where intrinsic motivation is quite low (Sharp et al., 2006), researchers may underestimate participants' cognitive performance.

4.2. Feedback

Removing feedback may also induce uncertainty during performance. Performance feedback indicates how far away one is from a desired goal, consequently signaling the need for greater effort (Hattie & Timperley, 2007). Feedback can be quite motivating if the distance is small (Kluger & DeNisi, 1996), which was true for most Chapter 2 participants. When we removed feedback on the working memory task in Chapter 3, the effects of pressure remained significant but decreased in magnitude, and similarly, we saw reduced benefits of pressure on the verbal reasoning test. The relation between the manipulation on the working memory task and performance on the verbal reasoning test was unexpected, and could indicate a possible spillover effect in Chapter 2, where receiving positive feedback on the working memory task motivated participants' performance on the verbal test.

Feedback is key for calibrating confidence and performance (Hattie, 2012). Yet, with and without feedback, those under pressure had lower-than-expected confidence. We provided outcome-level feedback, which can counterintuitively lower metacognitive accuracy during working memory performance, possibly by reducing the need for self-monitoring (Adam & Vogel, 2018). Conversely, process-level feedback can promote more adaptive mastery approaches (Pekrun et al., 2014; Hattie & Timperley, 2007). Beyond simply ameliorating uncertainty, such growth-focused feedback may encourage self-monitoring for those under pressure, which could further promote performance. Future work should manipulate type of feedback and pressure within the same study.

4.3. Choking under pressure?

We pursued working memory as a mechanism for disentangling the role of pressure on performance, as prior work has shown working memory performance can be facilitated (e.g., Heitz et al., 2008) and hindered (see Schmader et al., 2008) by pressure and feedback (e.g., Adam & Vogel, 2016). Importantly, we did replicate that working memory measures were not stable per person but rather varied according to the level of pressure and uncertainty, and thereby argue that these must be considered in any measurement endeavor.

Regarding the direction of these effects, we used the same social-evaluative pressure that others (e.g., Beilock et al., 2004) have reliably used to demonstrate the choking under pressure phenomenon, where increased anxiety generates worry that reduces available working memory resources (Ashcraft & Kirk, 2001; Beilock, 2008). Surprisingly, we found that this pressure improved performance on the highest working memory-demanding trials (Heitz et al., 2008; Jimura et al., 2010; Pochon et al., 2002). We offer two potential explanations.

First, in line with inverted-U models (Yerkes & Dodson, 1908), the social-evaluative manipulation could have induced an optimal amount of pressure—one that sufficiently motivates effort and increases performance without inducing excessive concern. Though participants under pressure reported greater increases in stress and anxiety than controls, their scores were typically below the midpoint of each scale—numerically consistent with research using the same manipulation to examine choking under pressure (e.g., Beilock et al., 2004; Sattizahn et al., 2016), suggesting that these manipulations might induce a moderate, optimal pressure. As we and others have argued, individual-level cognitive (effort; Eysenck et al., 2007) and task-level contextual factors (feedback; Bonner & Sprinkle, 2002) may also explain when these purportedly anxiety-inducing manipulations threaten or facilitate performance. Still, a more severe or less controllable pressure might not increase effort, which should be explored in future work.

Alternatively, participants may have avoided choking by preemptively regulating their emotions (Johns et al., 2008; Pochon et al., 2002), perhaps biasing our understanding of their internal states. Moreover, increased effort expenditure itself may indicate that one is attempting to compensate for heightened anxiety (Eysenck et al., 2007). Rarely do studies examining choking under pressure measure effort; those that do, however, emphasize the importance of simultaneously considering anxiety-effort relations (Hardy et al., 2007; Putwain & Symes, 2018).

4.4. Conclusion

To summarize, in Chapters 2 and 3 we showed that a transient, task-relevant, low severity, and controllable stressor facilitated performance by increasing participants' task-directed effort. Increasing uncertainty in the performance context did not markedly change the facilitating role of pressure. Combined with participants' small yet unpredictive increases in stress and anxiety, the findings in these chapters suggest that the performance pressure induced a moderate, optimal amount of arousal, placing individuals at the peak of the inverted-U parabola. As such, because arousal was already optimized, there likely was no need for individuals under pressure to regulate their arousal, hence rendering reappraisal unnecessary and perhaps explaining why there was no difference between reappraisal and pressure groups in any performance or affective outcomes.

In Chapters 4 and 5, I next report on studies in which we examined the arousal-performance relationship with a different stressor: distress about the COVID-19 pandemic. In contrast to the pressure induction, the COVID-19 pandemic is a more enduring, task-irrelevant, high severity, and uncontrollable stressor. We examined whether higher distress might in turn co-opt individuals' task-directed attention. Here, we tested the effects of COVID-19 distress on learning from a lesson, rather than cognitive performance as was done in Chapters 2 and 3. In Chapter 5, we also report on a study that examined whether emotion regulation strategies —here, reappraisal and mindfulness—could reduce the effect of distress on task-directed attention. We anticipated that these strategies for regulating emotions might have greater utility than in Chapters 2 and 3 if participants are experiencing high levels of distress.

Chapter 4

Distressed to distracted: COVID-19 distress threatens undergraduates' learning by increasing their mind wandering during instruction[1]

1. Introduction

It is no surprise that undergraduate students are under great distress during the novel coronavirus (COVID-19) pandemic. The pandemic has had far-reaching academic consequences, an early one for undergraduates being the need to rapidly modify their learning contexts away from in-person supports. This has transitioned to more stability in the learning context, though the medium has to date largely remained online. Though research has swiftly noted these increases in distress and warned of its impact on undergraduates' academic performance (e.g., Soria et al., 2020), little is known about the precise mechanisms by which pandemic-related distress may impact students' learning potential, providing little traction on strategies for best supporting learning when the stressor itself cannot be removed. While understanding the role of social-emotional wellness is a crucial one, we here aim to draw attention to a set of cognitive mechanisms that may underlie stress-performance relationships. We review literature drawn from learning in the context of other stressors and report data collected during the pandemic that has led us to propose a distressed-to-distraction pathway, such that COVID-19 distress may be compromising students' learning via increased distractibility during intervals of new learning and instruction.

Across Chapters 4 and 5, we used a controlled video lesson to show that students' distress regarding the pandemic threatens their learning by increasing mind wandering during the lesson. In Chapter 5 specifically, we explore the sources of their distress, and we test whether two

[1] A version of Chapters 4 and 5 is currently under review for publication.

emotion regulation strategies—mindfulness and stress reappraisal—may improve students' learning potential by reducing the frequency of mind wandering.

1.1. Undergraduate Distress During the COVID-19 Pandemic

Since the start of the pandemic, undergraduates have self-reported increased experiences of distress, anxiety, and depression (Son et al., 2020; Chirikov et al., 2020) to a greater degree than the general adult population (Wang et al., 2020). Longitudinal data show that these increases in distress, anxiety, and depression are considerably greater than typical years (Huckins et al., 2020; Zimmerman et al., 2020).

Like many adults, undergraduates share concerns about their health and safety, economic consequences of the pandemic, and social isolation (e.g., Zimmerman et al., 2020; Wang et al., 2020). Yet undergraduates carry the additional burden of rapidly navigating new online learning formats, which pose unique challenges, including completing demanding schoolwork in new, often distracting environments. Accordingly, national and university-wide surveys of undergraduates (Chirikov et al., 2020; Hoyt et al., 2020; Son et al., 2020; Soria et al., 2020; Zimmerman et al., 2020) and analyses of their social media content (Literat, 2021) reveal that concerns about academic success—particularly difficulties concentrating and increased distractions at home—are a primary stressor. These concerns have disproportionately affected women (Hoyt et al., 2020) and racial/ethnic minorities (Literat, 2021), particularly Latinx students (Zimmerman et al., 2020).

1.2. Distress, Mind Wandering, and Academic Performance

1.2.1. Distress and Academic Performance. Increased distress is a chief concern for students' academic performance during the pandemic. Prior to the pandemic, nearly half of undergraduates believed stress to be a major impediment to their academic performance

(American College Health Association, 2020) —a proportion that has grown since the pandemic began (Healthy Minds Network, 2020). Student perceptions align with reality: Experiencing excess stress in college has been linked to lower exam scores, lower course grades, and higher attrition rates (Amirkhan & Kofman, 2018; Zajacova et al., 2005). See Heissel et al. (2017) for how these factors might interact with students' marginalized identities.

1.2.2. Distress to Distraction. Despite the growing consensus that distress poses a threat to academic achievement, a critical, and to the best of our knowledge, unconsidered question is precisely *how* distress about the pandemic may impact learning and performance—information that would provide key insights for interventions to maintain students' academic success despite the continuing crisis.

Prevailing models (e.g., Blascovich & Mendes, 2010) describe stress as a balance between one's perceived coping resources and how demanding they believe the stressor to be. When one feels that a stressor exceeds their ability to cope (causing distress), it can become quite threatening for performance across a variety of domains, including cognitive performance (Blascovich et al., 1999). When one is distressed, it becomes difficult to focus on ongoing tasks, as the personal and often negative distressing thoughts are prioritized instead (Jamieson et al., 2012; see Matthews & MacLeod, 1994; McVay & Kane, 2010). Amirkhan and Kofman (2018) show that feeling overwhelmed with stress can induce long-term cognitive disruptions, including increased distractibility and decreased focus, much in line with undergraduates' stated concerns during the pandemic (Chirikov et al., 2020; Hoyt et al., 2020). Adjacent literatures examining choking under pressure and stereotype threat similarly find that negative affective experiences, like anxiety induced by stressful events, can generate intrusive, distracting worries that direct attention internally and away from the task at hand, leading to impaired test performance (see Beilock, 2008; Schmader et al., 2008) and learning (see Appel & Kronberger, 2012).

1.2.3. Mind Wandering. Behaviorally, these task-irrelevant and distracting cognitive intrusions may manifest as mind wandering (McVay & Kane, 2010). Mind wandering is a typically unintentional and unconscious redirection of attention from the external (e.g., an educational task) to the internal (e.g., personal concerns; Smallwood & Schooler, 2006), with consequences for test performance (see Randall et al., 2014 for a review) and potential cumulative effects for learning (see Smallwood et al., 2007). Mind wandering may be an important factor for online learning, particularly when students are distressed. Mind wandering is quite frequent during online lectures and can impair students' potential to learn from the lesson (Risko et al., 2012; Pan et al., 2020; see Schacter & Szpunar, 2015) and achieve longer-term outcomes, like high grades (Wammes et al., 2016b). We suggest therefore that feeling distressed during an online lecture may further impede students' learning potential. Mind wandering has been shown to mediate the relationship between daily life stressors (Banks & Boals, 2016) and experimentally induced stressors (Banks et al., 2015; Mrazek et al., 2011) on cognitive performance.

1.3. Emotion Regulation Interventions

Thus, to maximize students' learning potential, if distraction and mind wandering is the mechanism by which distress leads to reduced achievement, it will be important to support students in reducing the frequency of mind wandering, particularly during the pandemic when distress is elevated. One approach to reduce mind wandering is to help students monitor and redirect their attention (Szpunar, 2017): If stress causes one to divert attention inward, impairing performance, then can we help students change how they relate to their stressful thoughts so that they do not become distracting? Much research in emotion regulation has examined precisely that, finding that cognitive regulation strategies are most adaptive in academic performance contexts (see Harley et al., 2019). We test two of these strategies in Chapter 5: stress reappraisal and mindfulness. Though much of the evidence for their efficacy comes from studies conducted during in-person, pre-pandemic instruction, these strategies have both been shown to help students reduce their experiences of distress, maximize cognitive ability, and improve long- and short-term academic goals. Critically, both strategies underscore the role of attention in mitigating any impacts of distress on learning and performance (Johns et al., 2008; Mrazek et al., 2013; Schuster et al., 2015), making them choice candidates to aid students in attenuating mind wandering during learning.

1.4. Present Studies

A growing body of work has already shown that undergraduates, particularly students of historically marginalized identities, are under considerable distress during the pandemic, commonly reporting increased distractions and difficulty concentrating. Indeed, there is much concern about the extent to which the pandemic will impact academic success and achievement gaps now and in the future (Aucejo et al., 2020). However, relatively little is yet known about the precise mechanisms by which COVID-19 distress might impair students' potential to perform and learn —information that would provide key insights for interventions to maintain students' academic success despite the continuing crisis. Across Chapters 4 and 5, we narrow in on one possible mechanism by which pandemic-related distress may immediately compromise learning potential: mind wandering. We assess students' learning from a controlled, videotaped, online lesson. In Chapter 4, we measure COVID-19 distress in an undergraduate sample and report how distress threatens learning by increasing mind wandering. In Chapter 5, we replicate and extend findings from Chapter 4 by probing what students were distressed about and testing emotion regulation strategies as one way to mitigate the effects of distress on mind wandering during learning.

We had two primary aims in Chapter 4. First, we were interested to understand students' experiences during the pandemic and the extent to which the pandemic was causing them distress. Second, we explored whether and how distress had consequences for learning. We examined students' learning from a brief video lesson and tested whether distraction may be a key mechanism in distress-related decrements in learning.

2. Methods

2.1. Participants

Between May and June 2020, we recruited 258 students from six classes at a large public university that is a Minority-Serving Institution to participate in this study in exchange for a $20 Amazon gift card. Only the 204 (160 women) who finished the survey were included in analyses. The courses included two education courses (n = 54), two criminology courses (n = 99), and one biology course (n = 23). We also recruited students from a graduate-level education course (n = 25). Three students failed to provide course enrollment information. Student race/ethnicity largely mirrored the university's student body at large (44% Asian-American, 31% Latinx, 15% White, 1% Black, 9% Multiracial). Of these participants, 56% were first-generation university students.

2.2. Procedure

Students were informed that the purpose of the study was "to better understand the impact of course instructional strategies, as well as the unique social context and pressures during the time of the COVID-19 pandemic." All study materials were delivered to students via

Qualtrics. The study required approximately 45 minutes to complete and students were able to pause and resume the survey at their leisure. Students first provided informed consent, then completed a series of surveys assessing their pandemic-related distress and trait anxiety. Afterwards, they watched the video lesson, reported on their frequency of mind wandering during the lesson, and answered questions based on the video.

2.3. Measures

2.3.1. COVID-19 Distress. To assess students' distress regarding the COVID-19 pandemic, we administered the fifteen-item Impact of Events Scale (Horowitz et al., 1979). This is a widely used measure of subjective distress. Students used a 4-point Likert scale[2] (0: *Not at all;* 1: *Rarely*; 3: *Sometimes*; 5: *Often*) to report the extent to which they experienced certain thoughts or feelings towards the COVID-19 pandemic in the previous seven days (e.g., "I think about the COVID-19 pandemic when I don't mean to"). See Supplemental Materials for modified items. Internal consistency of the scale was satisfactory (Cronbach's $\alpha = 0.87$). Responses were summed to create a continuous measure of COVID-19 distress. A score between 0-25 corresponds to low-mild distress, 26-43 indicates moderate distress, and greater than 44 indicates severe distress. 26 is the recommended cut-off for clinical treatment (Horowitz et al., 1979; Sterling, 2008).

2.3.2. Trait Anxiety. We administered the Trait subscale of the State-Trait Anxiety Inventory (Spielberger & Gorsuch, 1983) in order to conceptually separate students' pandemic-related distress from their general tendency to be anxious. Students used a 4-point Likert scale (1: *Almost never* to 4: *Almost always*) to report the extent to which they had certain thoughts or

[2] We originally gave students a 4-point Likert scale with the same anchors and values 1-4. To be consistent with the original scale, and clinical severity interpretations, we rescaled students' responses to each item to correspond to the original 0-5 scale. We use these rescaled distress scores in all analyses. All results are consistent using either scale.

feelings (e.g., “I feel like a failure”) during the prior seven days. We reverse coded positively-framed items (e.g., “I am calm, cool, collected”), then summed across the twenty items to generate a continuous trait anxiety score.

2.3.3. Lesson and Learning. Students viewed a fourteen-minute neuroscience lesson in which the presenter detailed the neurological processes involved in song learning in birds and implicitly—but not directly—drew connections to the neuroscientific underpinnings of learning in humans. Thus, though the content presented was highly technical, the implications were quite general. The brief lesson-plus-comprehension check format closely aligns with highly-recommended asynchronous teaching methods common in remote learning contexts. After the lesson, students answered six multiple-choice comprehension items. Three of the items assessed students’ recall of the lesson content. The other three items assessed students’ higher order thinking, requiring students to infer and make connections beyond what was explicitly described in the lesson (see Supplemental Materials for comprehension items).

2.3.4. Mind Wandering. We assessed mind wandering during the lesson using the five-item Mind Wandering Questionnaire, modified to assess students’ mind wandering while they were watching the lesson (e.g., “During the lesson, I found myself listening with one ear and thinking about something else at the same time;” Mrazek et al., 2013). Students’ responses to the items (1: *Almost never* to 6: *Almost always*) were averaged to create a continuous measure of mind wandering.

2.4. Analytic Plan

First, we describe COVID-19 distress among our sample, using analyses of variance (ANOVAs) to explore differences among demographic groups. Then, we use regression analyses to test relations among COVID-19 distress, mind wandering, and learning during the lesson.

Lastly, we report a mediational analysis testing whether increased mind wandering served as a mechanism to explain theorized negative relations between distress and learning. Standardized beta coefficients and standard errors are reported. Full regression tables are provided in the Supplemental Materials.

3. Results

3.1. COVID-19 Distress

Descriptive statistics for all outcomes are provided in Table 4.1. Distress scores varied considerably with a slight positive skew (see Figure 4.1). COVID-19 distress positively correlated with trait anxiety ($r(202) = 0.35$, $p < .001$). On average, women experienced greater COVID-19 distress than men and gender-unspecified students ($F(2, 201) = 3.50$, $p = .03$, $\eta^2 = .034$). First-generation ($F(1, 202) = 0.11$, $p = .74$) and Latinx students ($F(1, 202) = 0.39$, $p = .53$) experienced similar distress to their peers. Of the sample, 45% met the criteria for moderate distress and 9% were severely distressed, a greater proportion of whom were women ($\chi^2(2) = 11.32$, $p = .003$).

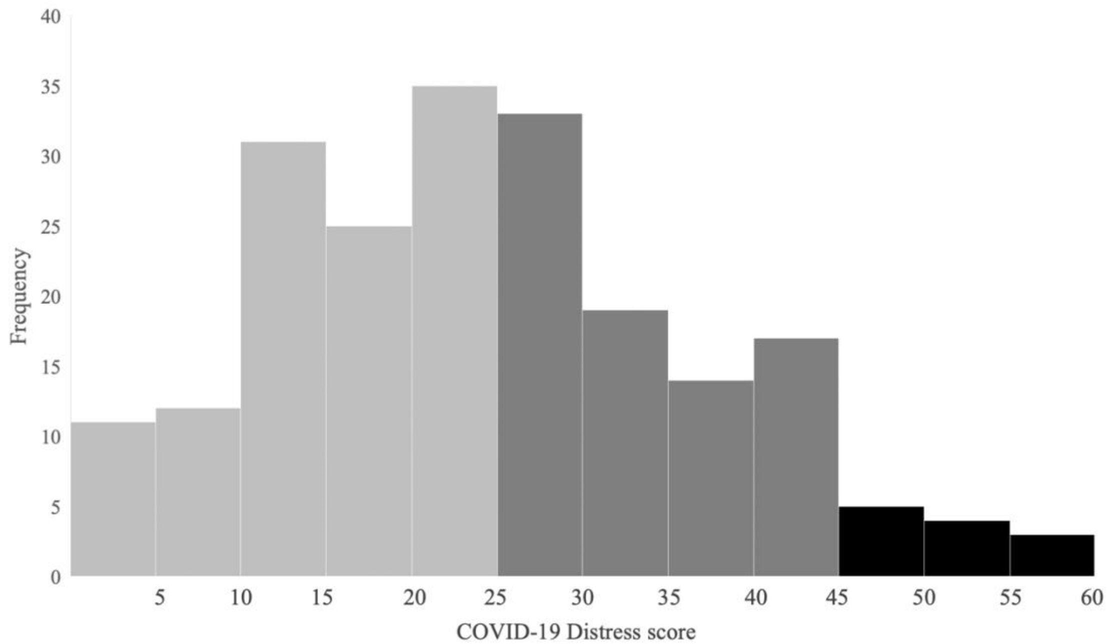
Table 4.1.

Descriptive statistics for all measures in Chapter 4.

Measure (range of scores)		*M (SD)*
Surveys		
	COVID-19 distress (0 - 75)	24.77 (12.44)
	Trait anxiety (20 - 80)	47.49 (11.31)
Lesson and Learning		
	Mind wandering (1 - 6)	3.36 (1.23)
	Question accuracy (0 - 6)	3.42 (1.56)

Figure 4.1.

Histogram of Chapter 4 COVID-19 distress scores, categorized by severity of distress. Light gray indicates low to mild distress, medium gray indicates moderate distress, and black indicates severe distress.



3.2. Learning and Mind Wandering

First, we examined impacts of COVID-19 distress on learning. We ran a regression analysis controlling for gender, given differences in distress, and controlling for course enrollment, given differences between classes in their accuracy on the items ($F(5,195) = 3.36$, $p = .006$). We also controlled for trait anxiety. COVID-19 distress was negatively related to learning from the lesson ($\beta = -0.22$, $SE = 0.07$, $p = .003$): Those who were more distressed about COVID-19 learned less.

We next tested mind wandering as a possible mechanism underlying distress-related differences in learning. A regression analysis revealed a positive relationship between COVID-19 distress and mind wandering during the lesson ($\beta = 0.21$, $SE = 0.07$, $p = .004$). Highly distressed students paid less attention to the lesson, even after controlling for their general anxious tendencies. Moreover, mind wandering during the lesson negatively predicted learning (β= -0.29, *SE* = 0.07, $p < .001$)—inattention came at a cost to learning gains.

3.2.1. Mediation. Given the relations between COVID-19 distress, mind wandering, and learning, we next tested whether mind wandering may mediate the relationship between COVID-19 distress (independent variable) and learning (dependent variable), conditional on students' gender, course enrollment, and trait anxiety using Hayes' (2013) PROCESS model. We found that mind wandering during the lesson mediated the effect of COVID-19 distress on learning (β = -0.06, *SE* = 0.03, 95% C.I.: [-0.11, -0.01]). This lends evidence to suggest that distress about the pandemic might harm learning potential by co-opting attention.

4. Discussion

To summarize, in this chapter (Chapter 4) we found that undergraduates—particularly women—were quite distressed about the COVID-19 pandemic. One in two students met the clinical criteria for treatment, and one in ten met the criteria for extreme distress. Moreover, we found that this distress impaired students' ability to learn from one brief neuroscience lesson by inducing mind wandering during instruction. These findings build on prior work establishing distraction due to mind wandering as an important mechanism underlying distress-related decrements in learning and performance (Banks & Boals, 2016; Banks et al., 2015; Mrazek et al., 2011). We add to this by showing the same pathway can explain how students' distress regarding the COVID-19 pandemic may also impact their learning, even in one brief learning opportunity.

Still, questions remained that we wished to address in Chapter 5. First, though the Impact of Events Scale provided a useful assessment of global distress, it was unclear what specifically about the pandemic might have caused students distress, and whether this may differ across student populations. Second, given the important mediating role of mind wandering, we next asked whether we could reduce the impact of distress on distraction by instructing students on how to regulate their feelings of stress prior to instruction.

Chapter 5

Can mindfulness or reappraisal instruction mitigate the effects of COVID-19 distress on distraction and learning?

1. Introduction

Recent work has called for research into how best to mitigate experiences of distress during the pandemic (Behan, 2020; Hagger et al., 2020). Two emotion regulation strategies have received growing support prior to and during the pandemic: stress reappraisal and mindfulness. Each is reviewed in turn.

One strategy to alleviate the deleterious impacts of stress on performance is to reframe how we think about stress in the first place. It is commonly believed that stress is debilitating for performance (Liu et al., 2017). However, recognizing the benefits of moderate stress and the functional purposes of stress responses can actually promote learning and performance (Crum et al., 2020). Stress reappraisal interventions highlight the adaptive functions of moderate stress—including heightened focus, mobilization of cognitive resources, and increased blood flow to the brain—and encourage participants to think about their stress as an asset when facing a stressor (Brooks, 2013; Jamieson et al., 2010).

Stress reappraisal may promote performance by reconceptualizing stress itself as a coping resource (see Jamieson et al., 2018). In other words, though students may initially feel distressed, reappraising their sensations and perceptions means that stress would not necessarily translate to distracting thoughts and worries, lower performance, and other typically debilitating consequences of stress. Additionally, if students' stressful and distracting thoughts are appraised as beneficial, rather than threatening, then they are less likely to engage in maladaptive coping strategies, like suppressing their thoughts and feelings, resulting in less mind wandering and improved performance (Johns et al., 2008; Schuster et al., 2015). Accumulating evidence shows that training undergraduates to reappraise their stress yields improvements in performance on stressful tests (Brooks, 2013; Jamieson et al., 2010; 2016; Johns et al., 2008) and increases in grades (Keech et al., 2018; 2021). These interventions are quick and oftentimes delivered via short informational videos (Crum et al., 2013; Keech et al., 2021). As such, recent work (Hagger et al., 2020) has called for researchers and practitioners alike to employ stress reappraisal strategies to reduce the psychological impact of the COVID-19 pandemic.

Another emotion regulation strategy recommended during the pandemic is mindfulness (Behan, 2020; e.g., Sweeny et al., 2020). Mindfulness is a practice aimed at being intentionally attentive to the present moment (Kabat-Zinn, 2003; Bishop et al., 2004) and is characterized by an ethos of metacognitive monitoring, nonjudgmental acceptance, and detachment (Lindsay & Creswell, 2019; Rahl et al., 2017). Like stress reappraisal, mindfulness practices, including mindfulness-based stress reduction interventions, can reduce the impact of stress on a variety of behavioral, affective, and cognitive indices (see Brown, 2007).

Mindfulness and mind wandering are, by definition, negatively related (Mrazek et al., 2012)—one occurs in the absence of the other. Just minutes of mindfulness training can reduce the frequency and salience of mind wandering and task-irrelevant thoughts (Mrazek et al., 2012). Evidence from short and long-term interventions show that mindfulness training can promote cognitive and test performance while under high stress (Brunyé et al., 2017; Jha et al., 2010) by reducing the frequency of mind wandering (Mrazek et al., 2013). In fact, researchers have called for mindfulness training to alleviate detrimental impacts of mind wandering on academic performance (Smallwood et al., 2007).

Therefore, for the experiment reported here in Chapter 5, we randomly assigned some students to receive stress reappraisal or mindfulness instructions prior to watching the video lesson. Additionally, we were curious to learn more about students' experiences during the pandemic: Specifically, what aspects of the pandemic were particularly worrisome to students? Importantly, and given prior work (Hoyt et al., 2020; Literat, 2021; Zimmerman et al., 2020), we examine whether these worries may systematically concern some students of historically marginalized identities more than others.

2. Methods

2.1. Participants

This study was preregistered through the Open Science Framework (http://osf.io/kq9gp). Planned and exploratory analyses are outlined below in the Analytic Plan. Data collection for Chapter 5 occurred between October 2020 and March 2021, when online learning was no longer novel or in emergency implementation. A power analysis originally called for a sample size of 251 to determine a medium effect size between three conditions at alpha = 0.05 and power = 0.95; we oversampled to account for incomplete or inattentive student responses and the addition of a partial survey option (described below).

In total, 569 students from seven classes at two large public universities, both Minority-Serving Institutions, participated in this study. Forty-nine students opted for a partial version of the survey and are analyzed separately from the remainder of the sample. Of the primary sample, students were dropped from analyses for incomplete data (n = 33) or for failing one or both of the attention checks (n = 60), leaving 432 students (343 women) for whom we had complete data. The undergraduate courses included four education courses (n = 71), two psychology courses (n = 275), four biology courses (n = 54), and one anthropology course (n = 27). Five students did not provide course enrollment information. Students' self-reported race/ethnicity (44% Asian-American, 35% Latinx, 10% White, 2% Black, 9% Multiracial/Other) and the number of first-generation students (56%) resembled Chapter 4 and the universities' student bodies at large.

2.2. Procedure

The procedure was identical to Chapter 4 with a few exceptions. To better understand whether our volunteer sample was representative of the student body, all recruited students were provided the option to complete the full survey or a five-minute partial survey that assessed demographics, general perceptions, and attitudes during the pandemic. We also made two additions to the procedure prior to students watching the lesson. First, we probed what pandemic-related concerns students were worried about. Immediately after, we manipulated stress regulation instructions for students prior to the lesson. Each modification is described below.

2.3. Measures

2.3.1. Partial Survey. Students who volunteered to complete the approximately 45-minute survey may have been qualitatively different than the student body at large. To examine the representativeness of our sample, we offered all recruited students a five-minute, partial survey option, which consisted of the original demographic questions from Chapter 4 plus four additional items assessing perceived changes in academic and personal wellbeing during the pandemic. All students first completed the partial survey, either for course extra credit or a $5 Amazon gift card, then were asked if they would like to continue to the full survey to receive the $20 Amazon gift card. No differences on any of the items emerged between those who completed the full or partial versions, lending some evidence to suggest that study participants who volunteered to complete the full survey were not systematically different from the student body[1].

2.3.2. Pandemic-related Worry. Immediately following the Impact of Events Scale, we added items to assess which domains of pandemic-related concerns students found worrisome. Based on prior work (Son et al., 2020) and pilot data from Chapter 4, we inquired about six broad domains of concern during the pandemic. Three domains captured worries about learning (technological obstacles to learning, social obstacles to learning, distractions in the learning environment) and three captured more general worries (health concerns, economic concerns, social support concerns). Example quotes are provided in Table 5.1. For each domain, we asked students whether or not they worried about it, and if so, the extent to which they worried about it. The latter was measured on a 0-100 sliding scale (0: *Not worried*, 100: *Very worried*) and we summed across these values for each domain to create a composite worry index (range: 0-600).

Table 5.1.

Domains of pandemic-related concerns and example quotes.

Domain	Example Quote
Technological obstacles to learning	"I worry that I will not have internet connection when I have an important assignment, test or meeting, and I fear that the professor will not understand"
Social obstacles to learning	"I do not feel as engaged in a zoom classroom whereas in person we would be able to connect with our teachers and peers. I am not receiving the college experience I have been hoping for."

[1] Three items were answered using a 0-100 sliding scale (0: *Not at all stressed* to 100: *Very stressed*): How stressed out have you felt about classes this quarter? To what extent do you feel that the COVID-19 pandemic has affected your ability to perform this quarter? To what extent do you feel that the COVID-19 pandemic has affected your overall well-being? One item asked students to use a 5-point Likert scale (1: *Not at all* to 5: *A great deal*) to report how different their at-home learning context was compared to pre-pandemic learning contexts. 49 students opted to complete the partial survey in lieu of the full one, though not all students answered every item. There were no differences between partial and full samples in terms of their gender ($\chi^2(2) = 2.26$, $p = .32$), race/ethnicity ($\chi^2(5) = 3.64$, $p = .60$), or first-generation status ($\chi^2(1) = 0.01$, $p = .91$). At-home learning contexts were equally novel for both samples ($t(479) = 1.29$, $p = .21$). Moreover, both samples reported feeling equally stressed in their classes during the quarter ($t(424) = -0.31$, $p = .75$) and agreed to a similar extent that the pandemic had impacted their academic performance ($t(417) = -0.41$, $p = .68$) and their overall wellbeing ($t(419) = -0.05$, $p = .96$).

Table 5.1.

Domains of pandemic-related concerns and example quotes (continued).

Distractions while learning	"At home it is very distracting because I have a younger sister and brother, as well as my parents who will continuously ask me for help, bother me or simply be loud in the house which makes taking quizzes and tests especially stressful."
Health concerns	"I have asthma and my family members also have their own conditions. My grandfather is 87 so he is at risk too. It worries me if one of us gets sick it would be hard to try and quarantine because there is *(sic)* more people than rooms."
Economic concerns	"My dad has been working on and off at restaurants since March and my mom nannies children only occasionally now, whereas before she did so every day during the week. This has obviously translated to less income and it worries me."
Social support concerns	"I am actually losing contact with many of the close friends I cherish. More than not seeing people who provide me social support, I feel that these friends lack social support as well and I try to reach out to them but contact is overall harder online than in-person."

2.3.3. Stress Reappraisal and Mindfulness Instructions. Prior to the lesson, students were randomly assigned to a control condition or to one of two stress regulation conditions: Stress Reappraisal or Mindfulness. All students were informed that they would watch a video that would teach them a research-based technique to help students learn during difficult times. The videos were designed by the researchers and modelled after prior research. Each consisted of images, animation, and on-screen text plus narration.

Stress reappraisal and mindfulness videos consisted of the same four parts. First, we described the concern about distraction expressed by undergraduates at their institution. Then, we briefly summarized the science behind stress and distraction. Third, we defined stress reappraisal or mindfulness. Lastly, we described how the strategy can reduce the impact of distress on distraction.

Critically, both videos highlighted the attention-enhancing attributes of each strategy. In the stress reappraisal video (modeled after Beltzer et al., 2014; Crum et al., 2013; Jamieson et al., 2010), students were informed of the often-unconsidered adaptive side of stress—specifically, that stress hormones can activate higher order cognitive and physiological functions necessary for performance, including helping students focus their attention on what they need to learn. Students in the stress reappraisal condition were encouraged to view any distressing thoughts or feelings that may arise as adaptive when watching the video lesson. In the mindfulness video (modeled after Erisman & Roemer, 2010; Mrazek et al., 2012, 2013; Schuster et al., 2015), students were instructed to mindfully and nonjudgmentally accept and let go of any stressful thoughts or feelings. Doing so during the lesson, they were informed, would help them preserve their limited higher order cognitive functions and help them focus their attention on what they needed to learn.

After the video instructions, those in the stress reappraisal and mindfulness conditions were asked to take three minutes to practice the strategy before the lesson began. Students were invited to free-write about any current distressing or distracting thoughts and feelings and describe how they would apply their given strategy to mitigate these experiences during the lesson.

Those in the control condition watched a shorter video that simply asked them to pay attention to the upcoming lesson. They did not free-write prior to the lesson.

2.3.4. Strategy Use and Perceived Efficacy. After the lesson, students in the mindfulness and reappraisal conditions were asked whether or not they actually attempted their instructed strategy (strategy use) and were asked to use a 7-point Likert scale (1: *Not at all*; 4: *Somewhat;* 7: *Very much*) to report how much they agreed that the strategy they learned about could be useful for improving their learning in future online courses (perceived efficacy).

2.4. Analytic Plan

The analytic plan is similar to Chapter 4. We first describe COVID-19 distress among our sample and use exploratory ANOVAs to explore demographic correlates of distress. Next, in another exploratory analysis, we use Chi-squared tests and *t*-tests to describe students' pandemic-related worries and examine how this too may differ among students. Then, in line with Chapter 4, we use multiple regression analyses to test predicted relations between distress, mind wandering, and learning from the video lesson, and test the mediational pathway. Finally, we test the effects of mindfulness and stress reappraisal instructions on students' mind wandering and learning, and their perceived efficacy of each strategy. We conclude with an exploratory analysis of students' implementation of each strategy. Full regression tables are provided in the Supplemental Materials.

3. Results

3.1. COVID-19 Distress

Overall descriptive statistics for all measures are provided in Table 5.2. First, we examine students' global COVID-19 distress (Impact of Events scale). Then, we explore their specific pandemic-related worries. Again, COVID-19 distress positively correlated with trait anxiety ($r(430) = 0.33$, $p < .001$), and women trended towards greater COVID-19 distress than men ($F(2,429) = 2.87$, $p = .06$, $\eta^2 = .013$). First-generation ($F(1,430) = 0.03$, $p = .87$) and Latinx ($F(1,430) = 0.35$, $p = .56$) students experienced similar distress to their peers. Fifty percent of the sample met the criteria for moderate distress, and 12% were severely distressed (see Figure 5.1). Compared to their peers, a greater proportion of women were moderately or severely distressed ($\chi^2(2) = 7.44$, $p = .02$).

Figure 5.1.

Histogram of Chapter 5 COVID-19 distress scores, categorized by severity of distress. Light gray indicates low to mild distress, medium gray indicates moderate distress, and black indicates severe distress.

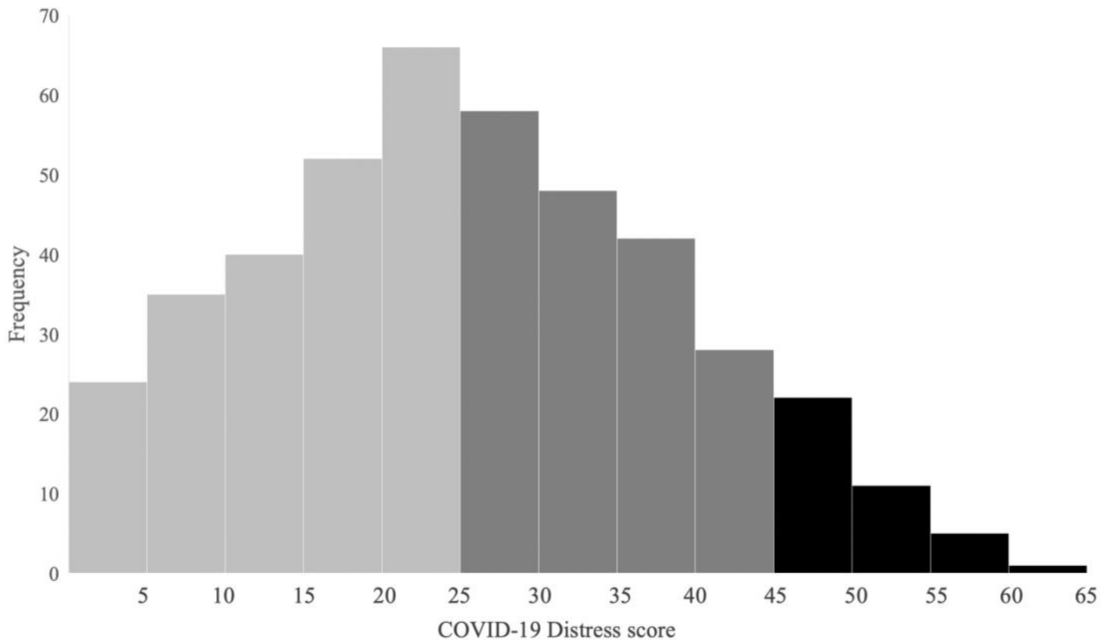


Table 5.2.

Descriptive statistics for all measures in Chapter 5, by condition.

Measure (range of scores)	Control (n = 141)	Mindfulness (n = 148)	Stress Reappraisal (n = 143)	Total (n = 432)
Surveys				
COVID-19 distress (0 - 75)	26.74 (13.34)	24.92 (13.40)	27.17 (13.30)	26.26 (13.35)
Trait anxiety (20 - 80)	52.16 (11.12)	52.01 (11.60)	51.39 (11.77)	51.85 (11.48)
Lesson and Learning				
Mind wandering (1 - 6)	3.52 (1.32)	3.09 (1.26)	3.60 (1.33)	3.40 (1.32)
Question Accuracy (0 - 6)	3.89 (1.51)	3.87 (1.73)	3.78 (1.50)	3.85 (1.58)
Strategy Use and Efficacy				
Proportion used strategy	--	86%	62%	74%
Perceived efficacy (1 - 7)	--	4.91 (1.25)	4.78 (1.28)	4.85 (1.26)

Note. Strategy Use and Efficacy measures applied to mindfulness and stress reappraisal conditions only.

3.2. Pandemic-related Worry

Data for pandemic-related worries are provided in Table 5.3. At least half of the sample reported worrying about each domain of concern, highlighting the pervasive impact of the pandemic. Students most commonly reported concern regarding the health of themselves and their loved ones, with 80% of the sample reporting having worried about it at some point, followed by worries about social obstacles to their learning, worry regarding finding necessary social support, and worry about distractions during learning.

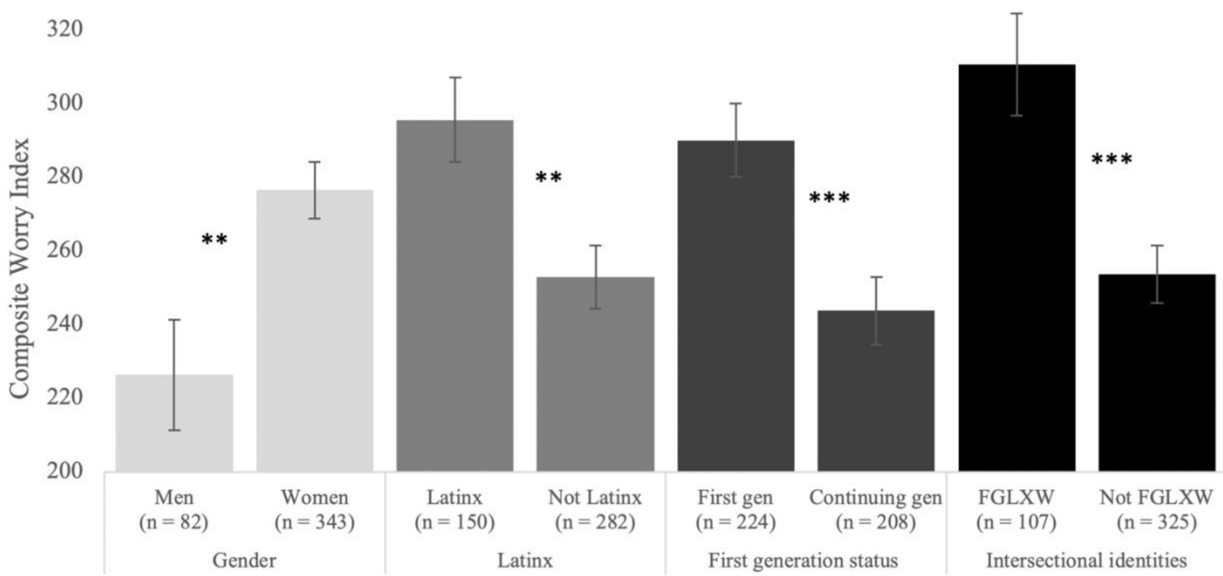
These worries disproportionately affected some students more than others. Figure 5.2 shows students' composite worry index by student-reported identity. Students' worry index was positively related to their COVID-19 distress ($r(430) = 0.43$, $p < .001$). In line with gender differences in students' general COVID-19 distress, in an exploratory analysis we found that women worried to a greater extent than men ($t(423) = -2.86$, $p = .004$, $d = -0.35$). We also found that Latinx students ($t(430) = -2.97$, $p = .003$, $d = -0.30$) and first-generation students ($t(430) = -3.40$, $p < .001$, $d = -0.33$) were more worried than their peers. In fact, these identities intersected to predict worry: first-generation, Latinx women (FGLXW) worried to a greater extent than their peers ($t(423) = -3.61$, $p < .001$, $d = -0.40$).

We next explored whether these differences in worry were specific to certain domains of pandemic-related concern. Differences by student self-reported identity were most pronounced in the domains of economic concerns and distractions (see Table 5.3). Again, these identities intersected to disproportionately impact FGLXW, a greater proportion of whom expressed worry about distractions while learning ($\chi^2(1) = 8.40$, $p = .004$) and economic consequences of the pandemic ($\chi^2(1) = 4.78$, $p = .03$) compared to their peers.

Thus, not only do FGLXW worry to a greater extent than their peers across all pandemic-related domains, which is related to more COVID-19 distress in general, but they also worry about distractions while learning disproportionately more frequently than their peers.

Figure 5.2.

Students' composite worry index by self-reported student identity. Error bars are ± 1 standard error of the mean. Cohen's d effect sizes are reported. FGLXW is an indicator for whether or not a student is a first generation, Latinx woman. ** $p < .01$ *** $p < .001$



3.3. Learning and Mind Wandering

Because women were more distressed (see above) and, surprisingly, learned less than their peers ($F(2,429) = 3.22$, $p = .04$, $\eta^2 = .015$), gender is included as a covariate alongside trait anxiety in all subsequent analyses (though all results held with and without gender as a covariate). COVID-19 distress was a marginal predictor of students' learning ($\beta = -0.09$, $SE = 0.05$, $p = .08$) and a significant predictor of students' mind wandering during the lesson ($\beta = 0.15$, $SE = 0.05$, $p = .003$). Again, greater mind wandering predicted lower learning from the lesson ($\beta = -0.33$, $SE = 0.05$, $p < .001$).

Table 5.3.

Frequency of worry about pandemic-related domains by self-reported student identity.

	Tech obstacles	Social obstacles	Distractions	Health concerns	Economic concerns	Social support concerns
Gender						
Women (n = 343)	50%	74%	60%	81%	55%	61%
Men (n = 82)	37%	74%	49%	72%	46%	52%
Non-specified (n = 7)	57%	100%	57%	100%	43%	86%
Difference?	^			^		
Latinx						
Latinx (n = 282)	44%	76%	68%	84%	57%	61%
Not Latinx (n = 150)	49%	74%	53%	77%	51%	59%
Difference?			**	^		
First generation status						
First gen (n = 224)	48%	75%	66%	80%	60%	59%
Continuing (n = 208)	47%	74%	50%	79%	47%	60%
Difference?			***		**	
Intersectional Identities						
FGLXW (n = 107)	48%	76%	70%	85%	63%	64%
Not FGLXW (n = 325)	47%	74%	54%	78%	37%	59%
Difference?			**		*	
Overall (n = 432)	47%	75%	58%	79%	53%	60%

Note. Percentage values refer to the proportion of students responding yes to worrying about each pandemic-related domain. Difference? indicates a significant difference between groups as measured by Chi-square tests. ^$p < .10$ * $p < .05$ ** $p < .01$ *** $p <.001$

3.3.1. Mediation. Using the same mediation analysis as in Chapter 4, we found that mind wandering completely mediated the relation between COVID-19 distress and learning (β = -0.05, *SE* = 0.02, 95% C.I.: [-0.09, -0.02]). The direct effect was insignificant after accounting for mind wandering (β = -0.05, p = .35). Again, distress regarding the pandemic compromised learning potential by increasing distraction.

3.4. Effects of Stress Reappraisal and Mindfulness on Mind Wandering and Learning

We next test whether the prompts to use mindfulness or stress reappraisal prior to the lesson might mitigate the relations among distress, mind wandering, and learning. Gender ($\chi^2(4)$ = 5.96, p = .20), first-generation status ($\chi^2(2)$ = 0.04, p = .98), race/ethnicity ($\chi^2(10)$ = 10.75, p =

.38), and COVID-19 distress levels ($F(2,429) = 1.18$, $p = .31$) were balanced across the three conditions.

A regression analysis revealed significant differences between conditions in mind wandering. On average, those in the mindfulness condition reported less mind wandering than those in the control ($\beta = -0.32$, $SE = 0.11$, $p = .006$) and those in the reappraisal condition ($\beta = -0.39$, $SE = 0.12$, $p = .001$). Interestingly, there were no differences in mind wandering between reappraisal and control conditions ($\beta = 0.07$, $SE = 0.12$, $p = .57$). Moreover, condition did not interact with COVID-19 distress levels ($ps > 0.20$), suggesting that mindfulness helped all students maintain attention, regardless of how distressed they were. Though mindfulness reduced mind wandering, there was no effect of condition on learning ($p = .82$), and this too did not interact with distress levels ($p = .26$).

3.5. Use and Perceived Efficacy of Stress Reappraisal and Mindfulness

Mean perceived efficacy across both experimental conditions was 4.89, roughly corresponding to the midpoint of the scale (*Somewhat* useful). An ANOVA revealed no differences between mindfulness and reappraisal conditions in their perceived efficacy ($F(1, 289) = 0.84$, $p = .36$), and this too did not interact with COVID-19 distress ($p = .45$).

In an exploratory analysis, we sought to understand whether students actually attempted the instructed strategy during the lesson, given that the strategies were perceived as only somewhat useful on average. Those who reported that they actually used the strategy ($M = 5.07$, $SD = 1.21$) also reported finding the strategy more effective than those who did not ($M = 4.20$, $SD = 1.19$; $t(289) = 5.38$, $p < .001$, $d = 0.72$). Strikingly, a greater proportion of students in the mindfulness condition reported using their instructed strategy than those in the reappraisal condition ($\chi^2(1) = 22.13$, $p < .001$): Approximately 2 of every 5 students in the reappraisal condition did not even attempt to use the strategy after instruction[2].

4. Discussion

Chapter 5 replicated the findings from Chapter 4 and included students from another university, at a later timepoint during the pandemic when online learning was no longer novel or in emergency implementation. We again found that COVID-19 distress impaired learning via increased mind wandering, emphasizing the important role of attention. Distress levels remained concerningly high across Chapters 4 (Spring and Summer 2020) and 5 (Fall 2020 and Winter 2021), suggesting that the psychological impacts of COVID-19 did not necessarily diminish as the pandemic continued, though comparisons are limited with our cross-sectional design (see Hoyt et al., 2020; Zimmerman et al., 2020 for longitudinal evidence).

4.1. Variation in Worry Across Students

Moreover, an exploratory analysis of student worry revealed considerable differences among students. Specifically, first-generation, Latinx women not only worried about a greater number of pandemic-related factors, but also worried to a greater extent about these concerns than their peers, which was related to the more global measure of COVID-19 distress. Our work and others' (Hoyt et al., 2020; Literat, 2021; Zimmerman et al., 2020) elucidate the unfortunate reality that the pandemic may exacerbate inequalities in educational attainment and opportunity at the university level. The shift to remote learning has meant that women, racial/ethnic minorities, and low-income students have had to shoulder more responsibilities at home, in

[2] When we reduced the sample to include only those who did use their instructed strategy ($n_{reappraisal} = 89$; $n_{mindfulness} = 127$), still no differences between conditions emerged in their perceived efficacy ($F(1, 214) = 0.02$, $p = .89$), and this again did not interact with distress levels ($p = .66$). However, reducing the sample to only those who complied biases our analyses. In future analyses, we will use instrumental variables to assess the causal effect of condition for those who did and did not comply.

addition to satisfying their course requirements without the supports and assistance afforded during in-person instruction (Hoyt et al., 2020; Yip et al., 2020). In line with this, we found that experiencing distractions during learning was the pandemic-related concern with the largest and most consistent differences across gender, racial/ethnic, and first-generation/continuing-generation groups, suggesting that certain students might already be cognizant of the impacts of distractions on their achievement.

4.2. Emotion Regulation Strategies: Utility and Efficacy

To combat this distress-to-distraction pathway, we instructed some students to use one of two research-backed emotion regulation strategies: stress reappraisal and mindfulness. Both have received growing attention as effective means to reduce negative affective experiences, like distress, increase task-directed focus and attention, and improve learning. Yet, we found that only mindfulness instructions, not stress reappraisal, reduced mind wandering during the lesson, though this did not necessarily translate to improvements in learning. Compared to reappraisal, participants were more likely to attempt the mindfulness intervention, which might have implications for realistic spontaneous usage in the future, though they endorsed both approaches equally.

Mindfulness and mind wandering are considered two sides of the same coin (Mrazek et al., 2012), yet stress reappraisal is also a tested means to reduce mind wandering (Johns et al., 2008; Schuster et al., 2015). In Chapter 5, we intentionally designed the videos such that mentions of focus, distraction, and attention were consistent across conditions. Nevertheless, perhaps mindfulness, with its emphasis on simply accepting and letting go of distracting thoughts, was easier to implement than reappraisal, which requires a complete reimagination of commonly held beliefs about stress and stressful experiences.

In support of this, Troy et al. (2018) asked adults to either accept or reappraise their feelings while watching a sad film. Those instructed to reappraise their feelings believed the strategy was more difficult to implement and less effective than those instructed to accept their feelings (also see Sheppes & Gross, 2011). A foundational element of mindfulness (Lindsay & Creswell, 2019), acceptance instructs against control and manipulation of emotional experience, unlike reappraisal.

In fact, adults do not commonly use reappraisal in everyday life (Brans et al., 2013; Ford & Troy, 2019; Suri et al., 2015), particularly as stressors become more intense (Sheppes et al., 2014). In a survey of undergraduates' coping during the pandemic, Son et al. (2020) found that only 2% of students reported using reappraisal to cope with stress, compared to 29% using mindfulness-like practices (e.g., breathwork). Both the perceived intensity of stressors and the perceived effort to implement strategies predict which emotion regulation strategies individuals will adopt (Sheppes et al., 2014). This could explain why fewer students even attempted reappraisal when instructed, and why reappraisal did not lead to reduced mind wandering. Perhaps with additional practice, reappraisal would have been perceived as less demanding and more likely to be adopted (McRae et al., 2012; Ortner et al., 2016; see Sheppes & Gross, 2011).

4.3. Conclusion

In sum, Chapters 4 and 5 showed that distress about the pandemic—a stressor that was enduring, uncontrollable, task-irrelevant, and quite severe to the nearly 700 sampled students—compromised students' learning by decreasing their task-directed attention during instruction. In Chapters 4 and 5, we only assessed learning from one short video lesson, yet research finds that even brief instances of mind wandering during learning can impair students' higher-order reasoning and inference (Smallwood et al., 2008), gaps which may compound over time

(Smallwood et al., 2007), Additionally, given systematic differences between students in their distress and worry, these initial differences could serve to widen achievement gaps in the long term.

This work adds to a growing literature showing that negative affective experiences during learning, like excess stress and anxiety, can divert limited attentional resources to threat-related thoughts and hinder learning potential (Jamieson et al., 2012; Schmader et al., 2008). Mapped onto the Inverted-U model described in Chapter 1, we conclude that on average, participants were performing at the rightmost tail, where they experienced excess arousal. Here, emotion regulation strategies could serve to pull students to the optimal zone by helping them either reappraise their arousing and stressful thoughts as adaptive for attention (stress reappraisal) or by helping them let go of the arousing and stressful thoughts in order to preserve task-directed attention (mindfulness). Mindfulness was effective for redirecting attention, but not for improving learning in the moment. Indeed, attention is necessary but insufficient to produce changes in learning: Motivational factors important for student engagement and learning, like interest in the material to be learned (Wammes et al., 2016a), are likely necessary to see further condition-related gains in learning, and thus warrant future investigation.

Chapter 6

Conclusion

1. Summary

The Inverted-U theory of arousal and performance posited by Yerkes and Dodson (1908) provides a useful framework for understanding how to optimize individuals' performance when considering arousal and performance. Research across scientific disciplines (behavioral economics, neuroscience, psychology) have assessed this relationship using different arousal-based phenomena (stress, pressure, and anxiety) and with seemingly paradoxical goals (e.g., eliminate negative emotional experiences, introduce pressure). Using the inverted-U model as a guide, this dissertation integrated prevailing theories of stress, pressure, and anxiety to elucidate key contextual and cognitive factors that inform 1) when and how heightened arousal may optimize or threaten individuals' cognitive performance, and 2) the utility and efficacy of emotion regulation strategies. Importantly, I showed that there is no uniform effect of context, cognitive engagement, or emotion regulation on performance in heightened arousal states. Rather, these factors interact to determine whether arousal threatens or optimizes performance.

In Chapters 2 and 3, colleagues and I induced performance pressure and showed that this transient, task-relevant, low-severity, and controllable stressor facilitated performance on a working memory task by increasing participants' task-directed effort. These findings suggest that in this paradigm, the pressure induced a moderate, optimal amount of arousal, placing individuals at the peak of the inverted-U model where performance is most optimized. As such, because arousal was already optimized, there likely was no need for one to regulate their arousal, hence rendering reappraisal unnecessary and perhaps explaining why there was no difference between reappraisal and no reappraisal groups in any performance or affective outcomes.

In Chapters 4 and 5, colleagues and I examined the arousal-performance relationship during learning and with a different stressor: distress about the COVID-19 pandemic. In contrast to the pressure induction, the COVID-19 pandemic is an enduring, task-irrelevant, high-severity, and uncontrollable stressor. The experiments reported in these chapters revealed that undergraduates were quite severely distressed, and that greater distress threatened performance by decreasing task-directed attention. Furthermore, the experiments showed that mindfulness instructions protected individuals from becoming too distracted, though this did not translate to gains in learning. Thus, these findings suggest that COVID-19 distress pushed individuals to the rightmost side of the inverted-U, where heightened arousal was overwhelming and no longer functional. In contrast to Chapters 2 and 3, where pressure optimized performance, here I showed that emotion regulation strategies have greater potential utility, although the novelty and demand of the strategy itself is important to consider. This dissertation thus overall highlighted the importance of simultaneously considering performance context, its consequences for cognitive engagement, and how these in turn influence the utility and efficacy of emotion regulation strategies.

2. Limitations

A few limitations of this dissertation are worth addressing. First, it is important to note that though this dissertation uniquely considered and linked theories from researchers interested in constructs (stress, pressure, and anxiety) often independently studied, this is only a first step. Beyond emphasizing the importance of context and cognitive engagement, this integration of theories raises many more important questions (e.g., differences in physiological and hormonal responses to stress, pressure, and anxiety). These questions are outside of the scope of this dissertation, yet speak to the importance of linking across theories of arousal to better understand implications for performance.

I found evidence to suggest that the type of stressor—including its task-relevancy, severity, and controllability—was one contextual factor that would predict whether arousal would optimize performance via cognitive engagement. I measured stressor severity in both studies using self-report of emotional experience during task completion, but differences in stressor relevancy were assumed across studies (pressure induction on task versus COVID-19 distress priming prior to task). Moreover, it was assumed that the laboratory pressure induction was more controllable to the participant than distress about the COVID-19 pandemic. However, prior work suggests that individuals might differ with regards to how much they perceive control over the same stressor (e.g., Perry et al., 2008) and that individuals can be trained to adopt perceptions of greater agency and control under stress (e.g., Bhanji et al., 2016; Perry et al., 2010). Future work should manipulate controllability and severity within the same study to isolate effects of both and determine which may most influence performance.

Relatedly, none of the studies measured intrinsic motivation to perform. Proxies for intrinsic motivation were the amount of motivation participants self-reported at baseline in Chapters 2 and 3, which were quite low. However, this measure did not distinguish between intrinsic motivation to complete the tasks and extrinsic motivation (e.g., experimenter expectancies). Some work suggests that imposing pressure might be an extrinsic motivator that undermines any baseline intrinsic motivation to perform (see Deci et al., 1999 for a review) Moreover, in Chapters 4 and 5, motivation to perform was assumed to be low, yet was not assessed. Given that intrinsic and extrinsic motivation can have divergent types of benefits for performance (Cerasoli et al., 2014) and given that intrinsic motivation may confer protective capacities when performing under threat (e.g., Ling et al., 2016), future work should measure baseline intrinsic motivation and examine whether this may interact with pressure and distress to predict performance.

With this in mind, I acknowledge that the claims made in this dissertation, and the studies herein, would be strengthened tremendously if elements of the performance context, individual-level cognitive engagement, and emotion regulation were manipulated within the same study. Through four independent studies, I have shown that all three of these factors were important in predicting when heightened arousal may facilitate or threaten performance. However, some modifications, like manipulating feedback (uncertainty), pressure, and reappraisal within the same study could further elucidate when, and by what means, each independently or interactively incentivizes or threatens individuals' cognitive performance. I am designing a follow-up study to assess this interaction in particular.

Similarly, I did not measure attention and effort within the same study. It is assumed that increased attention is a requisite for increased effort, such that those who are putting forth more effort are doing so in part because they are paying more attention (Bonner & Sprinkle, 2002). Yet increased effort may be deployed as a compensatory measure for those who are experiencing high states of anxiety (Hardy et al., 2007; Hayes et al., 2009; Putwain & Symes, 2018; see Eysenck et al., 2007), suggesting that assessing individuals' degree of cognitive task engagement alone may not accurately predict their emotional state or their performance outcome. For example, anxious individuals may be more distracted due to increased worry (i.e., appear on the rightmost side of the inverted-U), but expend far more effort than their less anxious counterparts and consequently show improved performance relative to others (i.e., appear in the optimal, motivated zone). Thus, future work should more carefully consider the nuances underlying effort and attention by measuring both within the same study.

Likewise, though I reported large, consistent relations between distress, mind wandering, and learning in Chapters 4 and 5, I note that interpretations of these relations may be somewhat limited as we did not probe precisely what students were mind wandering about during instruction. Mind wandering might not have led to decrements in learning were students distracted by thoughts relevant to the lesson (Jing et al., 2016; Wammes et al., 2016b). Rather than being distracted, such task-relevant mind wandering might in fact indicate more effort towards the task. Thus, beyond simply assessing whether individuals are attentive, future work should assess the contents of individuals' thoughts during task performance.

Finally, as a caveat, participants for all four studies were recruited from selective university populations. In Chapters 2 and 3, this meant that the undergraduate sample might have been fairly adept at managing feelings of pressure relative to the general population, suggesting that what was an optimal amount of arousal to them might have induced excess arousal in others. Moreover, with regards to Chapters 4 and 5, some work suggests undergraduates might experience greater distress during the COVID-19 pandemic than the general adult population (Wang et al., 2020), suggesting that non-undergraduate samples may not have been so distracted during the lesson. In either case, I exercise caution when generalizing these findings.

3. Final Summary and Implications

To summarize, this dissertation asked how to promote learning and cognitive performance by optimizing the amount of arousal one experiences. Beyond this dissertation, this question has implications for educators, cognitive researchers, and policy makers, all of whom are interested in promoting test performance and learning under various real-world forms of arousing, stressful, anxiety-inducing, and otherwise pressured situations. Critically, this dissertation aimed to orient stakeholders to the nuanced, delicate nature of heightening arousal while performing. As we have argued, optimizing arousal requires careful attention to the interactions between elements of the performance context and the performer's own cognitive engagement with the task.

Many single emotion regulation interventions have failed to replicate (Camerer et al., 2018; Ganley et al., 2021; Mesghina & Richland, 2020), as too have studies examining the effect of pressure or threat inductions on performance (Camerer et al., 2018; Flore & Witcherts, 2015). Failure to replicate does not necessarily imply untrustworthy results, but rather suggests that unconsidered individual and contextual factors may moderate when and to what extent phenomena manifest (Nosek & Errington, 2020). To this end, this dissertation emphasized the critical role of context in understanding 1) how to optimize the arousal-performance relationship and how this in turn relates to important mediating cognitive behaviors, and 2) when emotion regulation strategies can also be used to further promote individuals' learning and performance.

A primary implication relates to the link between theory and practice. Prevailing theories in stress (e.g., Blascovich & Tomaka, 1996) and trait anxiety (e.g., Ashcraft & Kirk, 2001; Eysenck et al., 2007) presume an individual is motivated to perform. For example, the BPS assumes an individual is in a motivated performance context, meaning they are in a situation that is relevant to their personal goals, in which they are able to act towards said goal, and where their performance outcome is uncertain. These conditions must be met in order for stress responses to be initiated and subsequent cognitive appraisals made (Blascovich & Tomaka, 1996). Yet, as this dissertation has shown, these conditions cannot be assumed in all performance contexts. This perhaps elucidates why the same manipulations of pressure may promote performance in one case (Chapters 2 and 3 of this dissertation) yet threaten performance in another (e.g., Beilock et al., 2004). Moreover, individual differences in appraisals of the stressor itself may determine whether or not subsequent appraisals and changes in performance occur. As Lazarus and Folkman (1984) argued, individuals may appraise a stressor as benign-positive, irrelevant, or stressful, only stressful appraisals could actually cause someone stress. Conversely, if a stressor is appraised as benign-positive or irrelevant to the individual, then no stress response will come about, and no coping is required. Researchers interested in arousal and performance could bypass this concern about assumed experiences by asking individuals to self-report how they appraise the stressor (e.g., Beltzer et al., 2014; Jamieson et al., 2016).

Across all four studies, this dissertation showed just how sensitive measures of performance and learning are to modifications to the performance context. This is most evident in Chapters 2 and 3, which showed performance pressure can boost working memory capacity via increased effort. Working memory is often treated as a stable individual difference. Yet, as I and others (Acklin, 2012; Adam & Vogel, 2016; Hodges & Spielberger, 1969) have shown, working memory is quite malleable to contextual features of the task used to measure it, meaning that performance might not reflect one's true capacity or potential. This has implications for researchers who use scores on cognitive tasks as diagnostic tools or to characterize differences between individuals in their cognitive capacity (i.e., categorizing people as high or low working memory).

With regards to Chapters 4 and 5 specifically, there is reason to suspect that mitigating the effect of distress on distraction will remain an important endeavor, even after the pandemic. A majority of students already believed stress to be a major impediment to their academic achievement before the pandemic (American College Health Association, 2020), and much work has reliably documented relations between excess daily stress and cognitive performance (e.g., Banks & Boals, 2016; Banks et al., 2015). Moreover, though I focused on video-based lessons, mind wandering reliably predicts learning during in-person instruction as well (Lindquist & McLean, 2011; Wammes et al., 2016b). Thus, researchers must continue efforts to preserve students' attention in the face of severe everyday stressors. I have posited that brief mindfulness training may be one way to reduce the effects of distress on distraction while learning, particularly when there is little time for training.

Supplemental Materials

Chapter 2 and 3: Full Reappraisal Prompts

Table S.1.

Full prompts and reminders for the reappraisal manipulation.

	Reappraisal	No Reappraisal
Prompt	It helps to consider that feeling stressed can be a good think for performance. Research has found that stress can help improve focus and attention. In fact, people actually perform better on tasks like these when they are stressed. Please take a moment to think about how feeling stressed can help improve your performance on the task	It helps to take a short break to think about your stress prior to the task. Most people reflect on their stress prior to tasks like these. Please take a moment to think about your stress prior to the task.
Reminder	Remember, it helps to take a moment to think about how feeling stressed can help improve your performance on the task.	Remember, it helps to take a moment to think about your stress prior to the task.

Note. The reappraisal manipulation was omitted from analyses as it had no effect on affect or performance outcomes. Full prompts were provided at the beginning of Block 2. Reminders were provided immediately before each of the two tasks in Block 2.

Chapter 4 and 5: COVID-19 Distress Items

The Impact of Events Scale (Horowitz et al., 1979) can be used to assess individuals' distress regarding any current life event. We modified items from the scale to specifically address distress regarding the COVID-19 pandemic.

1. I think about the COVID-19 pandemic when I do not mean to.
2. I avoid letting myself get upset when I think about the COVID-19 pandemic or when I am reminded of it.
3. I try to remove the COVID-19 pandemic from memory.
4. I have trouble falling asleep or staying asleep because of pictures or thoughts about the COVID-19 pandemic that come into my mind.
5. I have waves of strong feelings about the COVID-19 pandemic.
6. I have dreams about the COVID-19 pandemic.
7. I stay away from reminders of the COVID-19 pandemic.
8. I feel as if the COVID-19 pandemic has not happened or it is not real.
9. I try not to talk about the COVID-19 pandemic.
10. Pictures about the COVID-19 pandemic pop into my mind.
11. Other things keep making me think about the COVID-19 pandemic.

12. I am aware that I still have a lot of feelings about the COVID-19 pandemic, but I do not deal with them.
13. I try not to think about the COVID-19 pandemic.
14. My feelings about the COVID-19 pandemic are kind of numb.
15. Any reminders about COVID-19 brings back feelings about it.

Chapter 4 and 5: Lesson and Learning Materials

The video neuroscience lesson: https://www.youtube.com/watch?v=uF0tD_X0bQQ.

Recall Items

1. The cortical-basal ganglia circuit …
   a. Is a neural network implicated in motor learning
   b. Often makes errors in speech production that can impair speech learning
   c. Is oftentimes damaged in young songbirds
   d. Is unique to songbirds and humans

2. A motif is…
   a. The amount of activity of a single neuron during a vocalization
   b. The trial-by-trial variability in vocalizations
   c. The average frequency (pitch) of a vocalization
   d. A repeated series of vocalizations

3. When we damage the outflow component of the cortical-basal ganglia circuit to the motor pathway…
   a. The speech vocalizations no longer show trial-by-trial variability
   b. The cells start to fire in burst-like patterns
   c. The cells show activity that aligns with our speech vocalizations
   d. The speech vocalizations show increased trial-by-trial variability

Higher-order Reasoning & Inference Items

4. Why are songbirds useful models for understanding learning?
   a. They, like humans, have cortical-basal ganglia circuits that control social relationships
   b. They, like humans, can change the frequency (pitch) of their speech
   c. They, like humans, learn their speech from others
   d. They, like humans, experience diseases like Parkinson’s and Huntington’s due to dysregulation in their cortical-basal ganglia circuits

5. Damage to the cortical-basal ganglia circuit will result in…
   a. The inability to produce any song vocalizations
   b. The inability to change song vocalizations
   c. The inability to change song vocalizations in response to feedback, but only for those who are still learning songs
   d. The ability to produce song vocalizations in the absence of a tutor

6. This research teaches us that...
   a. Humans’ speech learning can suffer when they have social partners of the opposite sex

b. Humans' speech learning is facilitated by intentional variability made by the brain
c. The more people with whom humans can practice speech, the less likely it is that they will have error in their speech learning
d. If we damage humans' cortical-basal ganglia, we will see deficits in the frequency (pitch) of their speech

Chapter 4 Regression Tables

Table S.2.

Results from the regression analysis of learning from the lesson on COVID-19 distress in Chapter 4.

Predictor	β (SE)	*t*	Sig.
COVID-19 Distress	-0.22 (0.07)	-2.96	.003
Trait anxiety	-0.07 (0.07)	-1.00	.32
Gender			
Woman	0.22 (0.17)	1.29	.20
Unspecified	0.72 (1.01)	0.71	.48
Course enrollment			
Education 2	-0.70 (0.33)	-2.10	.04
Biology 1	0.08 (0.36)	0.23	.82
Criminology 1	-0.43 (0.33)	-1.30	.20
Criminology 2	-0.32 (0.32)	-0.97	.33
Graduate Education course	0.18 (0.36)	0.50	.62

Note. Standardized coefficients and standard errors are reported. The overall model is significant ($F(9,191) = 3.49$, $p < .001$, Adjusted $R^2 = 0.10$). Men and Education course 1 were included as reference categories for gender and course enrollment covariates, respectively.

Table S.3.

Results from the regression analysis of mind wandering during the lesson on COVID-19 distress in Chapter 4.

Predictor	β (SE)	*t*	Sig.
COVID-19 Distress	0.21 (0.07)	2.94	.004
Trait anxiety	0.22 (0.07)	3.04	.003
Gender			
Woman	-0.10 (0.17)	-0.57	.57
Unspecified	-0.91 (1.00)	-0.91	.37
Course enrollment			
Education 2	0.35 (0.33)	1.06	.29
Biology 1	-0.46 (0.36)	-1.30	.20
Criminology 1	0.07 (0.33)	0.22	.83
Criminology 2	-0.17 (0.32)	-0.51	.61
Graduate Education course	0.08 (0.35)	0.23	.82

Note. Standardized coefficients and standard errors are reported. The overall model is significant ($F(9,191) = 4.09$, $p < .001$, Adjusted $R^2 = 0.12$). Men and Education course 1 were included as reference categories for gender and course enrollment covariates, respectively.

Table S.4.

Results from the regression analysis of learning from the lesson on mind wandering in Chapter 4.

Predictor	β (SE)	*t*	Sig.
Mind wandering	-0.29 (0.07)	-4.09	<.001
Trait anxiety	-0.06 (0.07)	-0.87	.38
Gender			
Woman	0.14 (0.16)	0.84	.40
Unspecified	0.24 (0.99)	0.24	.81
Course enrollment			
Education 2	-0.61 (0.33)	-1.85	.07
Biology 1	-0.09 (0.35)	-0.24	.81
Criminology 1	-0.41 (0.33)	-1.26	.21
Criminology 2	-0.39 (0.32)	-1.21	.23
Graduate Education course	0.13 (0.35)	0.40	.69

Note. Standardized coefficients and standard errors are reported. The overall model is significant (F(9,191) = 4.48, p <.001, Adjusted R^2 = 0.14). Men and Education course 1 were included as reference categories for gender and course enrollment covariates, respectively.

Chapter 5 Regression Tables

Table S.5.

Results from the regression analysis of learning from the lesson on COVID-19 distress in Chapter 5.

Predictor	β (SE)	*t*	Sig.
COVID-19 Distress	-0.09 (0.05)	-1.73	.08
Trait anxiety	-0.05 (0.05)	-0.92	.36
Gender			
Woman	-0.21 (0.12)	-1.74	.08
Unspecified	0.41 (0.39)	1.05	.30

Note. Standardized coefficients and standard errors are reported. The overall model is significant (F(4,427) = 3.00, p =.02, Adjusted R^2 = 0.02). Men were included as the reference category for gender.

Table S.6.

Results from the regression analysis of mind wandering during the lesson on COVID-19 distress in Chapter 5.

Predictor	β (SE)	*t*	Sig.
COVID-19 Distress	0.15 (0.05)	2.99	.003
Trait anxiety	0.21 (0.05)	4.27	<.001
Gender			
Woman	0.10 (0.12)	0.81	.42
Unspecified	0.02 (0.38)	0.06	.95

Note. Standardized coefficients and standard errors are reported. The overall model is significant (F(4, 427) = 10.83, p <.001, Adjusted R^2 = 0.08). Men were included as the reference category for gender.

Table S.7.

Results from the regression analysis of learning from the lesson on mind wandering in Chapter 5.

Predictor	β (SE)	*t*	Sig.
Mind wandering	-0.33 (0.05)	-7.09	<.001
Trait anxiety	0.01 (0.05)	0.22	.83
Gender			
Woman	-0.19 (0.12)	-1.62	.11
Unspecified	0.43 (0.37)	1.14	.26

Note. Standardized coefficients and standard errors are reported. The overall model is significant ($F(4, 427) = 15.06$, $p < .001$, Adjusted $R^2 = 0.12$). Men were included as the reference category for gender.

Table S.8.

Results from regression analysis of learning from the lesson on condition in Chapter 5.

Predictor	β (SE)	*t*	Sig.
Model 1			
Reappraisal	-0.07 (0.12)	-0.59	.56
Mindfulness	-0.01 (0.12)	-0.12	.91
Model 2			
Reappraisal	-0.07 (0.12)	-0.35	.73
Mindfulness	-0.04 (0.12)	1.07	.28
COVID-19 distress	-0.06 (0.08)	-0.75	.45
Reappraisal*COVID-19 distress	0.01 (0.12)	0.11	.91
Mindfulness*COVID-19 distress	-0.16 (0.12)	-1.36	.18

Note. We first tested the main effect of assigned condition on learning in Model 1 ($F(2, 429) = 0.19$, $p = .82$, Adjusted $R^2 = -0.004$). In Model 2, we add COVID-19 distress to explore potential interactions among condition and distress ($F(5, 426) = 1.75$, $p = .12$, Adjusted $R^2 = 0.009$). The control group was the reference category.

Table S.9.

Results from regression analysis of mind wandering during the lesson on condition in Chapter 5.

Predictor	β (SE)	*t*	Sig.
Model 1			
Reappraisal	0.06 (0.12)	0.57	.57
Mindfulness	-0.32 (0.12)	-2.78	.006
Model 2			
Reappraisal	0.06 (0.12)	0.03	.98
Mindfulness	-0.29 (0.11)	-2.40	.02
COVID-19 distress	0.15 (0.08)	1.84	.07
Reappraisal*COVID-19 distress	0.03 (0.12)	0.23	.82
Mindfulness*COVID-19 distress	0.16 (0.11)	1.37	.17

Note. We first tested the main effect of assigned condition on learning in Model 1 ($F(2, 429) = 6.52$, $p = .002$, Adjusted $R^2 = 0.03$). In Model 2, we add COVID-19 distress to explore potential interactions among condition and distress ($F(5, 426) = 7.33$, $p < .001$, Adjusted $R^2 = 0.07$). The control group was the reference category.

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