Timing, Mindset, and the Link Between Stress and Performance: Evidence From Experience Sampling Data

by

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Abstract

This dissertation examines external stressors, perceived stress, and performance, using daily experience sampling data from undergraduate students during their final exam week. First, I investigate external stressors and the timing of perceived stress. Consistent with prior literature, I find that overall perceived stress negatively predicts semester GPA. However, looking more closely at perceived stress over time, I find that perceived stress on exam days did not predict semester grade point average (GPA), while perceived stress on non-exam days significantly negatively predicted semester GPA. Those individuals who experience high perceived stress even outside the temporal bounds of external stressors never have time to recover from the exertion of coping with stress. Then, once individuals feel stressed, one factor that may change how they respond is their beliefs about whether stress is enhancing or debilitating. I investigate the effects of these stress mindsets on the relationship between stress and performance. Results show that stress mindset moderates the relationship between stress and performance, such that the relationship between stress and performance is more negative the more individuals endorse a stress-is-debilitating mindset. I also provide evidence that this effect is partially explained by stress mindset's moderating effect on the relationship between stress and motivation. Together, these findings show that a more complete understanding of the relationship between stress and performance requires examination of both external stressors and perceived stress. Experience sampling methods such as used here provide the opportunity to study all of these variables. This research also has practical implications. Traditional stress management techniques that focus solely on reducing stress may be inadequate at best; both the timing of perceived stress relative to external stressors and individuals' stress mindset provide promising avenues for intervention.

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Chapter 1: Introduction

For the better part of a century, academic researchers have sought to advance their understanding of stress. In the 1930's, Selye (1935) described "a syndrome produced by diverse nocuous agents" observed in his experiments on rats (p. 32). From there, the study of the effects of stress spread widely to include the fields of "psychology, psychiatry, internal medicine, physiology, sociology, and anthropology [....] Stress, as a universal human and animal phenomenon, results in intense and distressing experience and appears to be of tremendous influence in behavior" (Lazarus, 1966, p. 2). In the psychological literature, research has focused on the effect of stress on an individual's cognitions and behavior.

In this dissertation, I examine how these outcomes arise from the interaction of external stressors, perceived stress, and individual beliefs, in the context of undergraduate students' experience of stress during their final exam week. First, I will discuss in broad strokes the different ways in which stress has been conceptualized, and specify the sense in which I study it here. The subsequent section provides an overview of the setting and data collection. In two empirical chapters, I examine the relationship between external stressors and the relative timing of perceived stress in predicting performance, and the role of stress mindset in moderating the relationship between perceived stress and performance. I conclude with a discussion of the results and implications.

What is stress?

As Selye himself put it, "Everybody knows what stress is and nobody knows what it is" (1973, p. 692). Stress is frequently discussed, and the word is used to describe a myriad of different circumstances and concepts. In general, the term refers to times when individuals' ability to obtain desired outcomes is threatened (Lazarus & Folkman, 1984). The range of situations that might be called stressors is broad, ranging from trauma and disaster to minor annoyances. The focus of the present work is relatively mundane stressors – common events that reasonably cause stress, but are not unambiguously negative. College exams, the case that I study here, are typical of this type of stressor. Additionally, exams require some action on the part of the individual; performing well may be difficult and the situation is uncertain, placing many demands on the test-taker. It is thus common and understandable for such an event to be stressful. However, although there may be negative consequences to performing poorly, there are also potential positive outcomes if one performs well. Further, it is not clear that it is practical or even desirable to completely avoid this kind of stressor. Instead, understanding when this type of stressor has negative consequences and when it does not is key to improving performance outcomes.

Even within the study of relatively routine stressors, the term "stress" is not always used consistently. Sometimes it refers to an event or situation, and sometimes it refers to a physiological or psychological response to such an event (Folkman, 2013). Stress is commonly defined in the psychology literature as a situation that threatens an individual's ability to achieved desired outcomes (Lazarus & Folkman, 1984). This definition includes both external and perceived components, which Lazarus (1966) categorized as the stimulus side and the response side of stress. When we think about stressful events, the situation itself is described fairly objectively: a busy schedule, a difficult exam, a crowded bus. Researchers have even developed scoring systems for life event stress that rest on event weights determined by judges' ratings of the events (Dohrenwend, Krasnoff, Askenasy, & Dohrenwend, 1978), implying that these assigned weights are relatively constant across individuals. Yet, intuitively, the same event does not provoke the same reaction for everyone. Lazarus (1966) suggested this, in writing that we should "define stress in terms of transactions between individuals and situations, rather than either one in isolation" (p. 5). And, as Cohen, Kamarck, and Mermelstein (1983, p. 385) put it more directly, "the impact of 'objectively' stressful events is, to some degree, determined by one's perceptions of their stressfulness." We can expect that to the extent that perceptions of these external stressors vary, the ultimate impact on behavior or performance will vary as well.

This perception of external stressors may take the form of a physiological or psychological reaction. Physiological research on stress reactivity focuses on changes in physiological measures, such as heart rate, blood pressure, or endocrine markers, from a baseline period as the subject is exposed to a stressor. This physiological reactivity may vary for different types of stressors, different features of the situation, or different individuals. A meta-analysis found that cortisol responses to stressors varied depending on whether the stressor was controllable or uncontrollable (Dickerson & Kemeny, 2004). Situational variables also play a role in determining physiological responses. In a laboratory study, heart rate reactivity was reduced in the presence of social support (Kamarck, Manuck, & Jennings, 1990). Individual differences in physiological stress reactivity may occur with differences in attachment security or age (Nachmias, Gunnar, Mangelsdorf, Parritz, & Buss, 1996; Uchino, Holt-Lunstad, Bloor, & Campo, 2005). A large body of research has linked physiological reactivity to higher risk of cardiovascular disease (for reviews, see Krantz & Manuck, 1984, and Treiber et al., 2003).

Psychological perceived stress, what common usage refers to as "feeling stressed," is typically understood as the product of an individual's cognitive appraisal process. First, individuals will appraise a particular event as stressful; then, they will appraise their own resources in relation to the environment (Folkman, 2013; Lazarus, 1966). A situation is appraised as a challenge when resources appear to equal or exceed demands, or as a threat when resources are perceived as insufficient to meet demands (Blascovich, Mendes, Hunter, & Salomon, 1999). Various factors influence these appraisals. For instance, participants with higher belief in a just world (beliefs that the world is just, orderly, and stable) appraised a laboratory task as less stressful, compared to those with lower belief in a just world (Tomaka & Blascovich, 1994). In another lab study, participants with higher self-efficacy had lower appraisals of stress, compared to those with lower self-efficacy (Jerusalem & Schwarzer, 1992). However, individual differences are only one factor influencing appraisal; Folkman, Lazarus, Gruen, & DeLongis (1986) measured individuals' responses to several stressors and found considerable within-individual variability in appraisals.[1]

Certainly, both external stressors and perceived stress – both physiological and psychological – have each been linked to performance outcomes (for reviews, see Gilboa, Shirom, Fried, & Cooper, 2008, and Seipp, 1991). Yet relatively few studies have actually examined whether the impact of external stressors varied depending on the perceived stress that they invoked. A series of diary studies that did collect data on both external stressors and perceived stress found that psychological reactions to external stressors were a more important factor than mere exposure to external stressors in predicting health and psychological outcomes (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995). In some cases, then, perceived stress provides a more relevant picture of the demands an individual faces. It is important to note, however, that perceived stress alone does not provide a full picture of an individual's stress, because early coping mechanisms that play a role in the link between external stressors and

[1] Although physiological and psychological reactions to stress comprise different constructs, the two are related. For example, Gaab, Rohleder, Nater, and Ehlert (2005) showed that cognitive processes can precede a neuroendocrine stress response. The reverse is also possible; physiological reactions can affect psychological responses, sometimes in combination with environmental cues (e.g., Schachter & Singer, 1962; Dutton & Aron, 1974).

perceived stress may themselves also affect behavior (Bovier, Chamot, & Perneger, 2004). Therefore, in thinking about stress and performance, both external stressors and perceived stress, and their relationship to each other, should be considered.

The present research

In this dissertation, I use data from undergraduate students during final exam period, and study both external stressors and perceived stress. These final exams represent external stressors – in particular, demanding events during which students' performance is highly consequential. Because perceived stress determines, at least in part, the impact of external stressors, I also collect data on students' psychological perceived stress throughout this time period. Thus, I will be able to examine both the external and perceived components of stress over time.

Data and Method

To study these relationships, I use experience sampling data that includes information on external stressors, perceived stress, and performance. These data were collected during three final exam weeks. During each study period, participants responded to longer-form surveys shortly before and shortly after their final exam week, as well as to daily experience sampling surveys during the final exam week (see below for more on the experience sampling method).

Participants

Participants included freshman and sophomore students at the Massachusetts Institute of Technology (MIT). Some of them were participants in the Interphase EDGE program, an enrichment program with a residential portion during the summer before students begin their freshman year (http://ome.mit.edu/programs-services/interphase-edge-faq). Participants also included non-Interphase students from the general MIT population, who were recruited through email lists and Facebook. Other portions of this project not reported on here administered an intervention to Interphase participants, and examined differences in outcomes for students in the intervention and control conditions. Students were each paid $50 for their participation during each exam period.

Data were collected during three consecutive final exam periods. During the first round, participants were 54 undergraduate students in their first year of college (M_{age} = 18.59, SD = 0.50; 35 women and 19 men). During the second round, participants were 130 undergraduate students in their first year of college (M_{age} = 18.15, SD = 0.35; 88 women and 42 men). During the third round, participants were 113 undergraduate students in their first and second years of college (M_{age} = 18.92, SD = 0.70; 82 women and 30 men). The third round of data collection included some participants from both the first and second rounds of data collection, such that the final sample included 297 observations of 210 unique participants. For a summary of participant counts in each of the three rounds of data collection, see Table 1. These are the sample sizes for the initial survey in each round; attrition between the initial and final survey in each round ranged from 5.6% to 10%. Table 2 describes some characteristics of the students who completed the final survey compared to those who dropped out. Overall, there are no statistically significant differences in initial Perceived Stress Scale scores, gender, or class year. There are non-significant differences in round 3 of data collection, such that students who dropped out reported slightly more stress and were more likely to be second-year students (see Appendix C for more details on attrition).

In general, this sample was reasonably representative of the MIT undergraduate population (see Table 3). Scholastic Aptitude Test (SAT) score quartiles and race representation approximated the population distribution (although there is a higher representation of students who identified as Black/African-American and Hispanic or Latino/a among study participants than among the undergraduate population). However, there was a significantly larger proportion of female students in our sample than in the undergraduate population ($\chi^2(1) = 6.49, p = .01$). This is likely due to differential interest in participation, since recruitment methods did not target students by gender. Where noted in the results, I include gender as a control variable.

Table 1: Participant counts

Round		Class year cohort 1	Class year cohort 2	Total
1 (May)	Interphase	27		
	Non-Interphase	27		
	Total	54		54
2 (December)	Interphase		39	
	Non-Interphase		91	
	Total		130	130
3 (May)	Interphase	21	24	
	Non-Interphase	17	51	
	Total	38 (15 also participated in Round 1)	75 (72 also participated in Round 2)	113

Materials and procedure

Long-form surveys. Participants responded to the pre- and post-exam week surveys via Qualtrics survey software. The surveys included a 10-item version of the Perceived Stress Scale (Cohen et al., 1983), the 8-item Stress Mindset Measure (Crum, Salovey, & Achor, 2013), previous academic performance (high school GPA and SAT scores), measures of general and exam-specific stress, semester course load and number of final exams, and demographic characteristics such as age, class year, gender, and race, in addition to several other measures not investigated here. The data collected during each round varied somewhat. In particular, students do not receive letter grades the first semester of their first year, and so no semester GPA data were available for round 2. See Appendix D for a full list of measures administered and the details of each scale.

Table 2: Participant attrition

	Round 1	*Round 2*	*Round 3*
Perceived Stress Scale, initial			
$M_{completed}$	2.86	2.69	2.84
$M_{droppedout}$	2.77	2.83	3.16
Sig. test	$t(2.21) = 0.24$, $p = .83$	$t(16.04) = 0.38$, $p = .38$	$t(8.65) = -1.56$, $p = .16$
Gender (female)			
$\%_{completed}$	65%	68%	74%
$\%_{droppedout}$	67%	62%	57%
Sig. test	$\chi^2(1) = 2e\text{-}31$, $p = 1$	$\chi^2(1) = 0.04$, $p = .85$	$\chi^2(1) = 0.30$, $p = .58$
Class year (first-year)			
$\%_{completed}$			69%
$\%_{droppedout}$			37%
Sig. test			$\chi^2(1) = 1.97$, $p = .16$

Note: *p<.05; **p<.01; ***p<.001

T-tests use Welch's approximation of degrees of freedom to account for unequal variances and sample sizes

Table 3: Sample and population demographics

Statistic		Current sample		MIT undergraduate pop.
Age				
	Mean (range)	18.42 (18 - 20)		
SAT Score				
	Mean (range)	2214.16 (1860 - 2400)		
	25th percentile	2125		2120
	75th percentile	2310		2350
Gender			%	%
	Male	68	32	55
	Female	142	68	45
Self-identified race			%*	%+
	White/European-American	79	38	41
	Black/African-American	40	19	6
	Asian/Asian-American	64	30	27
	Hispanic or Latino/a	50	24	18
	Middle Eastern	5	2	-
	Native American	4	2	< 1
	Self-specified or two or more	6	3	6
	Unknown			2
$N_{uniqueparticipants} = 210$				

Notes: *Percentages sum to more than 100 because participants could indicate more than once race

+Percent of U.S. resident students (who comprise over 90% of undergraduates

MIT population data from the 2013-2014 Common Data Set (Institutional Research, 2014)

Experience sampling method. Experience sampling (sometimes also called a diary study) refers to collecting data from participants during their daily lives, as they go about their regular activities. This method, in comparison to one-time sampling, allows researchers to examine within-person variation in emotion and cognition over time. In comparison to lab studies, it allows insight into how participants feel during their regular activities, rather than while in a lab. Further, responses are recorded almost in real time, reducing retrospective recall inaccuracy. This methodology also minimizes potential experimenter effects; no researcher is physically present to observe or interview participants. Thus, it can be an effective tool to collect systematic data on the affect and moods associated with daily activities (Csikszentmihalyi, Larson, and Prescott, 1977).

Experience sampling data was collected via a mobile phone application, facilitated by the widespread use of smartphones among our student population. This is an improvement over earlier studies using electronic pagers and paper surveys (Csikszentmihalyi et al., 1977; Csikszentmihalyi and LeFevre, 1989). In addition to making responding easier for participants, since they already carry their phones with them everywhere, the app passively collected data on the exact time of participant responses. The app, based on the open-source plans provided by the Experience Sampler Project (Thai & Page-Gould, in press), was created using Cordova Phonegap, a technology that converts HTML, CSS, and Javascript code into iOS and Android apps. Making the app available for iOS and Android covered the vast majority of smartphones owned by students in our sample; only a few indicated that they had a Windows phone or no smartphone. These students completed the daily survey via Qualtrics survey software on their laptops.

Once installed, the app alerted participants twice a day to fill out the short experience sampling survey. Alert times did not occur during final exam administration. If participants were unable to complete the survey when alerted, they were instructed to complete it as soon as possible. Compliance varied, although the number of days on which participants completed the experience sampling was not significantly correlated with semester GPA, initial PSS scores, or gender (see Table 4).

Table 4: Correlations with ESM compliance

	Number of ESM days completed		
	Round 1	*Round 2*	*Round 3*
Semester GPA	.07		.16
Perceived Stress Scale	.02	−.01	−.03
Gender (female)	−.10	.06	−.09
Note:	*p<.05; **p<.01; ***p<.001		

The survey consisted of 21 questions assessing emotions and stress (see Appendix D for the full list of questions). Participants answered these questions within the app, which then sent their responses to a server for compilation and storage.

The present research

In this dissertation, I use these data to examine factors affecting each of the links between external stressors, perceived stress, and performance. In Chapter 2, I examine the relationship between external stressors and the relative timing of perceived stress in predicting performance. In Chapter 3, I examine the role of stress mindset in moderating the relationship between perceived stress and performance, and the role of motivation as a mediator in this relationship. I conclude with a discussion of how these effects may influence each other, and how the experience sampling method allows a fuller description of the realities of stress. I also discuss implications for theory and practice, and suggest future directions for further research.

Chapter 2: Stress Recovery

Researchers have long sought to understand how stress affects performance, yet the empirical evidence for the effect of stress on performance is mixed. Both benefits and drawbacks to acute stress have been seen in lab studies, while in real-life settings, negative effects of chronic stress have been observed more often (see Staal, 2004). In the real world, outcomes are generated from a series of different stressors, yet stress is often measured as a snapshot of perceived stress at one point in time. Examining stress at more than one point in time, as well as in relation to external stressors, should provide a more detailed picture of an individual's stress. In particular, one overlooked factor in predicting performance may be how perceived stress varies as a function of the presence or absence of external stressors. If perceived stress remains high even between external stressors, it may be harmful because it does not allow time to recover in between stressors. Indeed, past research has provided evidence that performance is depressed after a stressor, but not necessarily during the stressor itself – suggesting that cognitive resources are temporarily depleted after coping with a stressor (Cohen, 1980). Therefore, I propose that reduced perceived stress between external stressors is more important than concurrent stress in predicting performance. The present research studies these questions in the context of undergraduate students' stress levels throughout final exam week, examining how their perceived stress levels vary in relation to the external stressors of exams.

Stress and performance in the lab

Much has been written about the effect of stress on performance. Since stress is when an individual's ability to obtain desired outcomes is threatened (Lazarus & Folkman, 1984), then we may reasonably expect that it will have consequences for performance. Many lab studies frame their findings within an inverted-U theory first described by Yerkes and Dodson (1908). In a classic paper on mouse learning speed, they proposed that increasing stimulus strength (higher shock intensity for wrong choices) led to faster learning, but above some optimal shock intensity, increases in intensity led to decreases in learning speed. Additionally, the optimal level of strength was higher for easy tasks than for difficult tasks. This finding and its implications have been supported, refuted and revisited many times in the century since, leading some to complain that it has been unfairly stretched to cover too wide a range of situations (Teigen, 1994). Indeed, in the literature building on this work, the independent variables have been variously interpreted as stress, punishment, motivation, or arousal, and the outcomes as learning, reaction time, or even sports performance (Raglin & Turner, 1993; Stennett, 1957; Teigen, 1994; Vaughn & Diserens, 1930). Perhaps because of this variation in constructs, findings often vary widely, and some lab evidence suggests positive effects while another set suggests negative effects: one review finds sets of studies that support each of a variety of relationships, including linearly positive, linearly negative, U-shaped, and inverted-U-shaped (Staal, 2004, Figure 2). Overall, this literature is often contradictory, and conflicting results bring the usefulness of this theory into question (Staal, 2004; Teigen, 1994).

Stress and performance in the field

Outside the lab, the literature finds more unambiguously that stress is detrimental to performance. Across settings, real-life evaluative situations have shown a negative relationship between stress and performance. Job interviewees' performance as rated by their interviewers was negatively correlated with measures of interview anxiety administered immediately prior to the interviews (McCarthy & Goffin, 2004). Subjective work load and time urgency were linearly negatively related to performance on a training course exam (Friend, 1982). A study of Israeli

Defense Force cadets found a monotonically negative relationship between perceived stress and exam scores (Westman & Eden, 1996).

This negative impact has been found with longer-term measures of outcomes as well.[2] Jamal (1984) found that both external job stressors and perceived stress were linearly negatively related to job performance among nurses. Among both managerial and blue-collar samples, job stress was negatively related to supervisors' performance ratings (Jamal, 1985). Across professional and clerical workers in four firms in three industries, there was a negative relationship between perceived stress and perceived organizational effectiveness (Allen, Hitt, & Greer, 1982). Among college students, too, perceived academic stress was related to poorer academic performance (Struthers, Perry, & Menec, 2000). Stress caused by chronic noise exposure has also been associated with negative outcomes, such as elevated neuroendocrine markers of stress, worse reading comprehension, and poorer long-term memory (Evans, Hygge, & Bullinger, 1995). Overall, a meta-analysis of 126 studies published from 1975 to 1988 found a mean negative relationship between anxiety and performance (Seipp, 1991). Another meta-analysis, examining 169 samples published between 1975 to 2008, likewise reported a negative correlation (Gilboa et al., 2008). Most of these studies have measured perceived stress at only one point in time.

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[2] One area of research that counters this prevailing claim includes observational studies that document positive changes following trauma, often called posttraumatic growth or adversarial growth (for a review, see Linley & Joseph, 2004). In these cases, a trauma or extreme stressor such as chronic illness, natural disaster, or military combat can be followed by positively perceived change and growth. However, these cases involve extraordinary instances of trauma and the phenomenon has been insufficiently, if at all, investigated for typical daily stressors.

Acute versus chronic stress

Typically, these differences in findings are reconciled by drawing a distinction between acute and chronic stress, with acute stress having potentially beneficial effects and chronic stress being detrimental. In this view, lab studies that have found positive effects of stress (e.g., Cahill & Alkire, 2003; Cahill, Gorski, & Le, 2003) are showing the potential positive effects of acute stress, while field studies that have found negative effects (e.g., Jamal, 1984; Struthers et al., 2000) are showing the downsides of chronic stress. However, each of these collections of studies provide an incomplete picture of stress in real life. Lab studies of the effect of acute stress on performance simply measure participants' performance when faced with a stressor, neglecting what might happen afterward. On the other hand, in the real world, individuals face many different stressors across points in time. Yet field studies examining chronic stress generally measure stress at only one or two points in time. Measuring chronic stress in this way conflates long-term constant stress, and a series of discrete periods of stress. However, in our daily lives, many typical stressors are not constant over time. Given a discontinuous pattern of multiple external stressors, it is difficult to derive a full picture of how stress affects long-term performance and achievement from studies that examine a single, isolated stressor in the lab, or that quantify long-term stress with one measurement at one time point.

External stressors and perceived stress

As discussed in Chapter 1, it is important to disentangle external stressors and perceived stress because they may vary somewhat independently over time. External stressors are events or situations, while perceived stress is an individual's subjective experience of feeling stressed in reaction to those external stressors. Importantly, depending on numerous individual and situational factors, people may differ in the degree to which their perceived stress varies in the presence or absence of external stressors. In a situation in which individuals face a sequence of external stressors, several patterns of perceived stress response are possible, including (but not limited to): (i) an individual may feel stressed when a stressor is present, and not stressed when a stressor is not present (levels of perceived stress that fluctuate with external stressors); (ii) an individual may feel stressed during the entire period (a constant, high level of perceived stress); or (iii) an individual may not feel stressed at all (a constant, low level of perceived stress).

Thus, when chronic stress is assessed at only one time point, it is unclear which of these situations is occurring. In order to differentiate between these possibilities, perceived stress should be examined across time in relation to external stressors, that is, both in the presence of external stressors and at times without external stressors. Individuals who have a more adaptive response would then show perceived stress levels that fluctuate in proportion to the presence of external stressors, in particular, lower perceived stress when external stressors are not present. In order for perceived stress to track appropriately with external stressors, an individual must be able to recover adequately from each stressor.

Physiological recovery

Physiological literature has examined recovery in the context of physiological resiliency, which is the overall pattern of physiological response to stress, "encompassing the rate of initial response to challenge, the magnitude of the response, and the rate of recovery ... to the basal state" (Seeman & Robbins, 1994, p. 233). This overall concept of resiliency can be broken into reactivity and recovery. Reactivity comprises changes in physiological measures from a baseline period as the subject is exposed to a stressor. Recovery, then, is the degree to which the elevation in these measures lessens after the stressor has ended (Linden, Earle, Gerin, & Christenfeld, 1997).

Less research has focused on recovery than on reactivity. One review of 105 papers on physiological resilience found that only 23% of studies reported recovery data in addition to reactivity data (Linden et al., 1997; for a more recent meta-analysis, see Forcier, et al., 2006). Some studies that do investigate physiological recovery have found that recovery speed varies across individuals. Aging has been associated with longer physiological recovery times (Seeman & Robbins, 1994). Individuals who were under chronic stress (operationalized as living in a crowded neighborhood) or who had elevated trait anxiety scores recovered more slowly from stress in the lab (Fleming, Baum, Davidson, Rectanus, & McArdle, 1987; Vitaliano, Russo, Paulsen, & Bailey, 1995). One particularly consistent effect is that physically fit individuals have been found to have significantly faster cardiovascular recovery times than physically unfit individuals (Counts, Loenneke, & Loprinzi, 2017; Jamieson & Lavoie, 1987; McCubbin, Cheung, Montgomery, Bulbulian, & Wilson, 1992; Du, et al., 2005).

Studies that investigate outcomes associated with varying physiological recovery speeds have mostly focused on long-term health and disease. Slower recovery after physical exertion predicted the development of hypertension or increased blood pressure (Hocking Schuler & O'Brien, 1997; Stewart & France, 2001). Among adults, delayed heart rate recovery after exercise predicted an increased risk of all-cause mortality (Cole, Blackstone, Pashkow, Snader, & Lauer, 1999; Dhoble, Lahr, Allison, & Kopecky, 2014). Flatter slopes in cortisol decline were also associated with both more coronary calcification and an increased risk of all-cause mortality (Kumari, Shipley, Stafford, & Kivimaki, 2011; Matthews, Schwartz, Cohen, & Seeman, 2006). In contrast to these health outcomes, shorter-term cognitive and performance effects have not been as well studied. Additionally, it is unclear to what extent physiological recovery translates into psychological recovery.

Since physiological recovery rate is predictive of important health outcomes, it may also be important to examine psychological recovery from stress. As previously discussed, field studies examining the effects of stress on performance have typically only measured perceived stress at one point in time. Thus, they have ignored any recovery in perceived stress levels over time. Moreover, without measures of external stressors as well as perceived stress, it is not clear whether a measure of perceived stress at any one point in time corresponds to the height of perceived stress, or measures a level of perceived stress after some degree of recovery.

Psychological aftereffects of stress

Another literature that examines the effects of stress over time is that on the psychological aftereffects of stress. A collection of experimental studies found deleterious effects of stress on performance, not during the external stressor itself, but after the stressor ended (for a review, see Cohen, 1980). In these studies, stress was induced in a variety of ways. In one lab study, as task demands increased, persistence on a subsequent task decreased (Cohen & Spacapan, 1978). In other studies, stress induced by noise also had aftereffects. For example, in one study, participants completed two reaction time tests in back-to-back sessions. Noise levels during the second test did not affect performance on that test. However, compared to a quiet first session, a loud, constant noise during the first session impaired performance in the second session, providing evidence that it was not the concurrent presence of noise that diminished performance, but the experience of noise during the first session which led to poorer performance in the second session (Hartley, 1973). Similarly, in a sample of students, exposure to noise and higher task demands did not affect concurrent task performance, but resulted in lower frustration tolerance and worse differentiation between target persons on a subsequent task (Rotton, Olszewski, Charleton, & Soler, 1978). Random noises caused the largest aftereffects;

exposure to loud, random intermittent noises reduced frustration tolerance and performance on a subsequent proofreading task, compared to quiet or predictable noise (Glass & Singer, 1972a, 1972b; Glass, Singer, & Friedman, 1969). In a longer study, participants did clerical work for three hours in a noisy or quiet environment, then worked on puzzles. Although there were no differences in performance on the clerical work, participants who had been in the noisy environment performed worse on the puzzles (Evans & Johnson, 2000). Again, stress from a noisy environment did not affect concurrent tasks, but seems to have drained some necessary resource for subsequent performance once the stressor was over.

Another study measured the aftereffects of a driving commute. After a commute, participants had faster heart rates and higher blood pressure (indicating that the commute was stressful), and lower frustration tolerance. Although there was no measure of performance during the stressful event, performance was hindered afterward (White & Rotton, 1998).

Crowding, or high social density, is another potentially stressful situation. A series of studies showed that it also had detrimental aftereffects. In one lab study, participants completed a series of simple and complex tasks under conditions of non-crowding, crowding, and crowding with control (in which they were expressly told they had the option to leave the crowded room at any time). After the period of crowding, participants completed a set of puzzles. Consistent with the previous studies that found no effect of stressful or aversive conditions on concurrent task performance, the crowding had no effect on performance of tasks during the first portion. However, in subsequent tasks, participants who had experienced crowding displayed significantly lower frustration tolerance than those who had not, with participants in the crowding with control condition in the middle (Sherrod, 1974). Another study examined the moderating effect of individuals' need for personal space on this post-crowding effect; crowding should be more stressful for those with a high need for personal space. Performance (speed or accuracy) on a market-themed arithmetic task was not affected by crowding, although the experience was rated as significantly more aversive by participants in the crowding condition (e.g., negative mood, unpleasant room). In a post-crowding proofreading task, however, those in the high social density condition, or who needed greater personal space, proofed fewer lines than those in the low social density condition (Dooley, 1978).

In light of this research on the aftereffects of stress, the timing of stress may be especially important in predicting performance. In particular, previous research that measured stress at only one point in time, and did not measure external stressors as well as perceived stress over time, could have conflated concurrent effects and aftereffects of stress.

Coping with stress depletes cognitive resources

Together, these studies suggest that these stressful situations, while not hindering performance on concurrent tasks, did have a negative effect on performance following the stress. The lab manipulations directly changed external stressors, rather than perceived stress, but the effect seems to rest on the fact that these stress conditions generally resulted in perceived stress; for instance, the aftereffects were greater when individual moderators caused the same external stressor to result in greater perceived stress (Dooley, 1978). One explanation is that enduring stress depletes some cognitive resource that is no longer available for the tasks that take place after the stress is over (Glass & Singer, 1972b). In addition, these effects of the coping itself are independent of whether the coping is successful in, for example, maintaining performance or reaching a desired goal. For instance, in lab studies, more anxious participants reported expending more effort during a cognitive task compared to less anxious participants, despite the fact that both groups performed comparably well (Dibartolo, Brown, & Barlow, 1997; Eysenck, 1979; Hadwin, Brogan, & Stevenson, 2005). This suggests that the mere act of coping with stress requires exertion and depletes cognitive resources. Importantly, this depletion would only become relevant for performance when an individual faces a series of external stressors over time. Therefore, prior literature that measured stress at only one time point, or investigated the effects of only one stressor, has neglected this possibility.

The ego depletion literature posits that a similar stock exists for the ego, or active self, and that this stock is depleted through self-regulation, making choices, and other active decisions. Once this stock is used up, an individual's ability to make further decisions is impaired (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Drawing a parallel to coping with stress, an individual's stock of cognitive resources is deployed while coping with stress, which does not necessarily impact concurrent performance, as long as there are sufficient reserves. Once this stock is depleted, however, withstanding future stressors will be more difficult. Resting, or being relieved of stress, can replenish this stock. In these ways, ego depletion and the cost of coping with stress are similar. However, the resources which are depleted during periods of stress differ from those theorized by ego depletion. The resources taxed in order to cope and adapt in the face of stress are drained even further if the stressor is uncontrollable (Glass & Singer, 1972a; Sherrod, 1974), whereas the theory of ego depletion posits that it is choice-making ability and executive control in itself which is drained, and therefore controllable events, requiring this control, should be more draining on the ego.

In sum, apart from any effects of stress during performance on the quality of that performance (whether positive or negative), evidence suggests that being stressed depletes cognitive resources necessary for later performance. Because of this, a pattern of perceived stress that varies in tandem with external stressors would be more beneficial for performance than a pattern of constant, elevated perceived stress. When perceived stress extends beyond the bounds of an external stressor, there is never a stress-free period, and performance will perpetually be occurring in a depleted post-stress state. In examining negative effects of stress in the field, then, it may be that the stress itself is not affecting performance per se; instead, perhaps the observed negative effects come from never recovering from the exertion of coping with stress, and always performing as if one is still recovering from a previous stressor. Therefore, we should anticipate that when an external stressor is no longer present, an individual must reduce their perceived stress to rebuild these resources and perform well on future tasks.

The present research

The present research examines the timing of external stressors and perceived stress in the context of undergraduate students during their final exam period, providing data on both external stressors (i.e., exams) and perceived stress, as well as academic performance. Here academic performance is operationalized as semester grade point average (GPA). Many of the outcomes in lab studies have been frustration tolerance or performance on simple reaction time or error detection tests. Although these brief and easily quantified measures lend themselves to lab studies, it is unclear how direct the link is between frustration tolerance or reaction time and more abstract or reasoning-based cognitive performance outcomes (although some studies have documented a correlation between reaction time, working memory, and intelligence, e.g., Wilhelm & Oberauer, 2006). These simple cognitive measures are only one consideration in life success and other outcomes; achievement depends on many more complex factors; thus, GPA represents a more realistic measure of student success.

Hypothesis 1. In the context of the present data, I will first test for the conventionally observed negative relationship between overall stress and performance. That is, I hypothesize that students with higher perceived stress will perform more poorly than students with lower perceived stress.

Hypothesis 2. Then, in examining the relationship between external stressors and timing of perceived stress, I hypothesize that apart from any effect of concurrent stress on exam performance, students who have reduced perceived stress on non-exam days will perform better, while those who have higher levels of perceived stress even on non-exam days will have lower performance overall.

Chapter 2 Method

Participants

Data were collected during two spring final exam periods in consecutive years. During the first round, participants were 54 undergraduate students in their first year of college (M_{age} = 18.59, *SD* = 0.50; 35 women and 19 men). During the second round, participants were 113 undergraduate students in their first and second years of college (M_{age} = 18.92, *SD* = 0.70; 82 women and 30 men). Some participants completed both rounds, resulting in a final sample that included 167 observations of 152 unique participants. Each student was paid $50 for their participation during each exam period.

Materials

Exams. Participants reported the classes they were enrolled in. These lists were cross-referenced with the final exam schedule published by the registrar to create, for each student, a classification of each day as an exam day (i.e., a day on which they took at least one exam), or a non-exam day (i.e., a day on which they had no scheduled exams).

Measures of perceived stress. As a measure of overall level of stress, I used scores on the Perceived Stress Scale (PSS; Cohen et al., 1983), assessed prior to final exam period (in the first round Cronbach's alpha = 0.87, in the second round Cronbach's alpha = 0.89). The response scale ranged from 0 (Never) – 4 (Very often). A second measure of overall stress was the mean of stress levels reported via experience sampling (ESM) during final exam week for each participant (mean ESM stress). The response scale ranged from 0 (Not at all) – 5 (Extremely). Then, to investigate perceived stress levels in the presence or absence of an external stressor, I calculated each participant's mean stress level reported on exam days, and their mean stress level reported on non-exam days. Finally, because students may experience stress unrelated to final exams, I use a one-item measure of general stress as separate from exam stress, measured at the initial survey time point. This measure was only collected in the second round, and the response scale ranged from 1 (No stress) – 5 (Extreme stress). For the complete text of these items, see Appendix D.

Academic performance. Semester GPA was used as a measure of academic performance. For confidentiality reasons, GPA was standardized (i.e., centered at 0 and scaled to a standard deviation of 1).

Control variables. To control for prior level of academic achievement, participants' high school GPAs and Scholastic Aptitude Test (SAT) scores were collected. High school GPAs reported on a scale other than out of 4.0 (e.g., out of 100) were converted to a 4.0 scale. SAT scores were treated as missing if students took the ACT instead of the SAT.[3] Because students' stress levels might justifiably vary as a function of the amount of academic work they have, number of exams and semester course load also served as control variables. Other control

[3] Although SAT to ACT conversion tables exist, their use is inexact and not endorsed by the makers of the ACT (Edwards, 2016).

variables included participant gender, round of data collection, and participation in the Interphase program.[4]

Procedure

During each round of data collection, participants completed online surveys shortly before and after their final exam week, which included the Perceived Stress Scale, course load, and background information such as demographics, high school GPA, and SAT scores. Then, they downloaded a smartphone app that prompted them to complete short experience sampling questionnaires each day during exam week. These questionnaires included a perceived stress item. For more detail on the data collection procedure, see Chapter 1.

Chapter 2 Results

Data analysis strategy. Since some individuals participated in multiple rounds of the study, the data are hierarchical, with multiple observations grouped by participant. Because of this, all models are mixed-effect linear regression models with random effects (random intercepts) for participant identity. These coefficients, along with coefficients for fixed effects controlling for round of data collection and participation in the Interphase program, are not reported but their inclusion in models is noted in the "control" rows of each table. Additionally, all models control for high school GPA and SAT score (these coefficients are reported).[5]

Descriptives. Overall, the five measures of stress were moderately correlated with each other (see Table 5, variables 2–5), suggesting that they measure related, but not identical, constructs. The average mean ESM stress on exam days ($M = 2.45$) was significantly higher than mean ESM stress on non-exam days ($M = 1.85$, $t(295) = 5.23$, $p < .001$), consistent with exams

[4] For details on the Interphase program, see Chapter 1, Data and Method
[5] A quadratic effect for SAT score is not significant when added to the models.

being an important driver of perceived stress during this time. See Table 5 for summary statistics and Table 6 for correlations.

Table 5: Chapter 2 descriptive statistics

Statistic	Mean	Median	Min	Max
Perceived Stress Scale, initial	1.860	1.900	0.400	3.300
Mean ESM stress	2.044	2.000	0.045	5.000
Mean ESM stress, exam days	2.454	2.500	0.000	5.000
Mean ESM stress, non-exam days	1.853	1.875	0.062	5.000
General stress, initial	3.027	3	1	5
Semester course load	4.071	4	2	6
Number of final exams	2.879	3	1	5
High school GPA	3.770	3.880	3.240	4.000
SAT score	2,197.286	2,230	1,860	2,400

Overall stress. As discussed, prior literature on long-term effects of stress on performance has often measured stress at only one time point. To determine if a negative relationship between perceived stress and performance existed in these data (Hypothesis 1), I used scores on the Perceived Stress Scale as well as mean ESM perceived stress to predict semester GPA. I fit separate mixed-effect linear regression models as described above with each of these measures of perceived stress predicting semester GPA (with additional control variables as noted above). Consistent with Hypothesis 1 and prior literature, overall perceived stress was negatively associated with semester GPA, as measured using Perceived Stress Scale scores (b = -0.32, p = .005) or mean ESM stress (b = -0.34, p < .001; see Table 7, models 1 and 2).

Table 6: Chapter 2 correlation matrix

	1	2	3	4	5	6	7	8	9
1. Standardized semester GPA									
2. Perceived Stress Scale, initial	-.25**								
3. Mean ESM stress	-.31***	.45***							
4. Mean ESM stress, exam days	-.15	.36***	.80***						
5. Mean ESM stress, non-exam days	-.34***	.45***	.95***	.62***					
6. General stress, initial	-.18	.52***	.31**	.31**	.26**				
7. Semester course load	.32***	-.16	-.04	.03	-.06	-.07			
8. Number of final exams	.05	-.06	.05	.05	.00	.02	.34***		
9. High school GPA	.12	-.02	-.05	-.05	-.05	.07	.03	-.05	
10. SAT score	.45***	-.02	-.12	-.10	-.14	.08	.22**	.21*	.08

Note: *p<.05; **p<.01; ***p<.001

Stress on exam versus non-exam days. Then, to test Hypothesis 2, I examined levels of perceived stress in the presence of and absence of an external stressor. I fit two models separately, testing the predictive value of ESM stress on exam days and on non-exam days. The mean level of ESM stress on exam days was not associated with semester GPA ($b = -0.08, p = .31$; see Table 7, model 3), consistent with lab studies that have found no effect of stress on concurrent performance. However, mean ESM stress on non-exam days was associated with semester GPA, such that the more stress reported on non-exam days, the worse a student's semester GPA ($b = -0.37, p < .001$; see Table 7, model 4). That is, compared to being stressed on exam days, being stressed on non-exam days, when there is no external stressor, is more strongly associated with lower academic achievement (see Figure 1). Because there was variation in external stressors depending on how many exams and classes students took, I also fit models controlling for number of final exams or semester course load; results remained substantively the same (see Appendix A, Table A1).[6]

Controlling for general stress. There is a possibility that students who are stressed on non-exam days are facing other, non-exam, stresses that affect their performance. To examine this possibility, I used data only from the second round, in which we collected separate measures of exam stress and general stress prior to exam week. I fit linear models predicting semester GPA from mean ESM stress, mean ESM stress on exam days, and mean ESM stress on non-exam days, controlling for general stress. On one hand, this analysis does not account for non-exam stressors which may arise during exam week and both justifiably increase students' perceived stress and hinder their performance. On the other hand, this analysis represents a

[6] In analyses controlling for participant gender, results remain substantively the same and the coefficients for gender are not significant (see Appendix A, Table A2).

Table 7: Predicting GPA from stress

	Dependent variable:			
	Standardized semester GPA			
	(1)	(2)	(3)	(4)
Perceived Stress Scale, initial	−0.321**			
	p = 0.005			
Mean ESM stress		−0.336**		
		p = 0.0003		
Mean ESM stress, exam days			−0.075	
			p = 0.306	
Mean ESM stress, non-exam days				−0.365**
				p = 0.00004
High school GPA	0.473	0.490	0.489	0.484
	p = 0.116	p = 0.103	p = 0.124	p = 0.109
SAT score	0.002**	0.002**	0.002**	0.002**
	p = 0.001	p = 0.008	p = 0.003	p = 0.008
Constant	−6.442**	−5.334**	−6.788**	−5.279**
	p = 0.0004	p = 0.005	p = 0.001	p = 0.005
Control for round and participant random effects	Yes	Yes	Yes	Yes
Control for Interphase	Yes	Yes	Yes	Yes
Observations	137	131	130	129
Log Likelihood	−176.216	−168.794	−173.884	−165.503
Akaike Inf. Crit.	368.432	353.589	363.769	347.007
Bayesian Inf. Crit.	391.792	376.590	386.709	369.885
Note:				$^{+}$p<.10; *p<.05; **p<.01

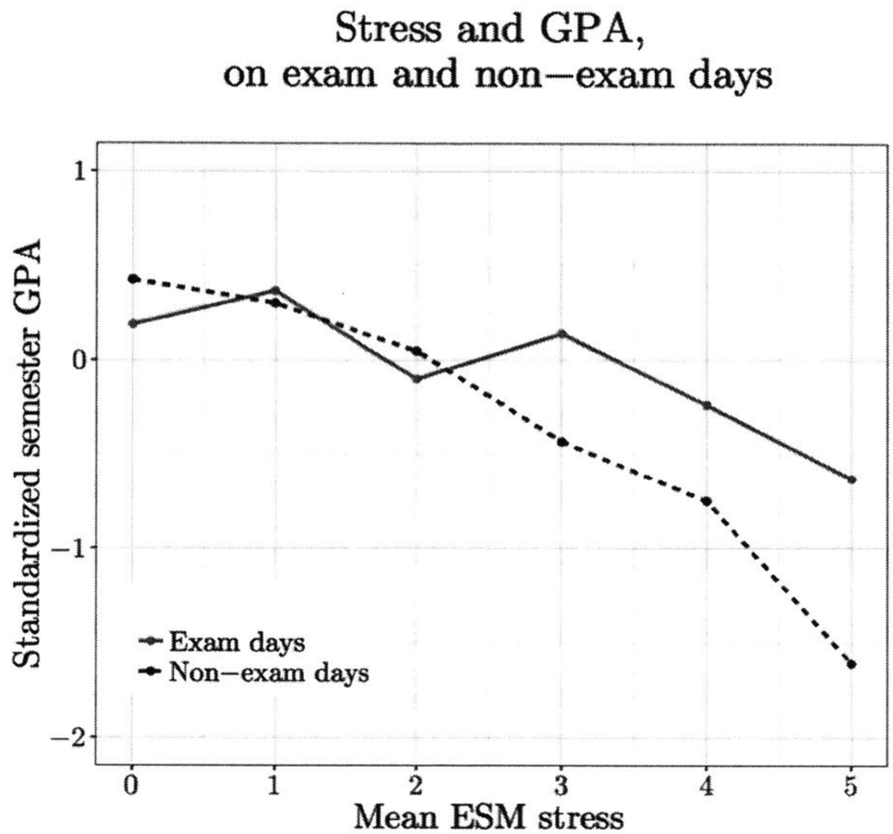

Figure 1: Average standardized semester GPA for each level of mean perceived stress reported during experience sampling, on exam days and non-exam days.

conservative test of Hypothesis 2 because controlling for general stress prior to exam period is to some extent controlling for students' trait-level perceived stress regardless of external stressors – which is precisely the individual difference that I propose affects performance. Results revealed that although there was an overall negative impact of general stress on performance, the difference in significance of ESM stress on exam days versus non-exam days remained (exam days $b = 0.02, p = .80$; non-exam days $b = -0.33, p = .003$; see Appendix A, Table A3).[7]

[7] Results remained substantively the same controlling for initial Perceived Stress Scale scores instead of initial general stress.

Chapter 2 Discussion

Consistent with the literature, overall perceived stress (both PSS and ESM stress) negatively predicted semester GPA. However, when stress levels were broken down by exam day or non-exam day, they revealed a different pattern. Stress level on exam days did not predict GPA, while stress level on non-exam days negatively predicted GPA. These results showed that, contrary to the straightforward intuition behind field studies that have linked high stress levels and poor performance, stress levels were not necessarily associated with concurrent performance. Instead, it is important to consider the relationship between perceived stress and external stressors in predicting performance: when perceived stress was high even on non-exam days in the absence of an external stressor, students performed more poorly. In light of prior research on negative post-stress effects (e.g., Evans & Johnson, 2000; Glass et al., 1969), one reason for this difference could be that students who show lower levels of stress on non-exam days replenish their cognitive resources during these periods, so that during their exams they are able to cope with stress and perform well.

Contributions

Theoretical contributions. Overall perceived stress, when measured at one time point, may be assumed to be associated with worse performance because it translates into high stress levels that impair performance on concurrent tasks. However, in the present data, there was no relationship between perceived stress on exam days and overall performance; instead, perceived stress on non-exam days negatively predicted performance. Thus, the present research demonstrated that measuring stress at one time point or as one global quantity provides an inadequate understanding of the relationship between stress and performance.

Empirical contributions. First, this study measured stress in much greater temporal detail than previous field studies, which have generally measured stress as a broad, overall level, and shown that it is negatively related to performance. In contrast, the present data measured stress levels at a finer granularity and provided no evidence of effects of stress on concurrent performance. Second, the current study brought research on the aftereffects of stress out of the lab and into a real-world setting. The performance outcomes used in lab studies typically measure persistence or simple cognitive measures, both of which represent only a portion of the considerations in academic and life success; achievement depends on many more complex factors. The present research used grade point average, a more realistic and highly consequential performance outcome. In addition, since students' real outcomes depend on their performance during exams, they may have had a more realistic reaction to these stressors, compared to lab tasks, on which participants' performance is less personally relevant.

Practical implications. Because stress during evaluative occasions was not related to concurrent performance, these results suggest that traditional stress management techniques (e.g., breathing or visualization exercises with the goal of reducing and avoiding stress) may be ineffective when utilized during performance settings. Instead, they may be better applied during periods in between external stressors and when evaluation of performance is not taking place, allowing individuals to benefit from a period of reduced stress in order to restore their cognitive resources. Moreover, these findings challenge traditional wisdom that stressors should be avoided and perceived stress levels should always be reduced. Instead, avoiding stress completely may not be practical or even desirable. The fact that stress on exam days did not predict performance suggests that perceived stress is not always harmful, if it varies appropriately, in sync with external stressors.

Limitations

This examination of the timing of stress and stress recovery has some limitations worth discussing. The use of semester GPA is advantageous in that it is highly consequential for undergraduate students, and is reported on a consistent scale. However, stress level data is reported only during final exam week, and subject grades may also depend on other exams, problem sets, or projects. However, this means that the ability to draw conclusions about the link between stress and rest periods and performance thus rests to some degree on the assumption that these patterns of changes in perceived stress are somewhat stable within each individual, and are therefore representative of how the student's stress levels *generally* fluctuate, and how stress has affected their performance throughout the semester.

For practical reasons, the granularity of reported stress levels is not as fine as would be ideal; it's uncertain whether perceived stress on exam day is truly representative of perceived stress level during the exact hours of the exam. However, stress levels on non-exam days are certainly being reported when there is no evaluation, and the exam day–non-exam day difference certainly reflects more granularity than one time point or retrospective report. To the extent that these day-level measures of perceived stress underestimate differences between perceived stress during an exam and at other times, these data provide a conservative test of the hypothesis.

Finally, the correlational nature of this data leaves some unavoidable questions: reverse causality is possible in this data, such that students who perform worse on their exams recognize this right away and remain stressed about it on subsequent days, while those who know they performed well are better able to reduce their stress. Alternatively, general competence could influence both grades and stress levels, if students know that they are not doing well. To determine causality, a true experimental design is necessary.

Future directions

These findings suggest several areas that might be fruitful for future research. A study that makes use of physiological measures of stress (e.g., with a wearable tracker) would be able to measure differences in stress levels at a much finer temporal granularity, without greatly increasing the burden to the research participants. This would make the differentiation between exam and non-exam time periods clearer. Additionally, performance results from specific stressors (in this context, specific exam grades) would allow more direct demonstration of a link between perceived stress and performance at a particular time.

Further investigation into recovery from perceived stress could provide insight into why perceived stress in the absence of external stressors is so important for performance. If performance is hindered by a lack of recovery in perceived stress after an external stressor ends, then there may be an opportunity for intervention. First, a true experiment that manipulates perceived stress (for example, with specific appraisal instructions) across multiple rounds of external stressors could clarify causality and rule out alternative explanations for these individual differences. Then, if the relationship between perceived stress and performance is indeed causal, the present data point to effective times to test stress reduction techniques (i.e., when external stressors are not immediately present).

Additionally, the current data did not include information on what activities students were engaging in on non-exam days. Future research that investigates the impact of different activities on perceived stress and performance, for example, with more detailed experience sampling data or with qualitative interview data, could shed light on how individuals can most effectively recover from stress.

Conclusion

The present research provides evidence that in real-world settings where outcomes are cumulatively determined across a period with multiple stressors, perceived stress at times when there are no external stressors is more important in predicting success than perceived stress when an external stressor is present. Although individuals are able to cope with stress without affecting their concurrent performance, those who do not recover adequately (i.e., report high levels of perceived stress even when no external stressor is present) perform worse. Traditional stress management techniques that aim to reduce stress (e.g., through meditation or breathing exercises) may be better targeted at periods in between stressors as a way to recover, rather than utilized directly in performance settings such as exams. Perceived stress is not necessarily harmful for performance, if it rises and falls appropriately in response to external stressors.

Chapter 3: Stress Mindset

Popular wisdom holds that stress is killing us. The research literature offers considerable evidence to support this conclusion, but also finds that stress can have positive effects (see Staal, 2004). Many existing explanations for the diverging effects of stress focus on features of the stressor or the situation, such as the intensity of the stressor or an individual's appraisal of the situation. However, equally important in explaining the effects of stress may be an individual's beliefs about the nature of stress in general: whether they hold the mindset that stress is debilitating, or that stress is enhancing. Indeed, a growing literature on stress mindset has found that beliefs about the nature of stress have important consequences for behavior (Crum, Akinola, Martin, & Fath, 2017; Crum, Salovey, & Achor, 2013). In this chapter, I propose that stress mindset moderates the relationship between perceived stress and performance through its effect on the relationship between perceived stress and motivation. That is, stress mindset moderates the relationship between stress and motivation, such that perceived stress is more demotivating for individuals who hold a stress-is-debilitating mindset. This effect of stress on motivation mediates the observed negative effect of stress on performance for individuals with a stress-is-debilitating mindset. I test these propositions with experience sampling data from undergraduate students during their final exam week.

Traditional accounts of stress and performance

One traditional account of the different possible effects of stress on performance centers on the amount of stress and individual faces or experiences. Often, with "amount" of stress referring to intensity, this relationship is hypothesized to be defined by an inverted-U shape. In a classic paper on mouse learning speed, Yerkes and Dodson (1908) proposed that up to a point, increasing stimulus strength (higher shock intensity for wrong choices) led to faster learning, but above some optimal level, increases in intensity led to decreases in learning speed (Dodson, 1917; see also Easterbrook, 1959; Yerkes & Dodson, 1908). Since then, researchers have made claims that the dependent variable in this relationship can be extended to performance as well as learning, although empirical support has been mixed (Teigen, 1994). If "amount" refers instead to the duration of stress, then the effects of a stressor will depend on whether it is acute or chronic. Typically, this research ascribes potentially positive effects to acute stress, and negative effects to chronic stress (Cohen et al., 1998; McGonagle & Kessler, 1990). This perspective suggests that it is the *amount* or *intensity* of stress that determines the effects of stress.

Appraisal theory takes a more nuanced view and posits that the effects of stress depend upon how individuals perceive the situation. First, individuals will appraise a particular event as stressful; then, they will appraise their own resources in relation to the environment (Folkman, 2013; Lazarus, 1966). Comparing the demands of a particular situation to their resources results in an overall appraisal: a situation is appraised as a challenge when resources appear to exceed demands, or as a threat when resources appear insufficient to meet demands (Blascovich, Mendes, Hunter, & Salomon, 1999). Stressors may therefore have different effects, depending on an individual's appraisal of the situation as a challenge or a threat (Skinner & Brewer, 2002; Tomaka, Blascovich, Kelsey, & Leitten, 1993).

Individual differences

One understudied moderator of the effect of stress, beyond the amount of stress or characteristics of the situation, is an individual's beliefs about the nature of stress in general, in particular, their beliefs about whether stress is enhancing or debilitating for functioning. There is evidence that individuals vary in their stress mindset (Crum, Salovey, & Achor, 2013). Although the dominant narrative in our culture is that stress is debilitating (e.g., causing us to freeze up, burn out, develop health problems), the idea that stress can be enhancing also holds intuitive appeal (e.g., stress means that we care about doing well, helps us to focus our energy on the task at hand, and makes us stronger).[8] People's beliefs fall at various points along this spectrum, and either mindset can be induced with a manipulation presenting selective research evidence (Crum et al., 2013). Stress mindset may influence performance outcomes by affecting individuals' behavior in response to stress.

In other domains, mindset has indeed been shown to affect functioning by determining how someone is likely to allocate attention and effort. For example, whether people hold the mindset that intelligence is a malleable or fixed trait is extremely consequential for their learning and achievement (Blackwell, Trzesniewski, & Dweck, 2007; for a review, see Yeager & Dweck, 2012). Someone holding a fixed mindset about intelligence may be more likely to avoid situations that might provide evidence they're not smart, or to withdraw from criticism, while someone with a growth mindset may be more likely to seek out opportunities to learn and receive feedback. Analogously, stress mindset may influence how individuals allocate attention when faced with stress: do they withdraw, or otherwise engage in behaviors and cognitions to avoid the stress, or do they accept the stress and feel motivated to take action to meet the demands of the situation?

A growing body of literature examines the effects of an individual's beliefs about the impact of stress. In a series of lab studies inducing stressful situations, participants holding a stress-is-enhancing mindset (greater endorsement of the idea that "experiencing stress enhances

[8] To be sure, some situations that induce stress are unambiguously negative or traumatic, and should not be minimized or ignored. For many everyday stressors, though, the stressor itself is not detrimental. For instance, an exam is not a negative event, yet it can easily cause stress. It is this type of stress that I discuss here.

performance and productivity" and "the effects of stress are positive and should be utilized") had more adaptive physiological and behavioral outcomes than those holding a stress-is-debilitating mindset (greater endorsement the idea that "experiencing stress debilitates performance and productivity" and "the effects of stress are negative and should be avoided"). For instance, those with a more stress-is-enhancing mindset had more moderate cortisol responses to a stressful public speaking task and were more likely to want to receive feedback (Crum et al., 2013). In another study that framed stressors as either a challenge or threat, experimentally inducing a stress-is-enhancing mindset led to greater positive affect and attentional bias, and increased cognitive flexibility under challenge conditions. In both the challenge and threat conditions, a stress-is-enhancing mindset led to a sharper spike in DHEAS (an anabolic "growth" hormone) during a social stress task (Crum, Akinola, Martin, & Fath, 2017). Thus, these beliefs about the nature of stress have effects that extend to performance as well. In a field study, self-reported work performance increased for those who received a stress-is-enhancing message, but not for those in the control (no message) or stress-is-debilitating conditions (Crum et al., 2013).

Likewise, teaching people about the enhancing nature of stress in a particular situation or domain can affect performance. In one study, participants in one condition were told to appraise anxiety as beneficial to negotiation, while those in the control condition receive no instructions about appraisal. Condition interacted with salivary cortisol increases (a general response to stressful or uncertain situations), such that for participants who were told to appraise anxiety as beneficial, cortisol increases were associated with better performance in a negotiation with a confederate, while for participants who were given no appraisal instructions, cortisol increases were associated with worse negotiation performance (Akinola, Fridman, Mor, Morris, & Crum, 2016). In another study, participants in a reappraisal condition who were told that anxiety could improve performance obtained better scores on both practice Graduate Record Examination (GRE) questions in the lab and on their actual GREs, compared to participants who received no reappraisal instructions (Jamieson, Mendes, Blackstock, & Schmader, 2010). In a stressful evaluative speech task, participants in the arousal reappraisal condition showed less negative affect and less avoidant nonverbal signaling (Beltzer, Nock, Peters, & Jamieson, 2014). (For a review of the arousal reappraisal literature, see Jamieson, Mendes, & Nock, 2012.)[9]

What is the process by which stress mindset affects outcomes?

These studies provide evidence that beliefs about the nature of stress can change outcomes, but there is limited evidence of the process through which stress mindset affects performance. To better understand stress mindset and develop interventions that improve performance, we should understand the intermediate mechanisms that are affected by stress mindset. It is possible that mindsets can work by affecting how individuals allocate effort. As mentioned previously, an intelligence-is-fixed mindset leads to different cognitions and behaviors than an intelligence-can-grow mindset, even in the same situation. For instance, individuals holding a fixed mindset were more likely to believe in the futility of effort, while those holding a growth mindset were more likely to believe in the utility of effort. After performing poorly on an intelligence test, this belief about effort led those with a growth mindset, compared to those with a fixed mindset, to more frequently choose to participate in a

[9] This reappraisal of the effects of stress or anxiety is distinct from other research on anxiety which also uses the term "reappraisal" but refers to a different effect. These studies instruct participants to reevaluate their anxiety as excitement (Brooks, 2014). This differs from stress mindset in that the manipulation instructs participants to reappraise stress as something that is not stress, whereas inducing a stress-is-enhancing mindset or arousal reappraisal instructs participants that stress is beneficial to performance.

tutorial learning exercise rather than an unrelated activity (Hong, Chiu, Dweck, Lin, & Wan, 1999).

Similarly, individuals holding a stress-is-enhancing mindset were more likely to want feedback on their performance after a stressful public speaking task (Crum et al., 2013). Stress mindset may improve performance through a similar mechanism as intelligence mindsets, in this case by influencing individuals' motivation under stress. In particular, the relationship between perceived stress and motivation to do well academically may be more positive for students who hold a stress-is-enhancing mindset.

Academic motivation

Motivation has frequently been linked to improved performance and success in school. This link has been demonstrated across grade levels, from elementary school to high school and college (Fortier, Vallerand, & Guay, 1995; Gottfried, 1985; Skinner & Belmont, 1993; Struthers et al., 2000; Wentzel, 1997). In particular, motivation has consequential effects on student persistence in higher education (Tinto, 1975). (For reviews, including a discussion of differentiation between types of motivation, see Deci, Vallerand, Pelletier, & Ryan, 1991, and Vansteenkiste, Lens, & Deci, 2006.) Because higher motivation can have these positive effects on performance, modifying the effect of stress on motivation could be beneficial.

Motivation can be conceptualized as either trait motivation – a stable disposition – or state motivation – a transitory response (Dörnyei, 2003). Trait motivation, along with situational variables, influences state motivation (Seegers & Boekaerts, 1993), and state motivation is more predictive of performance outcomes (Gardner & Tremblay, 1994, as cited in Tremblay, Goldberg, & Gardner, 1995; Tremblay, Goldberg, & Gardner, 1995). If we conceptualize state motivation as the product of trait motivation and situational factors, perceived stress may be one of these situational factors. Therefore, there is more likely to be a link between perceived stress and state motivation, and in the present study, I investigate state motivation.

The present research

The present research examines stress mindset, motivation, and performance in the context of undergraduate students during their final exam period. Stress mindset and perceived stress were assessed at the start of exam week, and additional state measures of perceived stress and academic motivation were collected throughout exam week. Again, academic performance was operationalized as semester grade point average (GPA).

Hypothesis 1. In the context of the present data, I expect that stress mindset will moderate the effect of perceived stress, such that students who endorse a stress-is-debilitating mindset will indeed have worse performance under more perceived stress, while students who endorse a stress-is-enhancing mindset will have better performance under more perceived stress.

Hypothesis 2. Then, measurements of academic motivation allow me to investigate whether perceived stress affects performance through its effect on motivation, and whether the relationship between stress and motivation varies by stress mindset. I hypothesize that the relationship between stress and performance will be mediated by academic motivation, subject to the moderation laid out above. That is, stress mindset will alter the way in which stress relates to performance, by altering the way in which stress relates to academic motivation: the relationship between perceived stress and motivation will be more negative for students who endorse a stress-is-debilitating mindset, compared to students who endorse a stress-is-enhancing mindset. These relationships are depicted in Figure 2.

Whether stress mindset moderates the relationship between perceived stress and motivation can be assessed in two ways: between participant and within participant. First, I hypothesize that stress mindset will predict the extent to which individuals who have generally high percieved stress also have generally high academic motivation (Hypothesis 2a). Second, I hypothesize that stress mindset will predict the extent to which each participant's ESM stress and academic motivation are correlated over time (Hypothesis 2b).

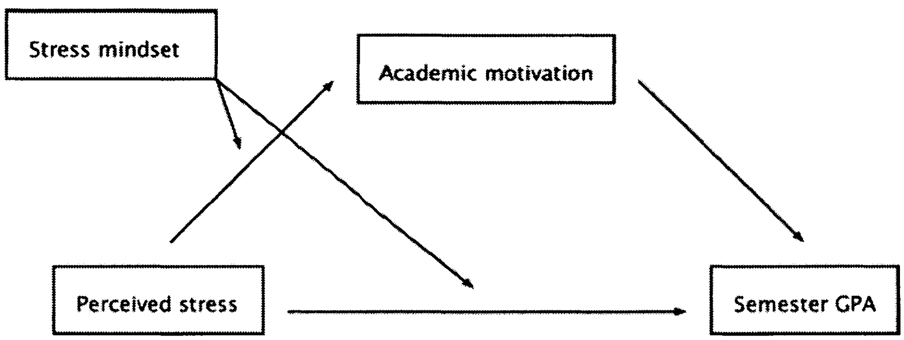

Figure 2: The hypothesized relationships between stress mindset, perceived stress, academic motivation, and semester GPA. Stress mindset moderates the relationship between perceived stress and semester GPA, and the relationship between perceived stress and academic motivation.

Chapter 3 Method

Participants

Data were collected during three consecutive final exam periods. During the first round, participants were 54 undergraduate students in their first year of college (*M*age = 18.59, *SD* = 0.50; 35 women and 19 men). During the second round, participants were 130 undergraduate students in their first year of college (*M*age = 18.15, *SD* = 0.35; 88 women and 42 men). During the third round, participants were 113 undergraduate students in their first and second years of college (*M*age = 18.92, *SD* = 0.70; 82 women and 30 men). Some participants completed multiple rounds of data collection, so that the final sample for analysis included 297 participant-semester observations of 210 unique participants. Each student was paid $50 for participating during each exam period.

Materials

Perceived stress. As a measure of overall level of stress, I used scores on the Perceived Stress Scale (Cohen et al., 1983) administered at the initial time point, at the beginning of exam week. The response scale ranged from 0 (Never) – 4 (Very often). Cronbach's alpha for rounds 1, 2, and 3 was 0.87, 0.86, and 0.89, respectively. The daily experience sampling surveys contained a second measure of perceived stress, on which the response scale ranged from 0 (Not at all) – 5 (Extremely). For the complete text of these items, see Appendix D.

Stress mindset. Stress mindset was measured at the initial time point with scores on the Stress Mindset Measure (Crum et al., 2013), on which higher scores indicate endorsement of a stress-is-enhancing mindset and lower scores indicate endorsement of a stress-is-debilitating mindset. Participants indicated their agreement with each of 8 items. The response scale ranged from 0 (Strongly disagree) – 4 (Strongly agree). Cronbach's alpha for rounds 1, 2, and 3 was 0.85, 0.82, and 0.85, respectively. For the complete text of these items, see Appendix D.

Academic performance. Semester GPA was used as a measure of academic performance in rounds 1 and 3 (during round 2, participants were first-semester freshmen and did not receive letter grades in their classes). For confidentiality reasons, GPA was standardized (i.e., centered at 0 and scaled to a standard deviation of 1).

Academic motivation. Academic motivation was assessed on daily experience sampling surveys during exam week. Participants indicated their agreement with the statement "I feel motivated to do well academically." Each participant's overall level of academic motivation is operationalized as the mean of their responses. The response scale ranged from 0 (Strongly disagree) – 5 (Strongly agree).

Correlation between perceived stress and academic motivation over time. To assess the relationship between perceived stress and state levels of academic motivation, I calculated the correlation between each student's perceived stress and academic motivation responses on the daily experience sampling surveys throughout exam week. The response scale for both of these items ranged from 0 – 5 as described above, and possible values for Pearson's *r* range from -1 to 1.

Control variables. To control for prior level of academic achievement, participants' high school GPAs and Scholastic Aptitude Test (SAT) scores were collected. High school GPAs reported on a scale other than out of 4.0 (e.g., out of 100) were converted to a 4.0 scale. SAT scores were treated as missing if students took the ACT instead of the SAT.[10] Because students' stress levels might justifiably vary as a function of the amount of academic work they have, number of exams and semester course load also served as control variables. Other control variables included participant gender, round of data collection, and participation in the Interphase program.[11]

Procedure

During each round of data collection, shortly before and after their final exam week, participants completed online surveys, which included the Perceived Stress Scale, Stress Mindset Measure, course load, and background information such as demographics, high school GPA, and SAT scores. Then, they downloaded a smartphone app that prompted them to complete short experience sampling questionnaires each day during exam week. These daily experience

[10] Although SAT to ACT conversion tables exist, their use is inexact and not endorsed by the makers of the ACT (Edwards, 2016).
[11] For details on the Interphase program, see Chapter 1, Data and Method.

sampling surveys included items to assess academic motivation and perceived stress. For more details on the data collection procedure, see Chapter 1.

Chapter 3 Results

Data analysis strategy. Since some individuals participated in multiple rounds of the study, the data are hierarchical, with multiple observations grouped by participant. Because of this, unless noted, all models are mixed-effect linear regression models with random effects (random intercepts) for participant identity. These coefficients, along with coefficients for fixed effects controlling for round of data collection and participation in the Interphase program, are not shown in the tables but their inclusion in models is noted in the "control" rows of each table. Models control for high school GPA and SAT score to account for prior academic achievement differences between students.[12]

Descriptives. The mean score on the Stress Mindset Measure was 1.93, and the median was 2 (the midpoint of the scale); approximately one half of the participants endorsed a more stress-is-debilitating mindset, and one half a more stress-is-enhancing mindset (see Table 8).[13] Stress mindset was positively correlated with academic motivation ($r(272) = .21, p < .001$). Academic motivation was positively correlated with semester GPA, suggesting that in general, academic motivation was beneficial to performance ($r(148) = .33, p < .001$; see Table 9).[14] See Table 8 for summary statistics and Table 9 for correlations.

[12]A quadratic effect for SAT score is not significant when added to the models.
[13] 34 of the 297 participants had a score of 2 on the Stress Mindset Measure, indicating that they did not endorse one mindset more than the other.
[14] It is also possible that previous academic performance influenced motivation.

Table 8: Chapter 3 descriptive statistics

Statistic	Mean	Median	Min	Max
Stress Mindset Measure, initial	1.93	2.00	0.00	4.00
Perceived Stress Scale, initial	1.79	1.80	0.20	3.30
Mean academic motivation	3.84	3.93	0.76	5.00
Stress-motivation correlation	−0.05	−0.08	−0.88	1.00
Semester course load	4.07	4	2	6
Number of final exams	2.88	3	1	5
High school GPA	3.78	3.89	3.24	4.00
SAT score	2,211.30	2,240	1,860	2,400

Table 9: Chapter 3 correlation matrix

	1	2	3	4	5	6	7	8
1. Semester GPA								
2. Stress Mindset Measure, initial	.09							
3. Perceived Stress Scale, initial	-.25**	-.28***						
4. Mean academic motivation	.33***	.21***	-.43***					
5. Stress-motivation correlation	-.03	.10	-.12	.02				
6. Number of final exams	.05	-.03	-.06	-.03	.08			
7. Semester course load	.32***	.06	-.16	.12	.02	.34***		
8. High school GPA	.12	.00	-.04	.00	-.02	-.05	.03	
9. SAT score	.45***	-.05	.00	.01	.03	.21*	.22**	.13*

Note: *p<.05; **p<.01; ***p<.001

Stress mindset, stress, and GPA. Given that stress mindset should affect behavior only under stress, I expected that there would be no main effect of stress mindset on performance. As expected, in a mixed-effect linear regression with random effects and controls as specified in the previous section, stress mindset did not predict semester GPA ($b = 0.13, p = .25$; see Table 10, model 1). Then, to determine whether stress mindset moderated the way perceived stress affects performance (Hypothesis 1)[15], I fit a model with stress mindset, perceived stress, and their

[15] I hypothesized that stress mindset would affect reactions to *perceived stress*, rather than to external stressors per se. To test this relationship to external stressors, I also fit models with number of final exams instead of perceived stress. Indeed, stress mindset only marginally

interaction. As predicted, there was a significant interaction between stress mindset and perceived stress ($b = 0.44, p = .009$; see Table 10, model 2), such that the relationship between perceived stress and semester GPA was more positive for students with a more stress-is-enhancing mindset, and conversely, the relationship between perceived stress and semester GPA was more negative for students with a more stress-is-debilitating mindset. These results hold when controlling for number of final exams or semester course load (see Appendix B, Table B2).[16]

To further investigate the relationship between stress and performance when individuals hold a stress-is-enhancing versus stress-is-debilitating mindset, I split the data into two groups: those who scored above the midpoint of the scale (also the median) of SMM scores (those who endorsed a stress-is-enhancing mindset), and those who scored below the midpoint (those who endorsed a stress-is-debilitating mindset).[17] Then, I fit separate regression models with perceived stress predicting semester GPA within each of these two groups. Perceived stress negatively predicted semester GPA among students more likely to believe that stress is debilitating ($b = -0.71, p = .002$; see Table 11, model 1), while there was a non-significant relationship between stress and semester GPA among students more likely to believe that stress is enhancing ($b = 0.08, p = .60$; see Table 11, model 2 and Figure 3 for a visualization).

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interacted with number of exams in predicting semester GPA (see Appendix B, Table B1 and Figure B1).

[16] Results of analyses controlling for gender remained substantively the same and the coefficients for gender were not significant (see Appendix B, Table B3).

[17] Students who scored at the median were not included in either group. The dichotomization of a continuous variable presents methodological issues, despite the prevalence of the practice (MacCallum, Zhang, Preacher, & Rucker, 2002). Here I have already demonstrated the interaction effect in the preferred way with regression and I split the data for visualization purposes. Further, if the students who scored at the median were considered, they showed an effect in between the effect for the stress-is-enhancing and stress-is-debilitating groups, suggesting that the interaction is linear (see Appendix B, Figure B2).

Table 10: Predicting GPA from stress mindset

	Dependent variable:	
	Standardized semester GPA	
	(1)	(2)
Perceived stress × Stress mindset		0.440**
		p = 0.009
Perceived Stress Scale, initial		−1.197**
		p = 0.001
Stress Mindset Measure, initial	0.130	−0.891*
	p = 0.253	p = 0.012
High school GPA	0.493	0.447
	p = 0.110	p = 0.131
SAT score	0.002**	0.003**
	p = 0.002	p = 0.0002
Constant	−7.342**	−5.224**
	p = 0.0001	p = 0.005
Control for round and participant random effects	Yes	Yes
Control for Interphase	Yes	Yes
Observations	137	137
Log Likelihood	−179.473	−174.831
Akaike Inf. Crit.	374.947	369.662
Bayesian Inf. Crit.	398.307	398.862
Note:	$^{+}$p<.10; *p<.05; **p<.01	

Table 11: Simple slopes for predicting GPA from stress, by stress mindset median split

	Dependent variable:	
	Standardized semester GPA	
	Stress-is-debilitating	Stress-is-enhancing
	(1)	(2)
Perceived Stress Scale, initial	−0.710**	0.078
	p = 0.002	p = 0.597
High school GPA	0.358	0.351
	p = 0.534	p = 0.393
SAT score	0.003+	0.003**
	p = 0.062	p = 0.001
Constant	−6.484*	−7.879**
	p = 0.044	p = 0.002
Control for round and participant random effects	Yes	Yes
Control for Interphase	Yes	Yes
Observations	58	62
Log Likelihood	−84.386	−73.339
Akaike Inf. Crit.	184.772	162.678
Bayesian Inf. Crit.	201.255	179.695

Note: +p<.10; *p<.05; **p<.01

Data are split at the median (also the center point of the scale)

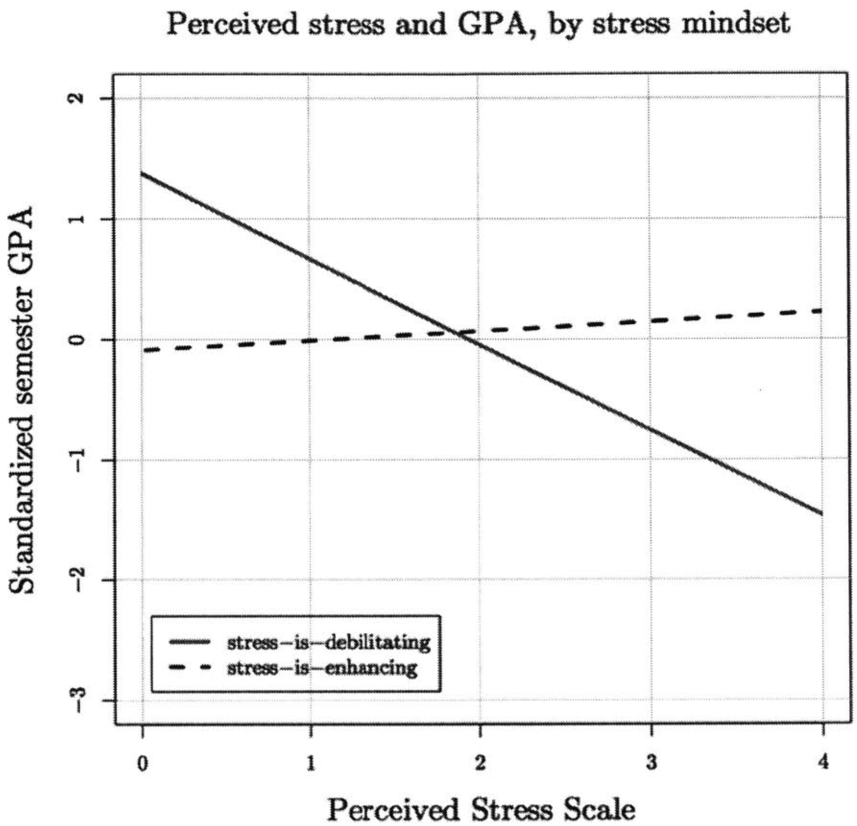

Figure 3: Fitted values of standardized semester GPA predicted by Perceived Stress Scale scores for students who fall at the mean high school GPA and SAT score (for this visualization, data was split at the median score on the Stress Mindset Measure scale, which also fell at the midpoint of the response scale). The relationship between perceived stress and semester GPA is moderated by endorsement of a stress-is-debilitating or stress-is-enhancing mindset (for stress is debilitating, b = -0.71, p = .002; for stress is enhancing, b = 0.08, p = .60).

Stress mindset, stress, and motivation. I then turned to testing whether academic motivation was a mechanism through which stress mindset affected performance (Hypothesis 2). There was a main effect of stress mindset on motivation, such that more endorsement of a stress-is-enhancing mindset was associated with greater reported motivation (b = 0.20, p = .006; see Table 12, model 1). To determine whether stress mindset influences the way perceived stress affects motivation, I fit a model with stress mindset, perceived stress, and their interaction predicting academic motivation. There was a marginally significant interaction between stress mindset and perceived stress ($b = 0.19, p = .06$; see Table 12, model 2), suggesting that stress mindset moderated how motivating or demotivating stress was for students: the relationship between perceived stress and motivation was more negative the more an individual endorsed a stress-is-debilitating mindset.[18]

Then, I again divided the data into those who endorsed a stress-is-debilitating mindset and those who endorsed a stress-is-enhancing mindset and fit two separate models. As expected, the relationship between stress and academic motivation was highly negative for those students who held a stress-is-debilitating mindset, ($b = -0.60, p < .001$; see Table 13, model 1). However, this negative relationship also exists, albeit to a lesser extent, among students with a stress-is-enhancing mindset ($b = -0.26, p = .006$; see Table 13, model 2 and Figure 4 for a visualization). Perceived stress is still negatively associated with academic motivation even for students with a stress-is-enhancing mindset.

[18] Again, in analyses controlling for gender, results remained substantively the same and the coefficients for gender were not significant (see Appendix B, Table B2).

Table 12: Predicting motivation from stress mindset

	Dependent variable:	
	Academic motivation	
	(1)	(2)
Perceived stress × Stress mindset		0.188^{+} p = 0.055
Perceived Stress Scale, initial		-0.770^{**} p = 0.0002
Stress Mindset Measure, initial	0.197^{**} p = 0.006	−0.283 p = 0.149
High school GPA	−0.084 p = 0.671	−0.163 p = 0.376
SAT score	0.001 p = 0.194	0.001 p = 0.134
Constant	2.331^{+} p = 0.053	4.214^{**} p = 0.0004
Control for round and participant random effects	Yes	Yes
Control for Interphase	Yes	Yes
Observations	234	234
Log Likelihood	−247.397	−234.164
Akaike Inf. Crit.	512.794	490.329
Bayesian Inf. Crit.	543.891	528.337
Note:	$^{+}$p<.10; *p<.05; **p<.01	

Table 13: Simple slopes for predicting motivation from stress, by stress mindset median split

	Dependent variable:	
	Academic motivation	
	Stress-is-debilitating	Stress-is-enhancing
	(1)	(2)
Perceived Stress Scale, initial	−0.601**	−0.260**
	p = 0.00000	p = 0.006
High school GPA	−0.391	−0.240
	p = 0.171	p = 0.330
SAT score	0.002*	0.0001
	p = 0.030	p = 0.896
Constant	2.587	5.233**
	p = 0.131	p = 0.0005
Control for round and participant random effects	Yes	Yes
Control for Interphase	Yes	Yes
Observations	107	100
Log Likelihood	−115.843	−95.463
Akaike Inf. Crit.	249.687	208.926
Bayesian Inf. Crit.	273.742	232.372

Note: $^{+}$p<.10; *p<.05; **p<.01

Data are split at the median (also the center point of the scale)

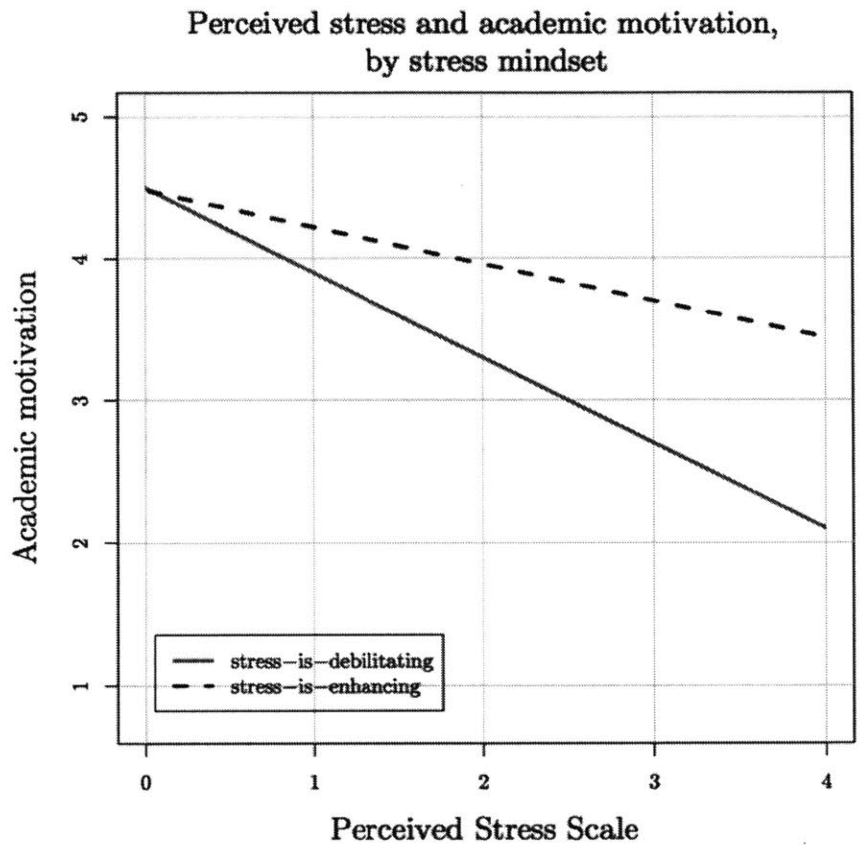

Figure 4: Fitted values of academic motivation predicted by Perceived Stress Scale scores for students who fall at the mean high school GPA and SAT score (for this visualization, data was split at the median score on the Stress Mindset Measure scale, which also fell at the midpoint of the response scale). The relationship between perceived stress and motivation is moderated by endorsement of a stress-is-debilitating or stress-is-enhancing mindset. For stress-is-debilitating, b = -0.58, $p < .001$; for stress-is-enhancing, b = -0.26, p = .006.

Motivation as a mediator. To investigate whether academic motivation mediated the relationship between perceived stress and semester GPA, I fit path analysis models with bootstrapped errors using the R package lavaan (Rosseel, 2012). I divided the data at the median of stress mindset scores (also the midpoint of the scale), and fit two models testing academic motivation as a mediator of the relationship between perceived stress and semester GPA – the relationship shown in Figure 5. For students who endorsed a stress-is-debilitating mindset, there was an indirect effect (b = -0.25, p = .05) and a marginal direct effect (b = -0.43, p = .09; see Table 14, Model 1, and Figure 6), suggesting that among these students, motivation accounted for part of the relationship between stress mindset and GPA. For students who endorsed a stress-is-enhancing mindset, however, there was no significant indirect (b = -0.11, p = .15) or direct effect (b = -0.03, p = .88; see Table 14, model 2, and Figure 7).

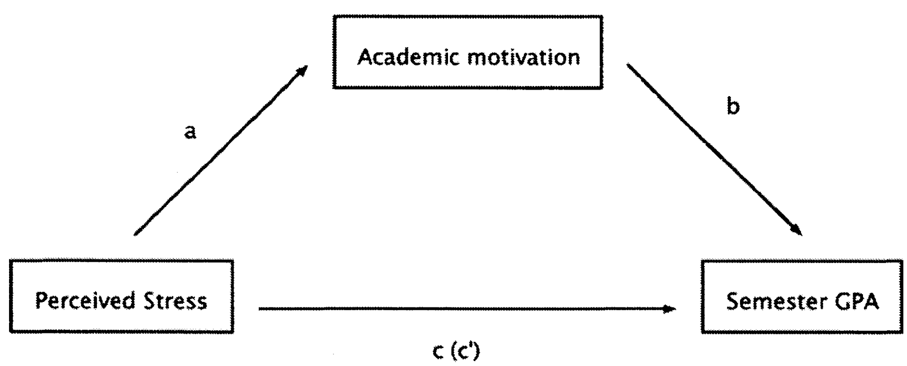

Figure 5: The tested mediation model. The direct effect is represented by c′, the indirect effect is a*b, and the total effect is c, which is equal to c′ + a*b. The total effect is the observed relationship between perceived stress and semester GPA, and the indirect effect is the product of a and b. If there is an indirect effect and no direct effect, the relationship is completely mediated. If there is both an indirect effect and a direct effect, the relationship is partially mediated (Baron & Kenney, 1986; see Zhao, Lynch, & Chen, 2010 for some caveats).

Table 14: Mediation effects by stress mindset median split

	(1) *Stress-is-debilitating*				(2) *Stress-is-enhancing*			
Regressions:	Estimate	Std.Err	z-value	P	Estimate	Std.Err	z-value	P
standardized semester GPA ~								
motivation (b)	0.428	0.192	2.231	.026	0.282	0.178	1.584	.113
perceived stress (c')	-0.429	0.251	-1.707	.088	-0.026	0.17	-0.156	.876
motivation ~								
perceived stress (a)	-0.580	0.146	-3.957	.000	-0.38	0.107	-3.572	.000
Variances:	Estimate	Std.Err	z-value	P	Estimate	Std.Err	z-value	P
standardized semester GPA	1.152	0.204	5.657	.000	0.721	0.124	5.788	.000
motivation	0.488	0.086	5.657	.000	0.338	0.058	5.788	.000
Defined Parameters:	Estimate	Std.Err	z-value	P	Estimate	Std.Err	z-value	P
ab (indirect effect)	-0.248	0.128	-1.943	.052	-0.107	0.074	-1.448	.148
c (total effect)	-0.677	0.234	-2.897	.004	-0.134	0.158	-0.845	.398
Converged after	13 iterations				17 iterations			
Number of observations	64				67			
		lavaan (0.5-23.1097)						

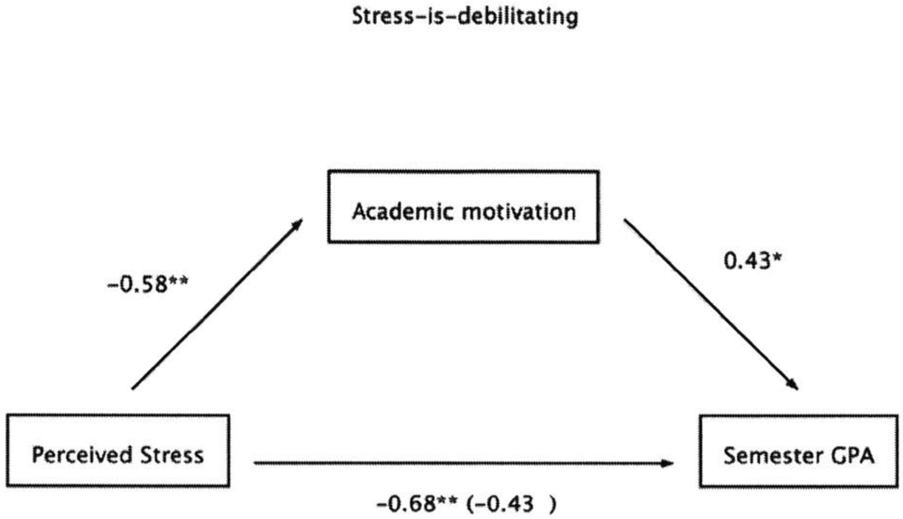

Figure 6: The mediation model for students endorsing a stress-is-debilitating mindset. There was a significant total effect of perceived stress on semester GPA, a significant indirect effect, and a marginal direct effect, indicating partial mediation ($^{+}$p<.10; *p<.05; **p<.01).

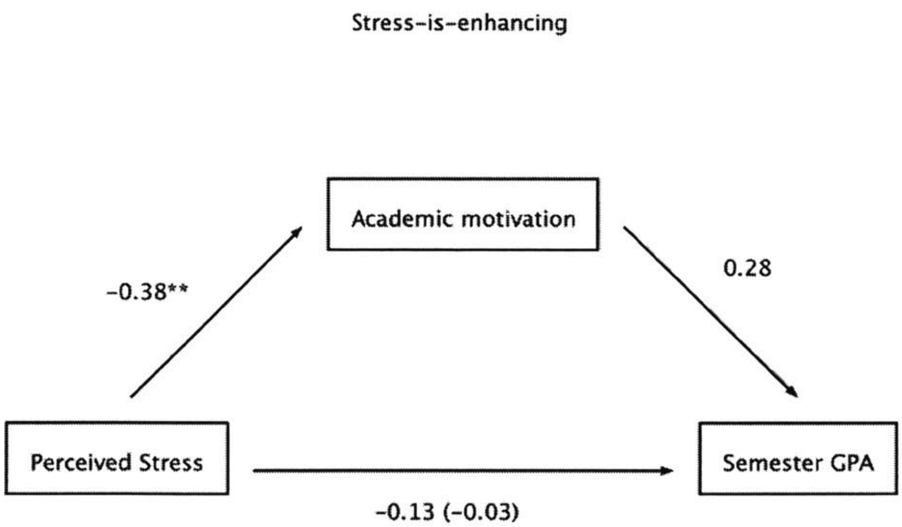

Figure 7: The mediation model for students endorsing a stress-is-enhancing mindset. There was no total or direct effect of perceived stress on semester GPA ($^{+}$p<.10; *p<.05; **p<.01).

Correlation between perceived stress and motivation over time. The previous analyses examined the extent to which those who generally had high stress also generally had low motivation, depending on students' stress mindset. A slightly different question is whether stress mindset affects the extent to which students' stress and motivation track together day to day. To answer this question, I correlated reported stress and academic motivation during experience sampling for each participant. I then fit a model with stress mindset predicting the correlation between stress and academic motivation. Consistent with the result that stress mindset influences how stress relates to motivation, participants' correlation between perceived stress and academic motivation was higher (more positive or less negative) the more they endorsed a stress-is-enhancing mindset ($b = 0.10$, $p = .03$; see Table 15 and Figure 8). Stress was more demotivating the greater the extent to which a student endorsed a stress-is-debilitating mindset.

Table 15: Predicting relationship between stress and motivation from SMS

	Dependent variable:
	Stress and academic motivation correlation during ESM
Stress Mindset Measure, initial	0.096*
	p = 0.028
High school GPA	−0.028
	p = 0.805
SAT score	0.0001
	p = 0.698
Constant	−0.275
	p = 0.685
Control for round and participant random effects	Yes
Control for Interphase	Yes
Observations	198
Log Likelihood	−101.945
Akaike Inf. Crit.	221.890
Bayesian Inf. Crit.	251.485
Note:	$^{+}$p<.10; *p<.05; **p<.01

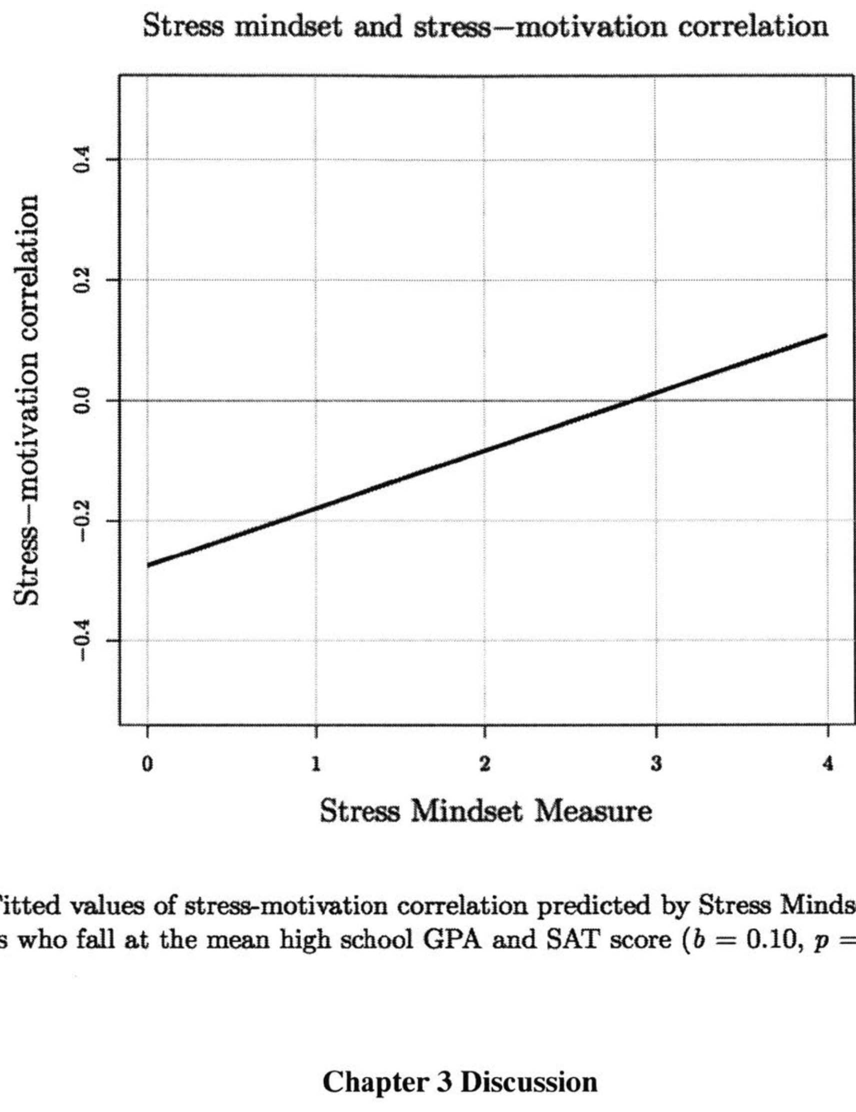

Figure 8: Fitted values of stress-motivation correlation predicted by Stress Mindset Measure score for students who fall at the mean high school GPA and SAT score ($b = 0.10$, $p = .03$).

Chapter 3 Discussion

Summary

The present research found that stress mindset moderated the relationship between perceived stress and semester GPA. For students who held a stress-is-debilitating mindset, as expected, there was a negative relationship between perceived stress and semester GPA; among these students, stress was indeed detrimental to performance. However, for students who held a stress-is-enhancing mindset, there was no relationship between perceived stress and semester

GPA, suggesting that such a mindset, at least at the levels present in this sample, does not actually result in benefits to being stressed, but reduces the negative effects of stress.

These mindsets may affect performance through their impact on motivation. Stress mindset moderated the relationship between perceived stress and motivation, such that there was a larger negative relationship between perceived stress and academic motivation among students who held a stress-is-debilitating mindset than among those who held a stress-is-enhancing mindset; that is, the greater students' endorsement of a stress-is-debilitating mindset, the more demotivating stress was. Additionally, the degree to which students endorsed a stress-is-enhancing mindset reduced the extent to which reported stress and motivation during experience sampling were negatively correlated. Together, these analyses provided consistent evidence that a stress-is-enhancing mindset reduced the negative relationship between stress and motivation.

This effect on motivation partially accounted for the relationship between stress and performance: for students who held a stress-is-debilitating mindset, motivation partially mediated the relationship between stress and semester GPA, such that part of the association could be explained by stress's effect on motivation and motivation's effect on GPA.

Contributions

Theoretical contributions. Stress mindset is theorized to moderate the effect of stress on performance by directing the way in which an individual responds behaviorally to stress. The present data provide empirical support for motivation as one way in which stress mindset affects behavior in response to stress. Stress mindset moderated the relationship between stress and motivation: a stress-is-debilitating mindset was associated with stress being more demotivating; a stress-is-enhancing mindset lessened this impact. For students who endorsed a stress-is-debilitating mindset, motivation to do well academically partially mediated the relationship between stress and semester GPA. That is, one way in which a stress-is-debilitating mindset hurt performance is that it increased the demotivating effects of stress, leading to worse performance.

Further, although a stress-is-enhancing mindset itself entails the idea that stress can actually positively impact performance, the present data did not provide evidence of this effect. Instead, a stress-is-debilitating mindset predicted a negative relationship between stress and performance, while a stress-is-enhancing mindset predicted mostly equivalent performance across stress levels. For academic motivation as well, a stress-is-enhancing mindset did not necessarily result in a positive relationship between stress and motivation, but rather a less negative relationship. Thus, at least at the levels of stress mindset observed in this sample, a stress-is-enhancing mindset may be mitigating or buffering against some of the negative effects of stress.

Empirical contributions. The main empirical contribution of this work is in extending the investigation of stress mindset to a real-world field setting, and showing that stress mindset has a moderating effect on the relationship between perceived stress and consequential performance. Previous studies have mostly been confined to the lab, while one field study used self-reported work performance as an outcome. Here effects are examined in a real-world setting, demonstrating that stress mindset moderates the way in which individuals respond to complex, real-world stressors. Further, effects on performance were established with a highly consequential and more objective performance measure, semester GPA.

Practical implications. A stress-is-debilitating mindset has damaging implications, as it is associated with a stronger negative relationship between both stress and motivation, and stress and performance. Thus, traditional stress management techniques that aim to avoid and minimize stress may backfire, given that the underlying implication, and perhaps even the explicit premise, is that stress is harmful and something to be avoided. Meanwhile, endorsing a stress-is-enhancing mindset can lessens the negative effects of stress. Stress mindset provides a promising approach to stress management techniques that can mitigate stress's negative effects while teaching people to perform well even under stress.

Limitations

A few limitations are of note in using the present data to test these hypothesis. First, these variables are measured over the course of final exam period, but semester GPA is potentially the result of multiple assignments and exams throughout the semester. Therefore, it is possible that students' stress mindset or perceived stress was very different earlier in the semester, and had a different effect on assignments completed then. However, both the Stress Mindset Measure and the Perceived Stress Scale have high test-retest reliability before and after exam period, indicating that they are at least somewhat stable (see Appendix C for details). Additionally, there is little reason to believe that the relationship between perceived stress and performance would vary systematically over time; if these variations are random, my estimates of effects will simply be conservative.

Second, these data are correlational. Although I am investigating how stress mindset influences the effect of stress on performance, it is possible that in this data, performance is actually affecting stress. An experimental design that induces stress could clarify causality; however, here I have traded experimental control for realism: these exams have real consequences for the students, and GPA is a direct measure of academic success.

Future directions

One interesting question is how individuals develop their mindsets. Given the vast array of studies that manipulate mindsets with persuasive essays or by presenting scientific evidence, they can certainly be learned explicitly (e.g., Yeager & Dweck, 2012). However, evidence suggests that mindsets are also shaped by the environment (e.g., Weisbuch, Grunberg, Slepian, & Ambady, 2016). It is possible not only that students' stress mindsets influence how stress affects their performance, but also that these mindsets are themselves influenced by students' experience of stress and performance. Following students' mindsets, stress, and performance across multiple semesters could provide insight into these processes and point to effective circumstances for intervention. For example, if high stress and poor performance one semester could lead to a stress-is-debilitating mindset and further diminished performance the next, that could be a critical point for intervention. Students could also learn these mindsets from others. Given that peer effects can be hugely influential (e.g., Sacerdote, 2011), students could pick up a stress-is-enhancing mindset from their peers. Interventions that capitalize on beneficial peer effects could increase their impact by reaching more students.

Another direction for future research is in further investigating the mechanism by which stress mindset moderates the relationship between perceived stress and performance. The current data found that stress mindset influences academic motivation under stress – for this motivation to translate into improved performance, it must be accompanied by concrete behavioral changes. Future research could investigate the specific behaviors in response to stress that arise from a stress-is-enhancing or stress-is-debilitating mindset. In particular, qualitative data such as interviews could provide evidence of what specific behaviors students engage in.

Overall, the literature on stress mindset has demonstrated that stress mindset is highly consequential, and yet knowledge about stress-is-debilitating and stress-is-enhancing mindsets is not symmetrical. Individuals who endorse a stress-is-debilitating mindset conform to many prior findings and expectations about the relationships between stress, motivation, and performance.

We have relatively less knowledge about the processes operating for those who endorse a stress-is-enhancing mindset. More research is needed to understand the stress-is-enhancing mindset specifically. Qualitative methods such as interviews with individuals who endorse a stress-is-enhancing mindset could help build evidence for the processes by which a stress-is-enhancing affects outcomes.

Conclusion

Overall, the present research provides evidence that stress mindsets change the way that individuals respond under stress, and that these changes are consequential for performance. For those with a stress-is-enhancing mindset, there was no relationship between perceived stress and performance, suggesting that such a mindset does not actually result in benefits to being stressed, but reduces the negative effects of stress. For those with a stress-is-debilitating mindset, there was a negative relationship between perceived stress and performance; stress was indeed detrimental to performance. This relationship was partially mediated by motivation: the more students endorsed a stress-is-debilitating mindset, the more demotivating stress was, and reduced motivation predicted lower performance. These results support stress mindset as a promising avenue for intervention that operates in a different way than traditional stress management techniques.

Chapter 4: Overall Discussion

Overview of findings

Chapter 2 found, first, that consistent with previous field studies, overall perceived stress was negatively associated with academic performance. However, this effect was not due to stress during exams; perceived stress on exam days was not related to semester GPA. Instead, it was perceived stress on non-exam days that negatively predicted semester GPA. Then, in Chapter 3, I found that stress mindset affects the relationship between perceived stress and performance, such that there was a negative relationship between perceived stress and performance for students who endorsed a stress-is-debilitating mindset, but no such relationship for students who endorsed a stress-is-enhancing mindset. The relationship between perceived stress and motivation was also affected by stress mindset; the greater the extent to which students held a stress-is-debilitating mindset, the more negative the relationship between perceived stress and motivation.

Theoretical implications

Together, these findings provide evidence that individuals vary in the extent to which external stressors translate into perceived stress, as well as the extent to which perceived stress relates to performance. Chapter 2 highlighted that perceived stress had different effects on performance, depending on whether it was concurrent or out of sync with external stressors. Chapter 3 showed that stress mindset moderated the way in which perceived stress affected performance, with consequences for real performance outcomes, partially through its moderating effect on the relationship between perceived stress and motivation.

Differentiating between these effects is only possible when an empirical distinction is made between external stressors and perceived stress, and thus research on the relationship between stress and performance should specify whether it focuses on external stressors, perceived stress, or the relationship between the two. This distinction is important because it can clarify the ways in which different effects interact with each other, as well as point toward possible mechanisms.

Because moderators and mediators of the relationship between stress and performance may operate on either of these links, we can use this information to make predictions about the cumulative effects of different interventions or conditions. For instance, since stress mindset moderates the relationship between perceived stress and performance, for individuals who rarely have high perceived stress even when they face many external stressors, their stress mindsets will be less consequential. On the other hand, for individuals who do have high perceived stress, the effects of stress mindset will be more pronounced. As another example, if reappraisal of situations as a challenge, rather than as a threat, reduces perceived stress, then the effects of reappraisal (and the accompanying reduced perceived stress) will be stronger among individuals who more strongly endorse a stress-is-debilitating mindset.

Of course, even if a particular effect on performance is due to perceived stress, to the extent that external stressors induce perceived stress, we will also observe a relationship between external stressors and performance. However, the relationship between perceived stress and performance should be more direct and stronger. For example, in Chapter 3, stress mindset only marginally moderated the relationship between external stressors (number of exams) and performance. Instead, individuals' beliefs about how stress affects performance changed their reactions to perceived stress: stress mindset moderated the relationship between perceived stress and performance.

Finally, different mechanisms are possible depending on whether a particular variable moderates the effect of external stressors or perceived stress. Knowing that stress mindset moderates the relationship between perceived stress and performance, rather than the relationship between external stressors and performance, can direct the consideration of possible mechanisms for this effect. Mechanisms that focus on individuals' reactions to their own affect and cognitions are more likely than those that focus on individuals' reactions to external events.

Empirical implications

Because the present data were collected with an experience sampling methodology, I was able to distinguish between perceived stress on exam days and on non-exam days, as well as track day-to-day changes in perceived stress and motivation. Modern technologies, in particular, the ubiquity of smartphones, allow for more frequent and yet less obtrusive collection of self-report data. These results suggest that this type of data collection is indeed worthwhile, and adds value beyond one-time surveys.

Practical implications

Organizational implications. The present research has practical implications for organizations seeking to improve performance under stress. First, organizations can be mindful of the timing of external stressors. Because organizations often have control over their employees' work schedules, they can determine the spacing of the most stressful tasks to ensure employees have adequate time to recover. While spacing out stressors in itself may not ensure that perceived stress does not persist between external stressors, it can increase the opportunity for individuals to reduce stress during these periods.

Organizations may have different practices and norms around taking vacations and breaks, or even about relaxing. Within some organizations, being stressed may in fact be perceived as a positive sign that the individual is working productively. In these cases, individuals might then be reluctant to try to reduce their perceived stress, even in the absence of external stressors, which the present research suggests would hurt performance. In other places, being calm and composed at all times may be desirable – even though it would not be harmful to feel stressed during periods of external stressors with high performance demands. In this case, individuals might needlessly expend energy trying to reduce their perceived stress at times when it is unnecessary, simply in order to conform to the organizational norm. Therefore, an organization's norms may influence how individuals' perceived stress levels vary in the face of external stressors, with a corresponding effect on performance. In order to ensure that their members do not have maladaptive patterns of perceived stress, organizational leaders must be aware of existing norms and values around stress, and perhaps change them to encourage more or less perceived stress at advantageous times.

Organizational culture and values could also impact individuals' stress mindsets. If individuals develop their stress mindsets in part from exposure to explicit or implicit messaging from management, or from others they work with, organizations may have a role in determining or reinforcing these mindsets. For instance, if management consistently communicates to employees that they should reduce stress or that stress is harmful, it may lead individuals to endorse a stress-is-debilitating mindset.

However, organizations and individuals within those organizations may have different incentives, particularly in the long term. An organization may care more about short-term performance, and relatively less about individuals' long-term health. Therefore, it is important for future research to investigate the effects of stress mindsets on outcomes beyond short-term performance, such as long-term performance and health.

Implications for stress management. As previously discussed, the best strategy for enhancing performance may not be to reduce stress overall. Instead, two strategies suggested by the present results are (i) to focus on reducing perceived stress when no external stressor is present (e.g., by speeding up recovery), and (ii) to change individuals' mindsets about the nature of stress, so that they believe stress can be enhancing.

More broadly, these results suggest that certain combinations of coping strategies will be more beneficial than others. For instance, the two strategies just suggested could be beneficial in combination. During stressful events, an individual with a stress-is-enhancing mindset could use that perceived stress to motivate themselves to meet the demands of the situation. Once the stressor passed, they could then focus on recovering and reducing their perceived stress. On the other hand, reducing stress overall and adopting a stress-is-enhancing mindset may be counterproductive in combination: to the extent that one is successful in lessening perceived stress, the mitigating effects of believing stress to be beneficial will be minimized. Going even further, attempting to avoid becoming stressed could induce or reinforce a damaging stress-is-debilitating mindset, because of the implicit (or explicit) premise that stress should be avoided because it is harmful.

To be sure, strategies focusing on one link (the relationship between external stressors or perceived stress) or the other (the relationship between perceived stress and performance) may be more appropriate in different settings or for different individuals. In some situations, focusing on reducing the extent to which external stressors induce perceived stress may be the practical solution. For example, while driving in traffic, it could be very beneficial to remain calm and not become stressed out. It's less likely that once perceived stress is elevated, it could be used to positive effect. In other situations, avoiding becoming stressed out may be impractical or undesirable. During final exam period, for example, we saw that reduced perceived stress on exam days did not necessarily affect performance, but individuals' stress mindsets were important in predicting how perceived stress would relate to performance.

Limitations

Given the discussion of limitations of the analyses in each empirical chapter, here I will discuss a few limitations of the overall data and setting and suggest future research that could address these limitations and further our understanding of stress.

Internal validity. I treat all final exams identically; in reality, exams vary in difficulty across classes. One way to address this would be to collect and control for subjective ratings of exam difficulty. Additionally, the intensity of external stressors is somewhat endogenous because students choose their classes, either during registration or by deciding to drop the class during the semester. First and second years (the present sample) have many required classes, but it is reasonable to assume they have some latitude in selecting both the number of classes and which classes to take.

The present study period included only final exam week. The outcome variable of semester GPA depends not just on final exams, but also on evaluations that take place throughout the semester, when I do not observe external stressors or perceived stress. Therefore these data may represent a noisy estimate of academic performance. Also, students may be entering final exam period with varying expectations developed during the semester. For example, those students who have previously done poorly in a particular subject may enter final exams with both higher stress and lower ability.

External validity. The present participant population was somewhat specialized: undergraduates at MIT are a highly specific group and their reactions or behavior may vary significantly from those of the general population. Additionally, exams represent only one specific type of stressor; the effects of other stressors may vary.

Future directions

A few avenues for future research could address the limitations discussed above. Experimental manipulation of stressors would ensure that timing and difficulty of external stressors was standardized for all participants, and increase the ability to draw causal conclusions. To generalize beyond students or specifically MIT students, future studies should draw on other samples of participants. To generalize beyond exams, future research should test these relationships with a variety of other stressors. As discussed earlier, exams represent a stressor that is performative, requiring an individual to act. People may respond differently when facing external stressors that do not specifically involve a performance aspect, for example, performance reviews are contingent on past performance, but performance in the moment is not necessarily being evaluated. Additionally, exams are finite and relatively short in duration, allowing a clear distinction between exam and non-exam time periods. Other stressors may have changeable end points, for example, submitting a paper to a journal without a specific submission deadline. Direct extension to external stressors whose time bounds are not clear is difficult, and future research should consider stressors of different durations.

The current results also suggest some broader future directions. The present research only investigated psychological perceived stress – physiological stress is also important. Although there is overlap, psychological and physiological stress reactions have different antecedents and consequences (Lazarus, 1993). Research that incorporates physiological measures would help in understanding the role of physiological stress in the relationship between external stressors and outcomes, as well as how this relates to or interacts with psychological perceived stress. For example, such data could provide evidence for whether a stress-is-enhancing mindset improves performance under both psychological and physiological stress. Additionally, technology such as wearable fitness trackers mean that physiological data recorded in this way can be collected more frequently and less obtrusively than self-report data.

These results suggested two possible avenues for intervention: (i) improving recovery in perceived stress after external stressors end, and (ii) inducing a stress-is-enhancing mindset to change the relationship between perceived stress and performance. Future research should investigate the benefits of stress management and coping techniques informed by these findings.

Finally, the present research focuses on effects on relatively short-term performance. If faster recovery from external stressors or endorsing a stress-is-enhancing mindset has negative impacts on longer-term outcomes, then these benefits must be weighed against any drawbacks. If these changes also have a positive impact on longer-term performance and health outcomes, then interventions in these areas would be all the more important.

Conclusion

The present research provides evidence that feeling stressed is not unequivocally negative, and that simply avoiding and reducing perceived stress at all times is not necessarily beneficial. Instead, reducing perceived stress is most effective when recovering from external stressors, and the relationship between perceived stress and performance can be improved by individuals' stress mindsets. Overall, in this setting the relationship between external stressors and performance seems to depend on perceived stress – in particular, the timing of perceived stress in relation to external stressors, and the relationship between perceived stress and performance, moderated by an individual's stress mindset. Thus, investigating these intermediate factors is critical to better understanding how stress affects performance in the real world, and can inform better stress management techniques.

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Table A1: Predicting GPA from ESM stress, controlling for external stress

	Dependent variable:					
	Standardized semester GPA					
	(1)	(2)	(3)	(4)	(5)	(6)
Mean ESM stress	−0.325**			−0.339**		
	p = 0.0003			p = 0.0003		
Mean ESM stress, exam days		−0.094			−0.075	
		p = 0.181			p = 0.308	
Mean ESM stress, non-exam days			−0.348**			−0.366**
			p = 0.00005			p = 0.00004
High school GPA	0.450	0.432	0.454	0.485	0.492	0.488
	p = 0.120	p = 0.155	p = 0.117	p = 0.110	p = 0.123	p = 0.107
SAT score	0.002*	0.002**	0.002*	0.002*	0.002**	0.002*
	p = 0.019	p = 0.008	p = 0.021	p = 0.011	p = 0.003	p = 0.011
Semester course load	0.245**	0.269**	0.249**			
	p = 0.001	p = 0.0005	p = 0.001			
Number of final exams				0.057	0.040	0.049
				p = 0.498	p = 0.645	p = 0.556
Constant	−5.604**	−6.837**	−5.576**	−5.350**	−6.847**	−5.335**
	p = 0.003	p = 0.0004	p = 0.002	p = 0.006	p = 0.001	p = 0.005
Control for round and participant random effects	Yes	Yes	Yes	Yes	Yes	Yes
Control for Interphase	Yes	Yes	Yes	Yes	Yes	Yes
Observations	131	130	129	130	130	129
Log Likelihood	−164.915	−169.531	−161.586	−169.289	−175.297	−166.890
Akaike Inf. Crit.	347.831	357.063	341.171	356.577	368.594	351.781
Bayesian Inf. Crit.	373.708	382.871	366.910	382.385	394.402	377.519

Note: $^{+}$p<.10; *p<.05; **p<.01

Table A2: Predicting GPA from ESM stress, controlling for participant gender

	Dependent variable:		
	Standardized semester GPA		
	(1)	(2)	(3)
Mean ESM stress	−0.339** p = 0.0004		
Mean ESM stress, exam days		−0.072 p = 0.342	
Mean ESM stress, non-exam days			−0.368** p = 0.00005
High school GPA	0.485 p = 0.110	0.496 p = 0.122	0.477 p = 0.118
SAT score	0.002** p = 0.008	0.002** p = 0.003	0.002** p = 0.008
Gender (female)	0.033 p = 0.850	−0.042 p = 0.821	0.037 p = 0.833
Constant	−5.385** p = 0.006	−6.720** p = 0.001	−5.339** p = 0.005
Control for round and participant random effects	Yes	Yes	Yes
Control for Interphase	Yes	Yes	Yes
Observations	131	130	129
Log Likelihood	−169.598	−174.619	−166.308
Akaike Inf. Crit.	357.196	367.238	350.616
Bayesian Inf. Crit.	383.073	393.046	376.354
Note:			$^{+}$p<.10; *p<.05; **p<.01

Table A3: Predicting GPA from ESM stress, controlling for general stress

	Dependent variable:		
	Standardized semester GPA		
	(1)	(2)	(3)
Mean ESM stress	−0.278*		
	p = 0.017		
Mean ESM stress, exam days		0.023	
		p = 0.801	
Mean ESM stress, non-exam days			−0.327**
			p = 0.003
General stress, initial	−0.198+	−0.273*	−0.207+
	p = 0.082	p = 0.024	p = 0.066
High school GPA	0.334	0.375	0.289
	p = 0.340	p = 0.305	p = 0.409
SAT score	0.003**	0.003**	0.003**
	p = 0.002	p = 0.001	p = 0.002
Constant	−6.465**	−7.704**	−6.010*
	p = 0.008	p = 0.003	p = 0.013
Control for round and participant random effects	No	No	No
Control for Interphase	Yes	Yes	Yes
Observations	87	86	85
R^2	0.356	0.302	0.377
Adjusted R^2	0.316	0.259	0.337
Residual Std. Error	0.784 (df = 81)	0.816 (df = 80)	0.775 (df = 79)
F Statistic	8.945** (df = 5; 81)	6.927** (df = 5; 80)	9.544** (df = 5; 79)

Note: +p<.10; *p<.05; **p<.01

Table B1: Predicting GPA from stress mindset and external stress

	Dependent variable:		
	Standardized semester GPA		
	Full sample	Stress-is-debilitating	Stress-is-enhancing
	(1)	(2)	(3)
Number of exams × Stress mindset	0.202^{+} p = 0.051		
Stress Mindset Measure, initial	−0.345 p = 0.221		
Number of final exams	−0.378 p = 0.103	−0.104 p = 0.564	0.184^{+} p = 0.063
High school GPA	0.481 p = 0.126	0.457 p = 0.478	0.332 p = 0.421
SAT score	0.002^{**} p = 0.002	0.003 p = 0.150	0.003^{**} p = 0.003
Constant	-6.503^{**} p = 0.001	-7.020^{+} p = 0.051	-7.735^{**} p = 0.002
Control for round and participant random effects	Yes	Yes	Yes
Control for Interphase	Yes	Yes	Yes
Observations	130	56	58
Log Likelihood	−173.954	−87.521	−69.183
Akaike Inf. Crit.	367.908	191.043	154.366
Bayesian Inf. Crit.	396.584	207.246	170.850

Note: $^{+}p<.10$; $^{*}p<.05$; $^{**}p<.01$

Table B2: Predicting GPA from stress mindset, controlling for participant gender

	Dependent variable:			
	Standardized semester GPA		Academic motivation	
	(1)	(2)	(3)	(4)
Perceived stress × Stress mindset	-7.146^{**}	-5.233^{**}	2.538^{*}	4.171^{**}
	p = 0.0002	p = 0.006	p = 0.039	p = 0.001
Perceived Stress Scale, initial		-1.198^{**}		-0.771^{**}
		p = 0.001		p = 0.0002
Stress Mindset Scale, initial	0.129	-0.891^{*}	0.189^{**}	−0.280
	p = 0.258	p = 0.012	p = 0.009	p = 0.154
High school GPA	0.510	0.445	−0.085	−0.163
	p = 0.101	p = 0.136	p = 0.665	p = 0.376
SAT score	0.002^{**}	0.003^{**}	0.001	0.001
	p = 0.002	p = 0.0002	p = 0.203	p = 0.133
Semester course load	−0.096	0.006	−0.094	0.023
	p = 0.592	p = 0.974	p = 0.408	p = 0.831
Gender (female)		0.440^{**}		0.187^{+}
		p = 0.009		p = 0.058
Control for round and participant random effects	Yes	Yes	Yes	Yes
Control for Interphase	Yes	Yes	Yes	Yes
Observations	137	137	234	234
Log Likelihood	−180.137	−175.664	−248.310	−235.464
Akaike Inf. Crit.	378.275	373.329	516.619	494.929
Bayesian Inf. Crit.	404.555	405.448	551.173	536.393

Note: $^{+}$p<.10; *p<.05; **p<.01

Table B3: Predicting GPA from stress mindset, controlling for workload

	Dependent variable:			
	Standardized semester GPA			
	(1)	(2)	(3)	(4)
Perceived stress × Stress mindset		0.456**		0.388*
		p = 0.010		p = 0.019
Perceived Stress Scale, initial		−1.213**		−1.060**
		p = 0.002		p = 0.003
Stress Mindset Measure, initial	0.161	−0.891*	0.109	−0.788*
	p = 0.175	p = 0.016	p = 0.327	p = 0.024
High school GPA	0.513	0.459	0.456	0.419
	p = 0.107	p = 0.133	p = 0.129	p = 0.149
SAT score	0.002**	0.003**	0.002**	0.002**
	p = 0.002	p = 0.0003	p = 0.004	p = 0.001
Number of final exams	0.043	−0.021		
	p = 0.615	p = 0.807		
Semester course load			0.220**	0.180*
			p = 0.003	p = 0.013
Constant	−7.574**	−5.343**	−7.466**	−5.548**
	p = 0.0001	p = 0.006	p = 0.00003	p = 0.003
Control for round and participant random effects	Yes	Yes	Yes	Yes
Control for Interphase	Yes	Yes	Yes	Yes
Observations	130	130	137	137
Log Likelihood	−174.454	−170.380	−176.809	−173.472
Akaike Inf. Crit.	366.909	362.760	371.617	368.943
Bayesian Inf. Crit.	392.717	394.303	397.897	401.063

Note: +p<.10; *p<.05; **p<.01

It is also interesting to note that semester course load is positively associated with semester GPA; students who are enrolled in more classes generally perform better overall. Likely this is due to underlying academic competence or integration (i.e., those students who are more involved on campus take more classes and also have higher achievement).

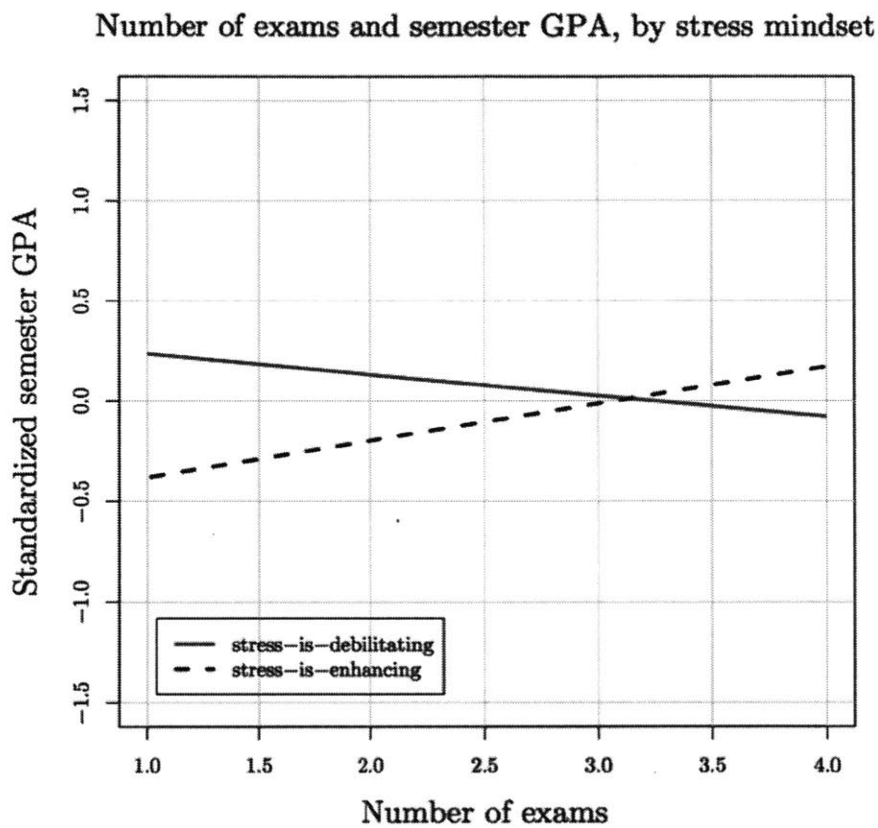

Figure B1: Fitted values of standardized semester GPA predicted by number of final exams for students who fall at the mean high school GPA and SAT score, by stress mindset (for this visualization, data was split at the median score on the Stress Mindset Measure scale, which also fell at the midpoint of the response scale). The relationship between number of exams and semester GPA is marginally moderated by endorsement of a stress-is-debilitating or stress-is-enhancing mindset. For stress-is-debilitating, b = -0.10, p = .56; for stress-is-enhancing, b = 0.18, p = .06 (see Appendix B, Table 1).

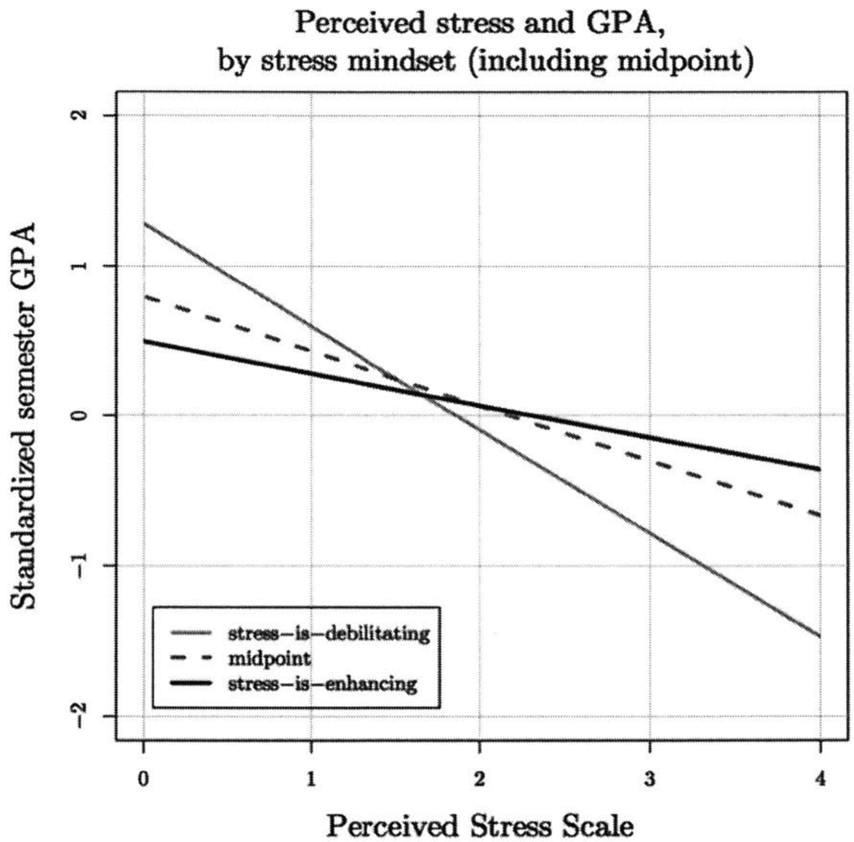

Figure B2: Fitted values of standardized semester GPA predicted by Perceived Stress Scale scores (no control variables), split into 3 groups by Stress Mindset Measure scores. The relationship between perceived stress and semester GPA is moderated by endorsement of a stress-is-debilitating or stress-is-enhancing mindset, with those students who scored at the midpoint of the response scale showing an intermediate effect.

Appendix C

Table C1: Attrition rates for all rounds of data collection

Round	Initial	Daily	Final	% attrition
1	54	51	51	5.6
2	130	119	117	10
3	113	113	106	6.2

Table C2: Variable means (standard deviations) across rounds of data collection

	Round 1 (May 2015)		Round 2 (Dec 2015)		Round 3 (May 2016)	
	Initial survey	Final survey	Initial survey	Final survey	Initial survey	Final survey
Stress Mindset Scale*	2.79 (0.65)	2.84 (0.71)	2.91 (0.63)	2.94 (0.68)	3.01 (0.59)	3.02 (0.63)
Perceived Stress Scale*	2.85 (0.60)	2.82 (0.70)	2.70 (0.62)	2.67 (0.64)	2.88 (0.68)	2.74 (0.67)
General Stress					3.04 (0.81)	2.08 (0.76)
Exam Stress					3.26 (0.90)	3.02 (1.21)

Note: *composite scale

Table C3: Variable means (standard deviations) by Interphase/non-Interphase group

	Round 1 (May 2015)		Round 2 (Dec 2015)		Round 3 (May 2016)	
	Initial survey	Final survey	Initial survey	Final survey	Initial survey	Final survey
Stress Mindset Scale*						
Interphase A	3.36 (0.38)	3.15 (0.84)	3.52 (0.40)	3.48 (0.64)	3.13 (0.93)	3.25 (0.80)
Interphase B	2.54 (0.61)	2.52 (0.64)	3.01 (0.64)	3.09 (0.72)	2.96 (0.65)	2.99 (0.69)
Non-Interphase	2.73 (0.63)	2.93 (0.63)	2.75 (0.58)	2.80 (0.62)	3.00 (0.44)	2.96 (0.54)
Perceived Stress Scale*						
Interphase A	2.96 (0.65)	3.00 (0.87)	2.71 (0.50)	2.59 (0.51)	2.92 (0.75)	2.87 (0.70)
Interphase B	2.74 (0.50)	2.67 (0.67)	2.57 (0.73)	2.46 (0.67)	2.80 (0.66)	2.60 (0.69)
Non-Interphase	2.88 (0.64)	2.85 (0.65)	2.73 (0.62)	2.73 (0.65)	2.89 (0.67)	2.75 (0.66)
General Stress						
Interphase A					3.15 (0.67)	2.30 (0.98)
Interphase B					2.96 (0.89)	1.96 (0.77)
Non-Interphase					3.03 (0.82)	2.05 (0.68)
Exam Stress						
Interphase A					3.40 (0.82)	3.15 (1.23)
Interphase B					3.20 (1.04)	3.26 (1.14)
Non-Interphase					3.25 (0.88)	2.89 (1.23)

Note: *composite scale

Table C4: Cronbach's alpha, standardized, for calculated scales

	Round 1 (May 2015)		Round 2 (Dec 2015)		Round 3 (May 2016)	
	Initial survey	Final survey	Initial survey	Final survey	Initial survey	Final survey
Stress Mindset Scale	.85	.90	.82	.88	.85	.88
Perceived Stress Scale	.87	.90	.86	.89	.89	.88

Table C5: Test-retest reliability (initial-final scores) for calculated scales

	Round 1 (May 2015)	Round 2 (Dec 2015)	Round 3 (May 2016)
Stress Mindset Scale			
Mean change	0.03	0.05	0.02
Mean absolute change	0.32	0.32	0.30
Correlation	.77**	.79**	.69**
Perceived Stress Scale			
Mean change	-0.04	-0.02	-0.12
Mean absolute change	0.35	0.27	0.35
Correlation	.81**	.85**	.80**
General Stress			
Mean change			-0.96
Mean absolute change			
Correlation			.28*
Exam Stress			
Mean change			-0.30
Mean absolute change			
Correlation			.45**

Notes: Mean absolute change refers to mean magnitude of change, either increase or decrease; Pearson correlation coefficient; *$p < .01$; ** $p < .001$

Appendix D

List of scales administered
(Details of selected scales can be found in the next section in alphabetical order)

Round 1 (May 2015) Initial survey

- Stress Mindset Measure
- Perceived Stress Scale
- Healthy days
- Mood and anxiety symptoms questionnaire
- Positive and Negative Affect Scale
- Exercise, breathing, sleep, diet
- Academic Identification
- Self-esteem
- Collective Self-esteem
- Organizational Identification
- Belongingness
- Demographic questions

Round 1 (May 2015) Final survey

- Stress Mindset Measure
- Perceived Stress Scale
- Coping
- Healthy days
- Mood and anxiety symptoms questionnaire
- Positive and Negative Affect Scale
- Exercise, breathing, sleep, diet
- Academic Identification
- Self-esteem
- Collective Self-esteem
- Organizational Identification
- Belongingness
- Grades, final exam and subject
- High school GPA and SAT scores
- Demographic questions

Round 2 (December 2015) Initial survey

- Stress Mindset Measure
- Perceived Stress Scale
- Healthy days
- Mood and anxiety symptoms questionnaire
- Positive and Negative Affect Scale
- Exercise, breathing, sleep, diet

- Academic Identification
- Self-esteem
- Collective Self-esteem
- Organizational Identification
- Belongingness
- Demographic questions

Round 2 (December 2015) Final survey

- Stress Mindset Measure
- Perceived Stress Scale
- Coping
- Healthy days
- Mood and anxiety symptoms questionnaire
- Positive and Negative Affect Scale
- Exercise, breathing, sleep, diet
- Academic Identification
- Self-esteem
- Collective Self-esteem
- Organizational Identification
- Belongingness
- Status Ladder
- Discrimination
- Grades, final exam and subject
- High school GPA and SAT scores
- Demographic questions

Round 3 (May 2016) Initial survey

- Stress Mindset Measure
- Positive and Negative Affect Scale
- Perceived Stress Scale
- Healthy Days
- Mood and anxiety symptoms questionnaire
- Belonging uncertainty
- Academic growth mindset
- Social belonging
- Exercise, sleep, breathing, diet
- Academic efficacy
- Self-esteem
- Academic belonging
- Demographic questions

Round 3 (May 2016) Final survey

- Stress Mindset Measure

- Positive and Negative Affect Scale
- Perceived Stress Scale
- Healthy Days
- Mood and anxiety symptoms questionnaire
- Belonging Uncertainty
- Academic Growth Mindset
- Social Belonging
- Exercise, sleep, breathing, diet
- Academic Efficacy
- Self-esteem
- Academic Belonging
- Grades, final exam and subject
- High school GPA and SAT scores

Daily experience sampling survey items (all reverse-scored)

Are you able to take the survey now?	Yes; No
What were you doing just before taking this survey?	Studying/academics; Taking a break; Eating; Sleeping; Exercising; Other
Indicate to what extent you are feeling mentally focused on the task ahead of you.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling excited.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling stressed.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling strong.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling anxious.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling determined.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling depressed.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling sad.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling happy.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling confident.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling angry.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling worried.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling inspired.	Extremely – Not at all (6 point scale)
Indicate to what extent you are feeling proud.	Extremely – Not at all (6 point scale)
I feel motivated to do well academically.	Strongly agree – Strongly disagree (6 point scale)
What is your energy level like right now?	Way too high – Way too low (5 point scale)
What is your health like right now?	Excellent – Poor (5 point scale)
I feel good about myself right now.	Strongly agree – Strongly disagree (6 point scale)

What time did you go to bed last night?	(Open-ended)
What time did you wake up this morning?	(Open-ended)

Perceived Stress Scale

Upset because of something that happened unexpectedly?	Never – Very often (5 point scale)
Felt that you were unable to control the important things in your life?	Never – Very often (5 point scale)
Felt nervous and "stressed"?	Never – Very often (5 point scale)
Felt confident about your ability to handle your personal problems?	Never – Very often (5 point scale)
Felt that things were going your way?	Never – Very often (5 point scale)
Found that you could not cope with all the things that you had to do?	Never – Very often (5 point scale)
Been able to control irritations in your life?	Never – Very often (5 point scale)
Felt that you were on top of things?	Never – Very often (5 point scale)
Been angered because of things that were outside of your control?	Never – Very often (5 point scale)
Felt difficulties were piling up so high that you could not overcome them?	Never – Very often (5 point scale)

Stress Mindset

The effects of stress are negative and should be avoided.	Strongly disagree – strongly agree (5 point scale)
Experiencing stress facilitates my learning and growth.	Strongly disagree – strongly agree (5 point scale)
Experiencing stress depletes my health and vitality.	Strongly disagree – strongly agree (5 point scale)
Experiencing stress enhances my performance and productivity.	Strongly disagree – strongly agree (5 point scale)
Experiencing stress inhibits my learning and growth.	Strongly disagree – strongly agree (5 point scale)
Experiencing stress improves my health and vitality.	Strongly disagree – strongly agree (5 point scale)
Experiencing stress debilitates my performance and productivity.	Strongly disagree – strongly agree (5 point scale)
The effects of stress are positive and should be utilized.	Strongly disagree – strongly agree (5 point scale)