Reducing the Effect of Stress on Executive Control

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CHAPTER 1

INTRODUCTION

Exposure to stress throughout life is unavoidable and often associated with emotional distress and depression. Nevertheless, not all individuals who experience a stressful event develop a mood disorder (Hammen, 2005). Individual differences in the ability to cope with stress may partially explain this variability, and coping ability may vary, partly as a function of cognitive processes (e.g., executive control). Deficits in executive control have been found in depressed individuals and tend to predict depressive symptoms (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013; Snyder, 2013).

Previous research has shown that stress impairs executive control (Shields, Moons, & Slavich, 2017). Further, such stress-induced impairment in executive control predicts subsequent depressive symptoms during times of elevated stress (Quinn & Joormann, 2015a, 2020). Through the successful implementation of emotion regulation strategies, however, it may be possible to reduce the negative effect of stress on executive control, and thereby decrease the likelihood of psychopathology when exposed to stress. The aims of the current study were (a) to replicate and extend the findings of Quinn and Joormann (2015a, 2015b, 2020) regarding the impact of stress on executive control, and (b) to test the efficacy of a brief emotion regulation intervention for reducing the impact of stress on executive control.

Executive Control

Executive control is a broad term used to describe various cognitive processes involved in goal-directed behavior (Banich, 2009; Quinn & Joormann, 2015a, 2015b, 2020). Although long considered a unitary construct, behavioral and neuropsychological evidence has shown that executive control is more accurately characterized as a set of separate, but related abilities, or executive functions. (Friedman et al., 2008; Miyake & Friedman, 2012). Miyake and Friedman (2012) proposed a unity/diversity framework of executive control, focusing on three operationally defined and reliably measured executive functions – response inhibition, updating working memory, and shifting. Response inhibition is the ability to restrain dominant, automatic, or pre-potent responses. Updating working memory is the ability to monitor incoming information for relevance and then update and replace current information as needed. Shifting is the ability to flexibly switch back and forth between tasks or mental sets (Friedman et al., 2008; Miyake & Friedman, 2012; Miyake et al., 2000; Snyder, Miyake, & Hankin, 2015). The unity/diversity framework proposes that each function can be decomposed into common and unique features. Together, these functions allow individuals to complete complex tasks such as problem solving, and setting and carrying out steps to achieve goals (Banich, 2009). Thus, impairments in executive control can have significant effects on the ability to function optimally.

Executive Control and Stress

Previous research has demonstrated that stress exerts an overall negative effect on executive control (Shields, Sazma, & Yonelinas, 2016). Specifically, stress is presumed to reallocate finite resources to bias the system toward reactive responding to salient features of the stressor, and away from more effortful responses involving working memory and cognitive flexibility (Shields et al., 2016). Although this pattern may be adaptive in response to acute threats that require fast action (e.g., jumping out of the path of oncoming traffic), it may be maladaptive during less immediately threatening forms of stress (e.g., social rejection).

Impairment in executive control is detrimental not only in that these cognitive functions are involved in most behaviors, but also because deficits in executive control are positively associated with psychopathology (Snyder et al., 2015). Most notably, in a series of studies, Quinn and Joormann (2015a, 2020) found that higher levels of impairment in executive control under stress predicted higher levels of depressive symptoms during a future, stressful time (e.g., final exams). Although intriguing, these studies had several limitations including small samples and possible practice effects, which may have reduced the size of the effect of stress on executive control. In particular, Quinn and Joormann re-administered the executive control (EC) measure (i.e., n-back test) within the same experimental session. There might have been carry over from the first to the second administration, resulting in less variability on the EC measure and less room for the stress manipulation to affect EC. Therefore, the first aim of the current study was to test whether stress significantly affects executive control using a design similar to the studies by Quinn and Joormann, but correcting for these methodological limitations.

Second, this study aimed to replicate that impairment of executive control under stress predicts depressive symptoms during a future stressful time. Executive control is thought to underlie emotion regulation ability. Under times of stress, impairment in executive control may lead to reduced ability to regulate emotions while experiencing adversity, which then may increase vulnerability to depression (Quinn & Joormann, 2020).

Executive Control and Emotion Regulation

The third study aim was to test whether we can reduce the effect of stress on executive control through training emotion regulation strategies. Emotion regulation (ER) is the process by which individuals influence the occurrence, timing, nature, experience, and expression of their emotions (Gross, 2013). Emotion regulation includes efforts to up- or down-regulate both positive and negative emotions. Similar to executive control, no consensus exists regarding the underlying structure of emotion regulation and the specific strategies that encompass it (Compas et al., 2014). In a meta-analysis, Compas and colleagues (2017) noted that there is considerable overlap in the theory and conceptualization of emotion regulation and coping, and that both constructs involve adaptive processes related to regulating emotions, cognitions, behaviors, and physiology.

Emotion regulation involves various executive functions, and emotion regulation can affect executive control (Jamieson, Mendes, & Nock, 2013; Jha et al., 2010; Johns, Inzlicht, & Schmader, 2008; Semple; 2010; Teper & Inzlicht, 2013; Wenk-Sormaz 2005). For example, during times of perceived threat, emotion regulation strategies can help decrease negative affect and alter negative cognitions (e.g., through cognitive reappraisal). Reducing the perception of threat then lowers reactivity to the stressor and frees up executive control resources.

Emotion Regulation Strategies

Cognitive Reappraisal

Reappraisal is one emotion regulation strategy linked to executive control, and is negatively associated with depressive symptoms (Joormann & Siemer, 2014; Troy, Willhelm, Shallcross, & Mauss, 2010). Reappraisal involves changing the interpretation of a situation with the goal of changing the emotional experience (Gross, 1998). Quinn and Joormann (2020) demonstrated that ineffective use of reappraisal was associated with impairments in executive control measured under stress. In contrast, successful reappraisal restored executive resources when processing stress and improved performance on a concurrent task (Jamieson, Mendes, & Nock, 2013; Johns, Inzlicht, & Schmader, 2008). Interventions targeted at improving reappraisal, therefore, may be an effective method of increasing executive control when under stress.

Meditation and Mindfulness.

Other emotion regulation strategies that have been tied to executive control include meditation and mindfulness-based approaches. Meditation requires individuals to “monitor their mind,” which partially relies on executive control (Teper & Inzlicht, 2013). Some studies have shown that meditation improves executive functions. For example, Wenk-Sormaz (2005) found that participants practicing meditation significantly improved aspects of executive control, as measured by performance on the Stroop task.

Mindfulness practice also improves components of executive control such as sustained attention (Semple; 2010; Teper & Inzlicht, 2013). Mindfulness involves engaging similar attention-related resources as meditation but includes the additional component of nonjudgmental acceptance of thoughts and emotions. Mindfulness practice particularly improves working memory capacity through enhanced ability to ignore cognitive and affective distractions (Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010). Thus, the ability to nonjudgmentally attend to and process stimuli through mindfulness is another strategy used for regulating emotion (Goldin & Gross; 2010; Teper & Inzlicht, 2013; Teper, Segal, & Inzlicht, 2013).

Typically, mindfulness trains individuals to engage in concentrated practice attending to specific bodily sensations and/or thoughts. During a common breath-based practice, individuals employ diaphragmatic breathing, which engages the parasympathetic nervous system, thereby resulting in slowed breathing and heart rate, and relaxation, while simultaneously attending to their thoughts or body sensations (Ma et al., 2017). During this practice, individuals are instructed to notice when their attention wanders, and to guide it back gently to the intended focal point. This process engages not only attentional control, but also emotion regulatory processes. Repeated practice of mindfulness skills strengthens regulatory processes that constitute executive control (Jha et al., 2010). Therefore, an effective approach to reducing the impact of stress on executive control may be to provide mindfulness training as a method of emotion regulation.

Affect and Executive Control

Given the finding of variability in the effect of stress on executive control (Shields et al., 2016), it is important to identify factors that may account for this difference; that is, potential moderators of the relation. The fourth aim of the current study was to explore positive and negative affect as possible moderators of the relation between stress and executive control. Lower levels of negative affect (NA) have been shown to correlate with better performance on executive control tasks (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013). Research on positive affect has produced mixed findings regarding its relation to executive control performance. For instance, higher levels of positive affect have been associated with better performance in the shifting component of executive control, but greater impairment on tests of working memory and inhibition (Dreisbach & Goschke, 2004; Rowe, Hirsch, & Anderson, 2006). Most research on affect and executive control has not measured executive control under stress. Positive emotions have shown "buffering" effects on the physiological and psychological effects of stress, and thus may attenuate some of the effects of stress on executive control (Folkman & Moskowitz, 2000; Fredrickson & Levenson, 1998).

Study Aims and Hypotheses

In summary, previous research has demonstrated that impairments in executive control occur after exposure to an acute, laboratory-induced stressor (e.g., Shields et al., 2016), although other studies have shown variability in the impact of stress on executive control across individuals (e.g., Quinn & Joormann, 2015a, 2015b, 2020). The present study builds upon this prior work in several ways. This study explored the association between stress and executive control and examined potential moderators of this relation. Moreover, the current study investigated whether the impact of stress on executive control can be modified using a brief, emotion regulation intervention.

Specific Aim 1: To test the effect of exposure to a laboratory stressor on executive control.

Hypothesis 1: Individuals randomized to the High-Stress/Control Intervention condition will show greater decrements in executive control than those randomized to the Low-Stress/Control Intervention condition.

Specific Aim 2: To explore the relation between executive control under stress and prospective depressive symptoms. We examined whether impairment on executive control tasks under stress predicted depressive symptoms during a future, stressful time.

Hypothesis 2. Impairments in executive control under stress will predict higher levels of depressive symptoms during a future, stressful time, after controlling for level of depressive symptoms at T1.

Specific Aim 3: To test the impact of a brief, emotion regulation intervention on executive control after exposure to an acute, laboratory-induced stressor.

Hypothesis 3. Among participants exposed to the laboratory stressor, those given the emotion regulation (ER) intervention will show better executive control after stress as compared to individuals who receive the control intervention.

Exploratory Aim 4. To explore whether positive and negative affect moderate the relation between stress and executive control performance among participants not given the ER intervention.

Hypothesis 4a. The effect of stress on performance on the executive control task will be stronger in individuals who report higher levels of negative affect before the laboratory stress induction (T2).

Hypothesis 4b. The effect of stress on performance on the executive control task will be weaker in individuals who report higher levels of positive affect before the laboratory stress induction (T2).

CHAPTER 2

METHODS

Participants

Participants were recruited through Vanderbilt University using the online research study tool, *SONAS.* Participants ranged in age from 18-29 years, with the average age being 19.17 years (*SD* = 1.39) and with 48.9% of participants being first-year university students. For participation in the study, each individual received course credit as well as monetary compensation for completion of the online follow-up questionnaires.

Before beginning the study, we performed an a priori power analysis using the statistical software, G*Power, for sample size estimation (Faul, Erdfelder, Lang, & Buchner, 2007). With an alpha = 0.05 and power = 0.80, the projected sample size needed for a moderate effect size (*F*=0.25) was *N*=158 for the simplest between group comparison (see Figure 1). Based on this value, we aimed to recruit a sample size of 175 to allow for some attrition. One hundred and thirty-three individuals completed the study. The sample (*N*=133) was 86.5% female, and racially and ethnically diverse, with 43.6% identifying as White/Caucasian, 32.3% Asian/Asian American, 13.5% Black/African American, 2.3% Middle Eastern/Arab, 6% multi-racial, and 2.3% Latino/Latina.

Measures

Intelligence

Two subtests from the Wechsler Abbreviated Scale of Intelligence, 2nd Edition (WASI-II; Wechsler, 2011) were administered to obtain an estimate of fluid intelligence. Participants completed the Vocabulary and Matrix Reasoning subtests. The composite score of these subtests was normed by age and used to generate a standardized score ($M = 100,\ SD = 15$), which provided an estimate of full-scale IQ (FSIQ-2). The WASI-II correlates well with other measures of intelligence and has good internal reliability ($\alpha = 0.89$) (Irby & Floyd, 2013). A measure of estimated intelligence was included because of its relation to executive control (Friedman et al., 2006).

Negative Life Events

The Negative Life Events Questionnaire (NLEQ; Saxe & Abramson, 1987) assessed the occurrence of stressful life events experienced during the prior month. The NLEQ is a 66-item self-report measure developed specifically for use with college students. Items cover a wide-range of stressful life events (e.g., stress regarding work, academics, family, friends). Given the population from which we sampled, we chose this particular measure to assess stress exposure over the course of an academic semester. Respondents indicate the extent to which the stressor occurred in the previous month using a 5-point Likert scale ranging from 0 (never) to 5 (always). The reliability and validity of the NLEQ have been found to be adequate (Metalsky & Joiner, 1992; Saxe & Abramson, 1987).

Depressive Symptoms

The Patient Health Questionnaire (PHQ-9; Kroenke, Spitzer, & Williams, 2001) is a 9-item self-report measure of the frequency of depressive symptoms within the past two weeks. Items are scored on a four-point Likert scale rated from 0 (not at all) to 3 (nearly every day) with a total score ranging from 0 to 27, with higher scores indicating more severe depression. The PHQ-9 has previously demonstrated acceptable reliability and validity ($\alpha = 0.89$), and correlates well with other validated measure of depressive symptoms (Kroenke et al., 2001). The observed reliability in this sample was $\alpha = 0.874$ for T1 and $\alpha = 0.896$ for T2.

Affect

The Positive and Negative Affect Schedule (PANAS; Watson, Clark & Tellegen, 1988) consists of positive and negative mood scales that assess participants' affect at T1 and T2. Participants were instructed to rate how much they experienced each emotion that day, using a five-point Likert-scale ranging from (1) "not at all" to (5) "extremely." Both the positive and negative affect scales of the PANAS have shown good internal reliability (PA: $\alpha = 0.90;$ NA: $\alpha = 0.87$; Watson et al., 1988). The observed reliability in this sample was as follows: T1: PA: $\alpha = 0.897$, NA: $\alpha = 0.839$; T2: PA: $\alpha = 0.912$, NA: $\alpha = 0.806$; T3: PA: $\alpha = 0.905$, NA: $\alpha = 0.875$.

Executive Control Task

Emotional N-back

A two-back version of the n-back task was used to measure executive control. The n-back measures both general, as well as the updating specific component of executive control (Chatham et al., 2011; Snyder et al., 2015). This task has demonstrated acceptable construct validity and reliability (Miyake & Friedman, 2012). In the n-back task, participants are presented with a series of words, one at a time, and are asked to indicate whether the current word is the same as the word presented two words earlier in the sequence. The stimuli presented were positive and negative words selected from the Affective Norms of English Words list (Bradley & Lang, 1999). The words chosen for this task were used in Quinn and Joormann (2020), and were selected based on normed ratings of valence and arousal provided by the Affective Norms of English Words list. Words were rated on a scale from 1 to 9 (see Appendix). Quinn and Joormann (2020) reported that positive (*M* = 5.91, *SD* = 1.09) and negative words (*M* = 6.33, *SD* = .79) did not differ in arousal ratings, $t(28) = 1.22$, $p = .232$, Cohen's $d = .44$. Nor did positive (*M* = 6.07, *SD* = 1.75) and negative words (*M* = 6.13, *SD* = 1.77) differ in word length, $t(28) = .10$, $p = .918$, Cohen's $d = .03$. Affective stimuli were used in order to be consistent with previous findings that executive control over affective material is associated with emotion regulation (Cohen, Mor, & Henik, 2015; Quinn & Joormann, 2015a; Schweizer et al., 2013). Both Cohen et al. (2015) and Schweizer et al. (2013) found that training participants on executive control tasks with affective, as compared to nonaffective, stimuli was associated with decreases in maladaptive emotion regulation (e.g., rumination) and increases in effective emotion regulation, respectively.

Participants completed a series of 120 trials during which a word was displayed for 500 ms followed by a blank screen presented for 2500 ms. Participants were instructed to indicate quickly and accurately whether the word matches or does not match a word that was presented two trials previously (see Figure 2). Total number of errors made during the task was recorded as the measure of executive control performance, with fewer errors indicating greater control (Snyder et al., 2015).

High- and Low-Stress Induction

High-Stress Induction

Participants in the high-stress conditions completed a version of the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993). The TSST is used to induce social-evaluative stress in a laboratory setting. This task reliably produces significant physiological and subjective stress (Dickerson & Kemeny, 2004). Similar to other versions of the TSST (Gotlib, Joormann, Minor & Hallmay, 2008; Quinn & Joormann, 2015a), this version included both a speech and arithmetic task completed in front of the experimenter. Participants were told that each task measures a different aspect of their intelligence. They were instructed to spend five minutes preparing a speech on why they are an ideal job candidate, and then they were prompted to stand in front of the experimenter and a camera to give the five-minute speech. They also were told that other students would rate the videotape of their performance to determine how well they compare to other students. For the arithmetic task, participants were instructed to count aloud backwards from 2083 to 0 in increments of 17. Each time a mistake was made, the experimenter prompted the participant to start from the beginning until they reached 0 or five minutes had elapsed.

Low-Stress Induction

Participants in the low-stress condition completed a control version of the TSST (Het, Rohlder, Schoofs, Kirschbaum & Wolf, 2009), which was designed to deliver similar physical demands on the participant without the social evaluative threat component of the TSST. For this condition, participants spent 5 minutes thinking about a movie, book, or recent trip. They then were asked to stand in place and talk aloud about the chosen topic for five minutes. Participants also completed an arithmetic task in which they spent five minutes counting up from 0 in increments of 15. During these tasks, the participant was alone in the room and was not being recorded.

Measure of Distress

The effect of the stress task was assessed by self-reported affect during the laboratory session using the “subjective units of distress” (SUDS) rating scale (see Figure 3). Participants gave 6 total SUDS ratings, which were collected immediately before, during, and after the high- or low-stress induction task, and immediately following the executive control task (n-back). The SUDS rating scale goes from 0 to 100, with eleven anchors describing increasing levels of distress (e.g., “No distress; totally relaxed, mild anxiety/distress, quite anxious/distressed).

Interventions

Emotion Regulation Intervention

Participants randomized to this condition participated in a brief emotion regulation (ER) training. This intervention incorporated four components of emotion regulation: attentional control, acceptance, relaxation, and reappraisal. Attentional control, acceptance, and relaxation are based in the practice of mindfulness (Kabat-Zinn, 2003). These skills aim to assist individuals in non-judgmentally noticing their current thoughts and feelings and shifting their attention away from negative stimuli; focusing first on their body and their breath. Next, participants can begin diaphragmatic breathing to lower physiological arousal and relax. The reappraisal component of the intervention involves shifting attention to thoughts, and adjusting their interpretation of the situation by generating more accurate and less negative thoughts about it. The experimenter introduced these skills to participants along with the acronym "N-A-B-A" (Notice, Accept, Breathe, Adjust) to help them remember the skills.

The experimenter worked with participants to practice each skill until they were able to demonstrate proficiency. Participants also practiced implementing the ER skills in three imaginary scenarios. The first scenario involved a general interpersonal stressor to which most individuals should be able to relate. For example,

> "You and your friend make plans to have dinner together during the week. You are the first to arrive at the restaurant, so you get a table and wait. Thirty minutes pass and the friend still has not arrived or responded to your texts asking where they are. Finally, after 45 minutes, the friend texts you back that they forgot about dinner and actually have plans with other friends already. How would you react?"

The experimenter then guided participants in generating two more scenarios and describing how they would implement the skills in those situations. To assist in practicing the skills over the next week, each participant was sent a daily practice reminder email, which asked the participant to indicate if they practiced the skills they learned (i.e., yes/no) and provided a space for them to describe their practice.

Control Intervention

The control intervention condition had a similar structure with similar attentional demands as the ER intervention. The material focused on 'Healthy Living,' and discussed behaviors that have been shown to contribute to overall health and well-being (e.g., healthy eating, sleep, and exercise) (Li et al, 2018; Rosekind et al, 2010). The experimenter introduced each aspect of healthy living and discussed with participants how to incorporate these components into their life. Participants also were sent a daily practice reminder email, which asked participants if they had practiced the skills they learned (i.e., yes/no) and provided a space for them to describe their practice.

Procedure

Session 1

Participants were asked to complete the online self-report baseline measures (demographic survey; PHQ-9; NLEQ) via RedCap before the session. Upon arrival at the lab, participants read and signed the informed consent form and completed the PANAS questionnaire. Experimenter 1 then administered the WASI-II subtests of Vocabulary and Matrix Reasoning, and then the executive control task (n-back). At the beginning of the n-back task, they were instructed how to identify target matches (target trials), and then completed a set of ten practice trials to ensure that they understood the task. An accuracy rate or 90% was required before participants could move on to the real task. The task, including instructions and practice, lasted approximately 15 min. After completion of the n-back task, participants were randomized to one of three conditions: (a) the High Stress + Control Intervention condition, (b) the Low Stress + Control Intervention condition, or (c) the High Stress + ER Intervention condition (see *Figure 4*). Randomization was stratified by participant sex and year in school (first-year/ upperclassman). Experimenter 2 then administered either the emotion regulation intervention or the control intervention, based on their randomization.

Emotion regulation intervention

Participants in the intervention condition received the emotion regulation (ER) training. The experimenter introduced each component of the intervention (attentional control, acceptance, breathing, and reappraisal); then participants were asked to practice the skills using several imaginary scenarios. Before concluding, the experimenter reminded the participant about the daily practice log and discussed any barriers to practicing the skills over the next week.

Control intervention

Participants assigned to the “Healthy Living” control condition learned ways to improve their health through lifestyle changes in various areas (e.g., diet, exercise, sleep) and discussed how they can apply these skills to their life. Before concluding, the experimenter reminded the participant about the daily practice log and discussed any barriers to the participant practicing these skills over the next week. In both the ER intervention and Healthy Living control condition, the entire first visit, including the measures, tasks, and intervention lasted approximately 75 minutes.

Session 2

One week after the first visit, participants returned to the lab. First, they completed the PANAS regarding their levels of positive and negative affect for the current day. Next, the same Experimenter 2 met with the participant to review and discuss their use of the skills trained in Session 1 (i.e., emotion regulation or Healthy Living) over the past week. For participants in the ER condition, the experimenter offered supportive and corrective feedback as needed, and guided participants to generate a list of future scenarios during which they could use the skills to help reduce stress. Similarly, participants in the Healthy Living control conditions were asked to describe the behaviors they engaged in during the past week and to generate a list of goals for healthy behaviors they would like to do in the future. Participants then provided a ‘SUDS’ rating.

Next, based on the condition to which they were randomly assigned, participants completed either the high- or low-stress induction task introduced by a *different experimenter* who was unaware of the intervention condition to which the participant was assigned. The “stress” task lasted approximately 20 minutes. Participants provided SUDS ratings before the speech task prep, before and after the speech task and after the academic task. Participants then completed the n-back task, after which they provided final ‘SUDS’ rating.

Follow-up Measures

Participants were contacted by email to complete self-report measures at the end of the semester, at least 30 days after the T2 sessions were conducted. The follow-up occurred toward the end of the semester when participants’ level of stress was likely to be high due to academic demands (e.g., final exams). The questionnaires were completed using REDCap and included the PHQ-9 (past two weeks) and the NLEQ (past month).

CHAPTER 3

RESULTS

Data Screening and Group Characteristics

Descriptive statistics

The 143 participants were randomized into the study. Of these, four participants dropped out before session 2 and two participants were unable to complete session 2 due to the COVID-19 pandemic and the associated restrictions on research. Additionally, two participants refused to complete the stress induction task and two participants experienced computer errors while trying to complete the executive control task. Thirteen participants did not complete follow-up questionnaires and therefore were excluded from analyses using T3 measures (e.g., T3 PHQ-9; T3 NLEQ). This resulted in a sample size of *N* = 133 for all analyses using baseline and T2 data, and *N* = 120 for analyses using T3 follow-up data. Analyses were performed using SPSS (26_{th} edition). Means, standard deviations, and ranges of scores on all measures were calculated, and skewness and kurtosis were assessed for all variables (see Table 1). Participants in the three groups did not significantly differ on any demographic characteristics or the WASI-II (see Table 1). Bivariate correlations among all participants who completed T1 measures are presented in Table 2. Bivariate correlations among all study variables by condition are presented in Table 3.

Distress Ratings

The SUDS ratings were used to assess the extent to which the stress induction was distressing. We conducted a condition by time repeated measures ANOVA, with SUDS ratings as the dependent variable. We collected a total of six SUDS ratings during session 2.

Estimated means for each SUDS rating were compared across groups, with specific contrasts between groups explored post-hoc using the Tukey test. There was an overall significant difference in SUDS ratings by condition (*p* = .013), with the partial eta-squared ($\eta^2 = .069$) indicating a moderate effect size. Specific contrasts indicated a significant difference between the High-Stress/Control Intervention and Low-Stress/Control Intervention (*p* = 0.010). There was no significant difference between the High Stress/Control Intervention and High-Stress/ER Intervention group (*p* = 0.69) or the Low-Stress/Control Intervention and High-Stress/ER Intervention group (*p* = 0.183) (See Table 4 and Figure 5).

Life Events

The follow-up measures were designed to be completed during the university's final exams in order to evaluate participants during a stressful time. The NLEQ scores from baseline and follow-up were compared in order to test this assumption. A paired t-test was used to compare the amount of stress as reported on the NLEQ at T1 to those reported at the T3 follow-up. The T1 NLEQ scores did not differ significantly from the T3 scores reported (*p*=0.143). Additionally, comparisons between the T1 and T3 scores on the achievement-related stress subscale of the NLEQ, was not significant (*p* = 0.603) (see Table 5).

Intervention Practice Data

Participants in all three groups were emailed a daily practice log to complete between sessions 1 and 2. In total, 98.5% of participants (*N* = 131) completed the practice log at least once. The mean practice days was $\mu = 2.83$ $(\mathrm{SE} = 1.958)$. There was no significant difference in practice amount among the three groups at the 95% significance level. Comparisons between groups using the Bonferroni method indicated a difference in practice approaching significance between the Low-Stress/Control group and the High-Stress/Emotion Regulation group (*p* = .080, $\mathrm{SE} = .431$), with those in the Low-Stress/Control group practicing more than those in the

High-Stress/Emotion Regulation group. Amount of practice was not significantly correlated with T2 n-back errors across groups (*r* = -.094; *p* = .287).

Additional correlations were run on the High-Stress/Intervention group, indicating no significant correlation between T2 n-back errors and amount of practice or type of practice specified by the participant (e.g., Attentional Control, Breathing, Acceptance, Reappraisal, Distraction) (see Table 6). Based on practice log data, the most commonly practiced skill was diaphragmatic breathing, with 68.9% of participants in this group (*N = 20)* reporting practicing this skill.

We conducted a multiple linear regression with T2 n-back errors as the dependent variable and T1 n-back errors, FSIQ-2 scores, and the interaction between condition (intervention vs. control) and practice amount as the independent variables. For this analysis, condition was dummy coded to represent the High-Stress/Control and High-Stress/intervention group; participants from the Low-Stress/Control group were not included in this analysis. An estimate of intelligence, the FSIQ-2 score, was included as a covariate in all analyses involving the n-back due to its demonstrated relation with executive control. The interaction between condition and practice amount was not significant ($\beta = .179$; *p* = 0.294), indicating that the groups did not vary in the extent to which practice amount predicted executive function under stress (see Table 7).

Primary Analyses

Aim 1

To test the hypothesis that exposure to stress worsens executive control (hypothesis 1), we conducted a one-way ANCOVA with Stress condition [High-Stress vs. Low Stress (both receiving the control intervention)] as the independent variable, and Time 1 total n-back errors and the FSIQ-2 score as the covariates; the dependent variable was Time 2 total n-back errors.

The effect of the stress condition on T2 n-back errors after controlling for time 1 n-back errors was not significant, *p* = 0.406 (see Table 8); the partial eta-squared ($\eta^2 = .008$) indicated a small effect size. Thus, the stress induction did not significantly affect the number of n-back errors participants made at T2, after controlling for their T1 n-back errors. Although not significant, the T2 n-back error means did follow the hypothesized pattern, with the High-Stress/Control intervention condition having the highest T2 n-back error mean ($\mu = 11.83; \mathrm{SE} = 0.692$), and the Low-Stress/Control intervention and High-Stress/Emotion Regulation conditions having lower means (control: $\mu = 11.07; \mathrm{SE} = 0.723$; intervention: $\mu = 10.94; \mathrm{SE} = 0.806$) (see Figure 6). Finally, we ran paired t-tests to examine the within group differences of performance on the T1 and T2 n-back tasks. Results indicated that participants had significantly fewer errors on the T2 n-back as compared with the T1 n-back for all three groups (see Table 9), thus indicating possible practice effects.

Aim 2

To test the prospective relation between executive control under stress (T2) and subsequent depressive symptoms, we conducted a multiple linear regression, controlling for T1 executive control, T1 depressive symptoms, and estimated intelligence. Participants' PHQ-9 assessed at the follow-up was the dependent variable, and errors on the n-back test conducted after stress exposure (T2) and the interaction between T2 n-back errors and the stress level (high vs. low) were the independent variables. For this analysis, stress level was a dummy coded variable to represent the High- and Low-Stress conditions; participants from the ER intervention group were not included in these analyses. The interaction between stress level and T2 n-back errors was not significant ($\beta = .332$; *p* = 0.188), indicating that the groups did not differ in the extent to which level of executive control at T2 predicted depressive symptoms, controlling for T1 n-back scores (see Table 10).

Aim 3

A one-way ANCOVA was conducted to test the hypothesis that individuals receiving the emotion regulation intervention would show better executive control under stress as compared to individuals exposed to stress who received the control intervention. Participant intervention condition (High-Stress/ER Intervention; High-Stress/Control Intervention) was the independent variable, with total number of n-back errors at Time 1 and FSIQ-2 scores as the covariates, and total errors on the second n-back task as the dependent variable. There was not a significant effect of condition on T2 n-back errors after controlling for T1 n-back errors (p = 0.316); the partial eta-squared ($\eta^2 = .012$) indicated a small effect size. These results demonstrate that the effect of the intervention did not significantly decrease the effect of stress on Time 2 n-back errors (see Table 11).

Exploratory Analyses

Aim 4

We conducted multiple linear regressions to test hypotheses 4a and 4b, with the number of errors from the T2 n-back task used as the dependent variable and regressed on the T2 pre-stress scores on the PANAS (PANAS-NA; PANAS-PA, tested separately), the number of errors on the T1 n-back, and the interaction between the T2 PANAS subscale and stress condition. For this analysis, stress condition was a dummy coded variable to represent the High- and Low-Stress conditions. The interaction between T2 pre-stress PANAS-NA and stress condition did not significantly predict T2 n-back errors ($\beta = -.010$; p = .975 (see Table 12), and the interaction between T2 pre-stress PANAS-PA and stress condition did not significantly predict T2 n-back errors ($\beta = -.453$; p = .158) (see Table 13).

Finally, we ran additional multiple regression analyses to test the relation between the PANAS subscales and performance on the n-back at both T1 and T2. The results of these analyses yielded nonsignificant trends, with T1 PANAS-NA positively associated with T1 n-back errors ($\beta = -.176$, p = 0.052), and T2 PANAS-PA negatively associated with T2 n-back errors ($\beta = -.146$, p = 0.061) (see Table 14).

CHAPTER 4

DISCUSSION

Executive control is essential to almost everything we do including planning, remembering, and attending to the world around us (Banich, 2009; Friedman et al., 2008; Miyake & Friedman, 2012; Quinn & Joormann, 2015a, 2015b, 2020). Previous research has shown that stress negatively impacts executive control (Shields et al., 2016) and that impairments in executive control under stress are related to ineffective use of emotion regulation strategies (Quinn & Joormann, 2020; Shields et al., 2017). Additionally, specific therapeutic strategies that can help with emotion regulation (e.g., reappraisal and mindfulness) have been shown to improve aspects of executive control (Goldin & Gross; 2010; Jamieson et al., 2013; Johns et al., 2008; Teper et al., 2013; Teper & Inzlicht, 2013). Taken together, it seems that regular engagement in emotion regulation strategies not only may decrease one's physiological and emotional reaction to stress, but also might reduce the impact of stress on executive control.

The present study investigated the effect of stress on executive control and self-reported distress. We sought to replicate and extend the work of Quinn and Joorman (2015a, 2015b, 2020) through testing whether a brief, emotion regulation intervention decreased the effect of stress on executive control. Additionally, we explored potential moderators of this relation.

Results showed that after the stress induction, participants in the High-Stress/Control Intervention reported significantly higher emotional distress than did those in the Low-Stress/Control Intervention. In contrast to previous research (e.g., Quinn & Joormann, 2015a), however, we did not find that the high stress induction produced more errors on the measure of executive control. Thus, the stress manipulation was sufficiently potent to produce a differential effect on the subjective distress ratings, but it did not significantly affect executive control as measured on the second administration of the n-back task, after controlling for the T1 scores.

One difference between this study and that of Quinn and Joorman was the inclusion of an intervention. It is possible that both interventions dampened the negative effect of the stress induction. Without a condition that did not include any intervention, we cannot determine if just intervening itself caused the observed nonsignificant effect of the stress induction.

Although not significant, the T2 n-back errors means did follow the hypothesized pattern, with the high-stress/control intervention group having the highest T2 n-back error mean, and the Low-Stress/Control intervention and high-stress/emotion regulation intervention having lower means. Given that this difference was not significant, however, and the SUDS ratings indicated that the High-Stress condition did induce subjective distress, other study limitations (discussed below) likely contributed to this result.

Although some studies have found an effect of stress on executive control, others have not (e.g., Shields et al., 2017). Quinn and Joormann (2015a) suggested that there likely are individual differences in the effect of stress on executive control, but those persons who do show a deficit in executive control after exposure to stress are especially vulnerable to depression when faced with negative life events because such deficits impact their ability to cope with adversity. Previously, Quinn and Joormann (2015a) showed that greater impairment in executive control under stress predicted depressive symptoms during a future, stressful event (i.e., final exams). The current study did not find this effect, however. Similar to Quinn and Joormann, we assessed the follow-up depressive symptoms during the end-of-semester final exams, which was presumed to be a naturally occurring, stressful period for this sample. Based on the life events questionnaire data, however, participants did not rate the end of semester time period as having more stressors than they reported at baseline, which could have been any time during the semester. The total number of life events (NLEQ) at baseline and follow-up were not significantly different ($p = 0.118$) and the levels of depressive symptoms reported on the

PHQ-9 between baseline and follow-up also were not significantly different ($p = 0.143$). Thus, it is possible that the rest of the semester was as stressful as the exam period, and exams did not increase their stress level substantively.

One other possible explanation is that participants might not have completed the follow-up measures during their most-stressful time during final exams. That is, the questionnaires were emailed starting on the reading day before exams, and participants had a 10-day window to complete them. Therefore, they could have completed the measures before the stress of exams had fully occurred or after it had dissipated at the end of the exam period. Thus, given that overall, participants did not report more stressors at the follow-up assessment, then this was not an adequate test of the relation between executive control under stress and subsequent depressive symptoms.

Also, of note is that during our third semester of data collection, the university shut down due to the COVID-19 pandemic and students had returned home. So, although the follow-up surveys were still sent out during their final exam period, the participants had been receiving virtual learning for much of the semester and may have had fewer or alternative exams as compared with other semesters. Additionally, given the stress associated with relocating due to the COVID-19 pandemic, it is possible that the most stressful time period for these students was not during exams, but rather earlier in the semester. We tested for differences in life events by cohort, however, and found no significant effects.

The third study aim was to test the efficacy of emotion regulation strategies in reducing the effect of stress on executive control. Results revealed no significant difference in errors on the n-back task for those who received the ER versus the control intervention. Previous research has indicated that impairments in executive control are related to ineffective use of emotion regulation strategies (Quinn & Joormann, 2020; Shields et al., 2017) such as those taught to those randomized to the ER condition. Additionally, the specific skills used (e.g., reappraisal, attentional control, mindful acceptance, diaphragmatic breathing) have been shown to improve components of executive control (Goldin & Gross; 2010; Jamieson et al., 2013; Johns et al., 2008; Teper et al., 2013; Teper & Inzlicht, 2013). We hypothesized that these emotion regulation strategies would improve the ability to decrease negative affect during the laboratory stress induction, thereby freeing up cognitive resources and reducing impairment in the executive control tasks.

Perhaps the N-A-B-A skills were too complex to be taught during a brief, 30-min training. Rather, it may be more effective to focus on one emotion regulation (e.g., cognitive reappraisal, acceptance) rather than four different skills at the same time. It also is possible that more emotion regulation training (e.g., a greater number of sessions; longer duration of sessions) is needed for the intervention to have an effect.

Additionally, participants were sent a daily practice log to help remind them to practice the skills they were taught in training (i.e., Emotion Regulation or Healthy Living). They were asked to indicate whether they had practiced any of the skills, and to briefly describe what they had done. As noted above, out of the 29 participants randomized to the Emotion Regulation intervention and who commented on the practice log, 95% reported practicing at least once, and the most common skill practiced was diaphragmatic breathing (reported by 68.9%). Perhaps focusing on a relaxation skill would be a more efficient and effective method to reduce the impact of stress.

Diaphragmatic breathing interacts with the hypothalamic-pituitary-adrenal (HPA) axis and helps to activate the parasympathetic nervous system; individuals have been found to subjectively experience the effects of these skills (e.g., slowed heart rate/respiration, muscle relaxation) even after brief utilization (Ma et al., 2017). Thus, people may be more likely to practice diaphragmatic breathing due to its immediate physiological benefits, which can be readily experienced in the face of a stressor, and therefore may be positively reinforcing and thereby increase its use.

The use of cognitive reappraisal to cope with stress has advantages and disadvantages. Notably, in a recent study, Ford and Troy (2019) showed that reappraisal was most effective in individuals who are skilled at it, whereas ineffective use of reappraisal is associated with increases in depressive symptoms over time. Additionally, they noted that reappraisal is most beneficial when used during lower-intensity as compared to high-intensity stressors, because reappraisal may reduce the tendency to take effective action (e.g., problem solve), which is especially necessary during high-intensity situations. In the current study, participants may not have been able to implement the reappraisal skills effectively during the relatively high-stress induction. To test this hypothesis, future studies should include a Low-Stress/ ER intervention condition as well.

Finally, regarding the efficacy of the ER intervention, we are unable to draw a conclusion given the lack of a significant difference between the two interventions. On the one hand, the control intervention might have been as effective or ineffective as the ER intervention. Without a no-intervention/high stress control condition, we cannot determine the strength of the effect of either intervention. Second, given that the high-stress manipulation did not significantly reduce executive control performance, we do not know if the ER intervention would have successfully blocked that effect. That is, without first showing that the stress induction impaired performance on the n-back task, without any intervention, we do not know if the ER intervention would have prevented such a decrement in executive control. Future studies need to test the efficacy of this brief intervention under conditions in which stress significantly decreases performance on the executive control task.

The last study aim was to test potential moderators of the effect of stress on executive control. Individuals differ in their response to stress and on the impact of stress on executive control (Alexander et al., 2007). Therefore, we explored the relations among state positive and negative affect, level of stress, and executive control. We hypothesized that the effect of stress on executive control would be stronger at low levels of positive affect, and at high levels of negative affect. Results revealed non-significant interactions indicating that the association between stress level and errors on the n-back task did not differ as a function of either PA or NA. We did find two nonsignificant trends in that state NA at T1 was associated with number of errors on the T1 n-back task, and state PA at T2 was negatively associated with errors on the T2 n-back task, when controlling for T1 n-back errors. These findings suggest that within this sample, both positive and negative affect were related to executive control, but this association did not vary by level of stress.

Study Limitations and Future Directions

The present study had several limitations that highlight directions for future research. First, the study was underpowered, which likely decreased the chances of finding significant effects. In general, our effect sizes were small to medium. Based on power calculations, we had targeted a sample size of 175, but the final sample included only 133 participants. Due to the COVID-19 pandemic, we were required to cease data collection before reaching our recruitment goal. Additionally, at the point the study was halted, the number of participants randomized to each condition was not yet balanced, with the High-Stress/Intervention condition having the fewest participants (N = 37).

Second, we administered the same n-back task twice, one week apart. In the studies by Quinn and Joormann (2015a, 2015b, 2020), the n-back was administered twice within the same session; the design of the current study was intended to reduce potential practice effects by spacing out the n-back administrations. Although the n-back task is considered a valid measure of executive control and is widely used as a task that can be delivered repeatedly, data regarding its test-retest reliability are mixed (Soveri et al., 2016). In the present study, participants in all three conditions demonstrated significantly fewer errors on the T2 n-back as compared to the T1 n-back, even with a week in between administrations, and the second n-back was completed after the stress manipulations. It is possible that there were practice effects even after a week that were more powerful than the effects of stress on task performance. Additionally, the n-back task used in this study is primarily a measure of updating working memory, which is only one component of executive control. Although this executive function has been linked to emotion regulation skills and has been used in previous studies to measure of executive control (Quinn & Joormann, 2020), future studies should include other measures of executive control that might be less likely to show practice effects and more likely to be affected by stress.

Third, the sample was comprised entirely of undergraduate students, within a narrow age range and a generally high level of intelligence. This likely resulted in considerable homogeneity in the types and frequency of negative life stressors experienced and in less variability in their executive control ability, respectively. Moreover, such sample homogeneity likely reduces the extent to which the results will generalize to samples that are not college students.

Finally, although there is considerable evidence that the Trier Social Stress Test is an effective and potent stress induction (Dickerson & Kemeny, 2004; Kirschbaum et al., 1993), it is possible that the two stress conditions were not sufficiently distinct to produce a differential effect on executive control. The SUDS ratings did indicate that the stress conditions differed regarding self-reported levels of distress, but this could have been due, in part, to demand characteristics. Future studies should use other measures, such as physiological indices (e.g., heart rate; skin conductance) to capture the effects of the different stress induction procedures.

To our knowledge, no study has investigated the efficacy of the specific skills in our emotion regulation intervention (i.e., reappraisal, attentional control, relaxation, acceptance) to reduce the effect of stress on executive control. Although we did not find that the brief emotion regulation training impacted the effect of stress on executive control, it may be that focusing more on a single emotion regulation strategy, more exposure to the intervention, or measuring participants' competency of the skills taught to them would be a worthwhile future direction.

Additionally, given that we did not detect an overall effect of stress on executive control, it is important that we continue to identify what study characteristics contributed to this lack of effect. This could include using other stress-induction techniques or measuring other aspects of executive function.

Previous research has shown a cyclic relation between executive control and emotion regulation ability, whereby improvement in emotion regulation results in better executive control and increases in executive control produce more successful emotion regulation (Jha et al., 2010; Semple; 2010; Teper & Inzlicht, 2013). This study focused on whether training emotion regulation skills could mitigate the effect of stress on executive control. Future studies should explore an alternative direction of this relation by examining whether intervening to improve executive control leads to better emotion regulation. Finally, by continuing to explore potential moderators of the relation between stress and executive control, we can determine under what conditions and for which individuals impaired executive control under stress is most likely to occur. It may be possible to screen individuals for these moderators, and then provide interventions that either target the moderator itself (e.g., increase positive affect) or provide skills to either help regulate emotion or bolster executive control.

REFERENCES

Alexander, J. K., Hillier, A., Smith, R. M., Tivarus, M. E., & Beversdorf, D. Q. (2007). Beta-adrenergic modulation of cognitive flexibility during stress. *Journal of Cognitive Neuroscience, 19*(3), 468-478.

Banich, M. T. (2009). Executive Function: The Search for an Integrated Account. *Current Directions in Psychological Science*, *18*(2), 89–94. https://doi.org/10.1111/j.1467-8721.2009.01615.x

Bradley, M. M., Lang, P. J. (1999). *Affective Norms for English Words (ANEW): Instruction manual and affective ratings*.

Bridgett, D. J., Oddi, K. B., Laake, L. M., Murdock, K. W., & Bachmann, M. N. (2013). Integrating and differentiating aspects of self-regulation: Effortful control, executive functioning, and links to negative affectivity. *Emotion*, *13*(1), 47.

Caspi, A., Houts, R. M., Belsky, D. W., Goldman-Mellor, S. J., Harrington, H., Israel, S.,. . . Moffitt, T. E. (2014). The p Factor: One General Psychopathology Factor in the Structure of Psychiatric Disorders? *Clinical Psychological Science: A Journal of the Association for Psychological Science, 2*(2), 119-137. doi:10.1177/2167702613497473

Chatham, C. H., Herd, S. A., Brant, A. M., Hazy, T. E., Miyake, A., O'Reilly, R., & Friedman, N. P. (2011). From an Executive Network to Executive Control: A Computational Model of the *n* -back Task. *Journal of Cognitive Neuroscience*, *23*(11), 3598–3619. https://doi.org/10.1162/jocn_a_00047

Cohen, N., Mor, N., & Henik, A. (2015). Linking executive control and emotional response a training procedure to reduce rumination. *Clinical Psychological Science, 3*(1), 15-25.

Compas, B. E., Jaser, S. S., Dunbar, J. P., Watson, K. H., Bettis, A. H., Gruhn, M. A., & Williams, E. K. (2014). Coping and emotion regulation from childhood to early adulthood: Points of convergence and divergence. *Australian Journal of Psychology*, *66*(2), 71–81. https://doi.org/10.1111/ajpy.12043

Compas, B. E., Jaser, S. S., Bettis, A. H., Watson, K. H., , Gruhn, M. A., Dunbar, J. P., Williams, E. K., & Thigpen, J. C. (2014). Coping, emotion regulation, and psychopathology in childhood and adolescence: A meta-analysis. *Psychological Bulletin*, *149*(9), 939-991.

Dickerson, S.S., Kemeny, M.E., (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130*(3), 355-391.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(2), 343.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-191.

Folkman, S., & Moskowitz, J. T. (2000). Positive affect and the other side of coping. *American Psychologist, 55*(6), 647-654.

Ford, B. Q. & Troy, A. S. (2019) Reappraisal reconsidered: A closer look at the costs of an acclaimed emotion-regulation strategy. *Current Directions in Psychological Science, 28*(2), 195-203. doi: 10.1177/0963721419827526

Fredrickson, B. L., & Levenson, R. W. (1998). Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. *Cognition and Emotion, 12*, 191-220.

Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., DeFries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science*, *17*(2), 172-179.

Friedman, N. P., Miyake, A., Young, S. E., DeFries, J. C., Corley, R. P., & Hewitt, J. K. (2008). Individual Differences in Executive Functions Are Almost Entirely Genetic in Origin. *Journal of Experimental Psychology. General*, *137*(2), 201–225. https://doi.org/10.1037/0096-3445.137.2.201

Goldin, P. R., & Gross, J. J. (2010). Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. *Emotion*, *10*(1), 83.

Gotlib, I. H., Joormann, J., Minor, K. L., & Hallmayer, J. (2008). HPA Axis reactivity: A mechanism underlying the associations among 5-HTTLPR, stress, and depression. *Biological Psychiatry*, *63*(9), 847–851. https://doi.org/10.1016/j.biopsych.2007.10.008

Gross, J. J. (Ed.). (2013). *Handbook of emotion regulation*. New York: Guilford publications.

Hammen, C. (2005). Stress and Depression. *Annual Review of Clinical Psychology*, *1*(1), 293–319. https://doi.org/10.1146/annurev.clinpsy.1.102803.143938

Het, S., Rohleder, N., Schoofs, D., Kirschbaum, C., & Wolf, O. T. (2009). Neuroendocrine and psychometric evaluation of a placebo version of the ‘Trier Social Stress Test.’ *Psychoneuroendocrinology*, *34*(7), 1075–1086. https://doi.org/10.1016/j.psyneuen.2009.02.008

Irby, S. M., & Floyd, R. G. (2013). Test Review: Wechsler Abbreviated Scale of Intelligence. *Canadian Journal of School Psychology, 28*(3), 295-299.

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology*, *46*(1), 208–212. https://doi.org/10.1016/j.jesp.2009.08.015

Jamieson, J. P., Mendes, W. B., & Nock, M. K. (2013). Improving Acute Stress Responses: The Power of Reappraisal. *Current Directions in Psychological Science*, *22*(1), 51–56. https://doi.org/10.1177/0963721412461500

Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion*, *10*(1), 54–64. https://doi.org/10.1037/a0018438

Johns, M., Inzlicht, M., & Schmader, T. (2008). Stereotype Threat and Executive Resource Depletion: Examining the Influence of Emotion Regulation. *Journal of Experimental Psychology. General*, *137*(4), 691–705. https://doi.org/10.1037/a0013834

Joormann, J. (2010) Cognitive inhibition and emotion regulation in depression. *Current Directions in Psychological Science*, 19(3), 161-166.

Joormann, J., & Gotlib, I. H. (2010). Emotion regulation in depression: Relation to cognitive inhibition. *Cognition & Emotion*, *24*(2), 281–298. https://doi.org/10.1080/02699930903407948

Joormann, J., & Siemer, M. (2004). Memory accessibility, mood regulation, and dysphoria: Difficulties in repairing sad mood with happy memories? *Journal of Abnormal Psychology*, *113*(2), 179.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: past, present, and future. *Clinical psychology: Science and Practice*, *10*(2), 144-156.

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

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9. *Journal of General Internal Medicine*, *16*(9), 606–613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Li, Y., Pan, A., Wang, D. D., Liu, X., Dhana, K., Franco, O. H., … Hu, F. B. (2018). Impact of healthy lifestyle factors on life expectancies in the US population. *Circulation*, https://doi.org/10.1161/CIRCULATIONAHA.117.032047

Ma, Xiao., Yue, Z., Gong, Z., Zhang, H., Duan, N., Shi, Y., Wei, G., & Li, Y. (2017). The effect of diaphragmatic breathing on attention, negative affect, and stress in healthy adults. *Frontiers in Psychology, 8*, 873-886. doi: 10.3389/fpsyg.2017.00874

Mathews, A., & MacLeod, C. (2005). Cognitive vulnerability to emotional disorders. *Annual Review of Clinical Psychology*, *1*, 167-195.

Metalsky, G. I., & Joiner, Jr., T. E. (1992). Vulnerability to depressive symptomatology: A prospective test of the diathesis-stress and causal mediation components of the hopeless- ness theory of depression. *Journal of Personality and Social Psychology, 63,* 667-675.

McRae, K., Jacobs, S. E., Ray, R. D., John, O. P., & Gross, J. J. (2012). Individual differences in reappraisal ability: Links to reappraisal frequency, well-being, and cognitive control. *Journal of Research in Personality*, *46*(1), 2–7. https://doi.org/10.1016/j.jrp.2011.10.003

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. https://doi.org/10.1177/0963721411429458

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Quinn, M. E., & Joormann, J. (2015a). Control when it counts: Change in executive control under stress predicts depression symptoms. *Emotion*, *15*(4), 522–530. https://doi.org/10.1037/emo0000089

Quinn, M. E., & Joormann, J. (2015b). Stress-induced changes in executive control are associated with depression symptoms: Examining the role of rumination. *Clinical Psychological Science*, *3*(4), 628–636. https://doi.org/10.1177/2167702614563930

Quinn, M. E., & Joormann, J. (2020). Executive control under stress: Relation to reappraisal ability and depressive symptoms. *Behavior Research and Therapy. In press.*

Rosekind, M. R., Gregory, K. B., Mallis, M. M., Brandt, S. L., Seal, B., & Lerner, D. (2010). The cost of poor sleep: workplace productivity loss and associated costs. *Journal of Occupational and Environmental Medicine*, *52*(1), 91-98.

Rowe, G., Hirsh, J. B., & Anderson, A. K. (2007). Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences*, *104*(1), 383-388.

Saxe, L. L., & Abramson, L. Y. (1987). *The Negative Life Events Questionnaire: Reliability and Validity.* Unpublished manuscript.

Schweizer, S., Grahn, J., Hampshire, A., Mobbs, D., & Dalgleish, T. (2013). Training the emotional brain: improving affective control through emotional working memory training. *Journal of Neuroscience*, *33*(12), 5301-5311.

Semple, R. J. (2010). Does mindfulness meditation enhance attention? A randomized controlled trial. *Mindfulness*, *1*(2), 121-130.

Shields, G. S., Moons, W. G., & Slavich, G. M. (2017). Better executive function under stress mitigates the effects of recent life stress exposure on health in young adults. *Stress*, *20*(1), 92–102. https://doi.org/10.1080/10253890.2017.1286322

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

Snyder, H. R. (2013). Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: a meta-analysis and review. *Psychological Bulletin*, *139*(1), 81.

Snyder, H. R., Miyake, A., & Hankin, B. L. (2015). Advancing understanding of executive function impairments and psychopathology: bridging the gap between clinical and cognitive approaches. *Frontiers in Psychology*, *6*. https://doi.org/10.3389/fpsyg.2015.00328

Soveri, A., Lehtonen, M., Karlsson, L. C., Lukasik, K., Antfolk, J., & Laine, M. (2016) Test-retest reliability of five frequently used executive tasks in healthy adults. *Applied Neuropsychology: Adult, 25*(2), 155-165. doi: 10.1080/23279095.2016.1263795

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A brief measure for assessing Generalized Anxiety Disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092. https://doi.org/10.1001/archinte.166.10.1092

Teper, R., & Inzlicht, M. (2013). Meditation, mindfulness and executive control: the importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive and Affective Neuroscience*, *8*(1), 85–92. https://doi.org/10.1093/scan/nss045

Teper, R., Segal, Z. V., & Inzlicht, M. (2013). Inside the Mindful Mind: How mindfulness enhances emotion regulation through improvements in executive control. *Current Directions in Psychological Science*, *22*(6), 449–454. https://doi.org/10.1177/0963721413495869

Troy, A. S., Wilhelm, F. H., Shallcross, A. J., & Mauss, I. B. (2010). Seeing the silver lining: Cognitive reappraisal ability moderates the relationship between stress and depressive symptoms. *Emotion*, *10*(6), 783–795. https://doi.org/10.1037/a0020262

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063-1070. doi:10.1037/0022-3514.54.6.1063

Wechsler, D. (2011). *Wechsler Abbreviated Scale of Intelligence, Second Edition*. San Antonio, TX: Pearson.

Wenk-Sormaz, H. (2005). Meditation can reduce habitual responding. *Alternative therapies in health and medicine*, *11*(2), 42-59.

Table 1.

Descriptive information of key study variables by condition

Demographic Characteristics	HL Control /High-Stress (*N* = 50)	HL Control/ Low-Stress (*N* = 46)	ER Intervention/ High-Stress (*N* = 37)	Test of Difference Between Condition
Age	19.14 (1.03)	19.17 (1.78)	19.19 (1.29)	$F(2,130) = .014$, p=.986
Sex				$F(2,130) = 2.68$, p=.071
Female	*N* = 46	*N* = 41	*N = 28*	
Male	*N* = 4	*N* = 5	*N = 9*	
Race/Ethnicity				$F(2,130) = .199$, p=.819
African American/ Black	*N* = 9	*N = 5*	*N* = 4	
Asian/Asian American	*N* = 14	*N = 17*	*N = 12*	
Caucasian/White	*N* = 23	*N = 18*	*N = 17*	
Latino/Latina	*N = 0*	*N = 2*	*N = 1*	
Middle Eastern/Arab	*N* = 1	*N = 1*	*N = 1*	
Multi-racial	*N* = 3	*N = 3*	*N = 2*	
WASI FSIQ-2	116.3 (12.97)	113.07 (11.24)	112.22 (12.81)	$F(2,130) = 1.38$, p=.255
Baseline Measures				
PHQ-9	5.62 (4.02)	5.43 (5.08)	5.19 (5.21)	$F(2,130) = .087$, p=.916
T1 PANAS-PA	2.65 (0.74)	2.62 (0.81)	2.63 (0.75)	$F(2,130) = .020$, p=.980
T1 PANAS-NA	1.76 (0.63)	1.54 (0.53)	1.51 (0.41)	$F(2,130) = 2.62$, p=.077
T2 PANAS-PA	2.59 (0.75)	2.58 (0.77)	2.72 (0.81)	$F(2,130) = .376$, p=.688
T2 PANAS-NA	1.61 (0.50)	1.54 (0.46)	1.46 (0.37)	$F(2,130) = 1.21$, p=.301
NLEQ (total sum)	37.78 (26.64)	37.04 (31.92)	36.57 (20.81)	$F(2,130) = .022$, p=.978
N-back Variables				
T1 n-back errors	15.30 (7.42)	16.43 (7.23)	14.35 (6.71)	$F(2,130) = .881$, p=.417
T2 n-back errors	11.78 (5.57)	11.50 (6.39)	10.49 (5.05)	$F(2,130) = .574$, p=.565
SUDS ratings				
(1) Pre-stress	29.12 (17.19)	27.84 (17.19)	24.59 (13.17)	$F(2,130) = .857$, p=.427
(2) Speech prep	27.10 (15.87)	25.11 (15.28)	21.54 (13.28)	$F(2,130) = 1.465$, p=.235
(3) Pre-speech	$43.96 (16.06)_a$	$25.17 (14.65)_b$	$44.84 (20.15)_a$	$F(2,130) = 19.35$, p=.000
(4) Post-speech	$43.24 (17.97)_a$	$27.41 (14.41)_b$	$42.92 (19.89)_a$	$F(2,130) = 12.21$, p=.000
(5) Post-math	$32.46 (15.28)_a$	$24.89 (13.24)_b$	$30.72 (13.57)_{ab}$	$F(2,130) = 3.67$, p=.028
(6) Post-cool down	25.98 (16.30)	21.47 (14.03)	20.25 (12.84)	$F(2,130) = 1.83$, p=.164
Follow-up Measures				
PHQ-9	5.29 (4.93)	6.95 (6.42)	5.97 (5.48)	$F(2,117) = .962$, p=.385
NLEQ (total sum)	35.40 (26.96)	32.09 (27.96	33.37 (25.06)	$F(2,117) = .170$, p=.844

Note: WASI FSIQ-2 = Wechsler Abbreviated Scale of Intelligence, 2nd Edition, full scale IQ; PHQ-9 = Patient Health Questionnaire-9; PANAS-PA = positive and negative affect schedule – positive affect subscale; PANAS-NA = positive and negative affect schedule – negative affect subscale; NLEQ = Negative Life Events Questionnaire; n-back errors = measure of executive control, fewer errors = better control; SUDS = subjective units of distress scale. Subscript letters (a,b) indicate significant ($p < .05$) differences between groups.

Table 2.

Correlations among study variable for the whole sample at Time 1

Whole Sample	Age	Sex	IQ	Minority status	n-back errors	PHQ-9	NLEQ	PA	NA
1. Age	--								
2. Sex	.000	--							
3. IQ	-.040	-.033	--						
4. Minority status	-.004	.082	-.008	--					
5. T1 n-back errors	-.137	.100	-.114	.238**	--				
6. T1 PHQ-9	.151	-.116	-.161	.153	-.035	--			
7. T1 NLEQ total	-.075	-.084	-.114	.164	.058	.517**	--		
8. T1 PANAS-PA	-.083	-.051	-.058	-.224*	-.085	-.378**	-.271**	--	
9. T1 PANAS-NA	.048	-.085	.004	.066	-.177	.469**	.424**	-.128	--

Table 3.

Correlations of key study variables by condition

High-Stress/ Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) T1 n-back errors	--									
(2) T2 n-back errors	.72**	--								
(3) T1 PHQ-9	.07	.07	--							
(4) T3 PHQ-9	-.15	-.21	.59**	--						
(5) T1 NLEQ total	-.07	.06	.40**	.25	--					
(6) T3 NLEQ total	.03	.09	.36*	-.64**	.42**	--				
(7) T1 PANAS-PA	-.15	-.04	-.47**	-.35*	-.26	-.11	--			
(8) T1 PANAS-NA	-.14	-.03	.29*	.27	.48**	.28	-.07	--		
(9) T2 PANAS-PA	-.34**	-.24	-.27	-.22	-.13	-.11	.70**	.15	--	
(10) T2 PANAS-NA	-.11	.04	.03	.28	.15	.20	-.08	.56**	-.06	--

High-Stress/ Intervention	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) T1 n-back errors	--									
(2) T2 n-back errors	.42**	--								
(3) T1 PHQ-9	-.15	.18	--							
(4) T3 PHQ-9	.18	.34	.67**	--						
(5) T1 NLEQ total	.17	.43**	.49**	.39*	--					
(6) T3 NLEQ total	.18	.38*	.66*	-.52**	.85**	--				
(7) T1 PANAS-PA	-.20	-.13	-.52**	-.51*	-.24	-.43*	--			
(8) T1 PANAS-NA	-.33	-.42*	.75**	.71**	.58**	.59**	-.37	--		
(9) T2 PANAS-PA	-.25	-.17	-.13	-.10	-.02	-.15	.61**	.03	--	
(10) T2 PANAS-NA	.05	.02	.07	.07	.31	.36*	-.21	.14	.11	--

Low-Stress/ Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) T1 n-back errors	--									
(2) T2 n-back errors	.41**	--								
(3) T1 PHQ-9	-.05	.19	--							
(4) T3 PHQ-9	-.07	.10	.47**	--						
(5) T1 NLEQ total	-.12	.34*	.64**	.43**	--					
(6) T3 NLEQ total	.15	.19	.49**	.59**	.73**	--				
(7) T1 PANAS-PA	-.04	-.20	-.23	-.10	-.29*	-.07	--			
(8) T1 PANAS-NA	-.15	.16	.57**	.43**	.35*	.19	-.12	--		
(9) T2 PANAS-PA	-.15	-.34*	-.02	-.12	-.10	-.18	.62**	.03	--	
(10) T2 PANAS-NA	-.01	.09	.39**	.54**	.38**	.46*	.15	.56**	.06	--

Note: n-back errors = measure of executive control, fewer errors = better control; PHQ-9 = Patient Health Questionnaire-9; NLEQ = Negative Life Events Questionnaire; PANAS-PA = positive and negative affect schedule – positive affect subscale; PANAS-NA = positive and negative affect schedule – negative affect subscale.

Table 4.

Repeated measures ANOVA testing the effect of the stress induction task as reported on the SUDS scores.

Tests of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	*F*	*p*	*Partial Eta Squared*
Intercept	649832.938	1	649832.938	582.549	.000	.828
Condition	10037.21	2	5018.605	4.499	.013	.069
Error	134975.322	121	1115.499			

Note: Dependent variable: SUDS scores

Tukey HSD Multiple Comparisons

	Mean Diff	Std. Error	*p*	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
High-Stress/Control Int. vs. Low-Stress Control Int.	8.38**	2.83	.010	1.66	15.10
High-Stress/Control Int. vs. High-Stress/ER Intervention	2.55	3.13	.695	-4.88	9.97
High-Stress/ER Intervention vs. Low-Stress Control Int.	5.83	3.20	.166	-1.76	13.42

Note: ** = the mean difference is significant at the .01 level. Int. = Intervention; ER = emotion regulation

Table 5.

Paired samples t-test comparing the means between T1 and T3 NLEQ to check whether the follow-up measures were completed during a more stressful time than at baseline.

Paired Samples t-test

	Mean	N	Std. Deviation	Std. Error Mean
T1 NLEQ Sum	36.8167	120	27.79	2.54
T3 NLEQ Sum	33.6750	120	26.65	2.43
T1 NLEQ-Achievement	2.7500	120	1.95	.178
T3 NLEQ Achievement	2.6667	120	1.83	.167

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	*p*
				Lower	Upper			
T1 NLEQ sum – T3 NLEQ sum	3.14	23.35	2.13	-1.08	7.36	1.47	119	.143
T1 NLEQ-Ach – T3 NLEQ-Ach	.083	1.75	.156	-.23	.40	.52	119	.603

Table 6.

Correlations of practice amount and specific skills used by participants in the High-Stress Intervention condition

High-Stress/ Intervention	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) T2 n-back errors	--						
(2) Total Practice	-.052	--					
(3) Notice skill	-.234	.192	--				
(4) Acceptance skill	-.029	-.135	.138	--			
(5) Breathing skill	-.079	.188	-.126	.023	--		
(6) Reappraisal skill	.017	.108	-.249	.062	.045	--	
(7) Distraction skill	.151	.122	-.073	-.050	-.108	-.094	--

Table 7.

Regression model testing whether high-stress groups varied in the extent to which amount of practice predicted executive control under stress (T2 n-back errors).

Practice amount predicting T2 n-back errors

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	*t*	*p*
(Constant)	6.823	4.785		1.426	.158
T1 n-back errors	.455	.068	.602	6.688	.000
FSIQ-2 scores	-.010	.039	-.025	-.265	.792
Total Practice	-.293	.341	-.111	-.860	.392
Intervention Condition	-2.226	1.526	-.206	-1.459	.149
Practice*Intervention	.511	.484	.179	1.056	.294

Note: Dependent Variable: T2 n-back errors; Intervention condition is dummy coded with High-Stress/ Control Intervention = 0.

Table 8.

One-way *ANCOVA testing-the effect of high- vs. low-stress condition on executive control at Time 2, controlling for T1*

Source	Type III Sum of Squares	df	Mean Square	*F*	*p*	Partial Eta Squared
Corrected Model	1062.994[a]	3	354.331	14.204	.000	.317
Intercept	45.989	1	45.989	1.833	.178	.020
T1 n-back errors	983.757	1	983.757	39.437	.000	.300
FSIQ-2 scores	7.386	1	7.386	.296	.588	.003
High- vs. Low Stress	17.599	1	17.599	.705	.403	.008
Error	2294.965	93	24.945			
Total	16378.000	96				
Corrected Total	3357.958	95				

Note: Dependent variable: T2 n-back errors

Table 9.

Paired t-tests indicating significantly fewer errors on the T2 n-back as compared with the T1-nback across all conditions.

High-Stress/Control Intervention Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		*t*	df	*p*
				Lower	Upper			
T1 n-back errors – T2 n-back errors	3.520	5.168	.731	2.051	4.989	4.817	49	.000

Low-Stress/Control Intervention Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		*t*	df	*p*
				Lower	Upper			
T1 n-back errors – T2 n-back errors	4.935	7.428	1.095	2.729	7.141	4.506	45	.000

High-Stress/Intervention Paired Samples Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	p
				Lower	Upper			
T1 n-back errors – T2 n-back errors	3.865	6.486	1.066	1.702	6.027	3.625	36	.001

Table 10.

Regression model testing whether executive control under stress predicted depressive symptoms (T3 PHQ)

T2 n-back errors predicting T3 PHQ-9

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	*t*	*p*
(Constant)	4.369	6.026		.725	.471
T1 PHQ-9	.636	.117	.517	5.419	.000
T1 n-back errors	.050	.091	.064	.555	.581
FSIQ-2 scores	-.001	.046	-.003	-.031	.975
Stress Condition	-1.096	2.489	-.096	-.440	.661
T2 n-back errors	-.282	.174	-.284	-1.621	.109
T2 n-back*Stress Condition	.258	.194	.332	1.327	.188

Note: Dependent Variable: T3 PHQ-9; Stress condition is a dummy coded variable with High-Stress/Control Intervention = 0.

Table 11.

One-way ANCOVA testing the effect of the intervention on executive control under stress, comparing the High-Stress/Control Intervention condition and the High-Stress/ER intervention group

Source	Type III Sum of Squares	df	Mean Square	*F*	*p*	Partial Eta Squared
Corrected Model	936.790[a]	3	312.263	16.867	.000	.376
Intercept	46.259	1	46.259	2.499	.118	.166
T1 n-back errors	859.041	1	859.041	46.401	.000	.367
FSIQ-2 score	6.877	1	6.877	.371	.544	.004
Control vs. Intervention	18.686	1	18.686	1.019	.316	.012
Error	1536.613	84	18.513			
Total	13445.000	87				
Corrected Total	2473.402	86				

Note: Dependent variable: T2 n-back errors

Table 12.

Regression model testing whether T2 negative affect (NA) moderated the relation between stress and executive control.

Moderation by NA

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	*t*	*p*
(Constant)	5.883	5.935		.991	.324
T1 n-back errors	.453	.073	.554	6.225	.000
FSIQ-2 scores	-.026	.044	-.053	-.594	.552
Stress Condition	-.681	3.618	-.057	-.188	.851
T2 PANAS-NA	1.257	1.464	.101	.858	.393
T2 PANAS-NA*Stress Condition	-.069	2.206	.010	-.031	.975

Note: Dependent Variable: T2 n-back errors; Stress condition is dummy coded with High-Stress/ Control Intervention = 0.

Table 13.

Regression model testing whether T2 positive affect (PA) as a moderator of the relation between stress and executive control.

Moderation by PA

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	*t*	*p*
(Constant)	10.442	6.420		1.627	.107
T1 n-back errors	.421	.074	.515	5.688	.000
FSIQ-2 scores	-.035	.044	-.071	-.808	.421
Stress Condition	4.085	3.637	.344	1.123	.264
T2 PANAS-PA	-.384	.989	-.049	-.388	.699
T2 PANAS-PA*Stress Condition	-1.921	1.351	-.453	-1.423	.158

Note: Dependent Variable: T2 n-back errors; Stress condition is a dummy coded variable with High-Stress/Control = 0.

Table 14.

Multiple linear regression analyses of the associations between state positive and negative affect and executive control.

T1 PANAS-NA Predicting T1 n-back errors

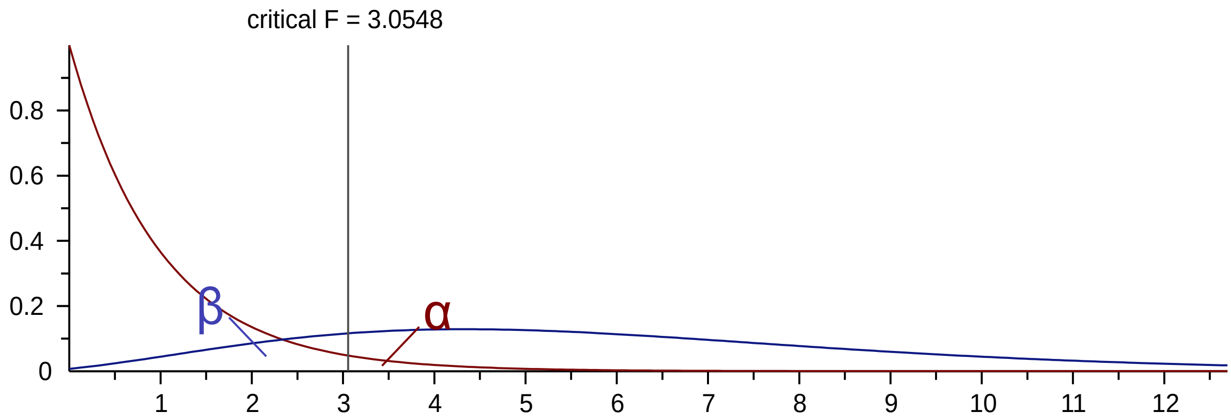
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	*t*	*p*
(Constant)	26.394	6.115		4.316	.000
FSIQ-2 scores	-.065	.051	-.114	-1.271	.206
T1 PANAS-NA	-2.262	1.150	-.176	-1.967	.052

Note: Dependent Variable: T1 n-back errors

T2 PANAS-PA Predicting T2 n-back errors

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	*t*	*p*
(Constant)	11.471	4.719		2.431	.016
T1 n-back errors	.388	.062	.483	6.265	.000
FSIQ-1 scores	-.029	.035	-.062	-.823	.412
T2 PANAS-PA	-1.082	.572	-.146	-1.815	.061

Note: Dependent Variable: T2 n-back errors.



F tests - ANCOVA: Fixed effects, main effects and interactions

Analysis: A priori: Compute required sample size

Input:	Effect size f	=	0.25
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	Numerator df	=	2
	Number of groups	=	3
	Number of covariates	=	1
Output:	Noncentrality parameter λ	=	9.8750000
	Critical F	=	3.0547708
	Denominator df	=	154
	Total sample size	=	158
	Actual power	=	0.8021469

Figure 1. Power Analysis output as computed by G*Power (Faul et al., 2007).

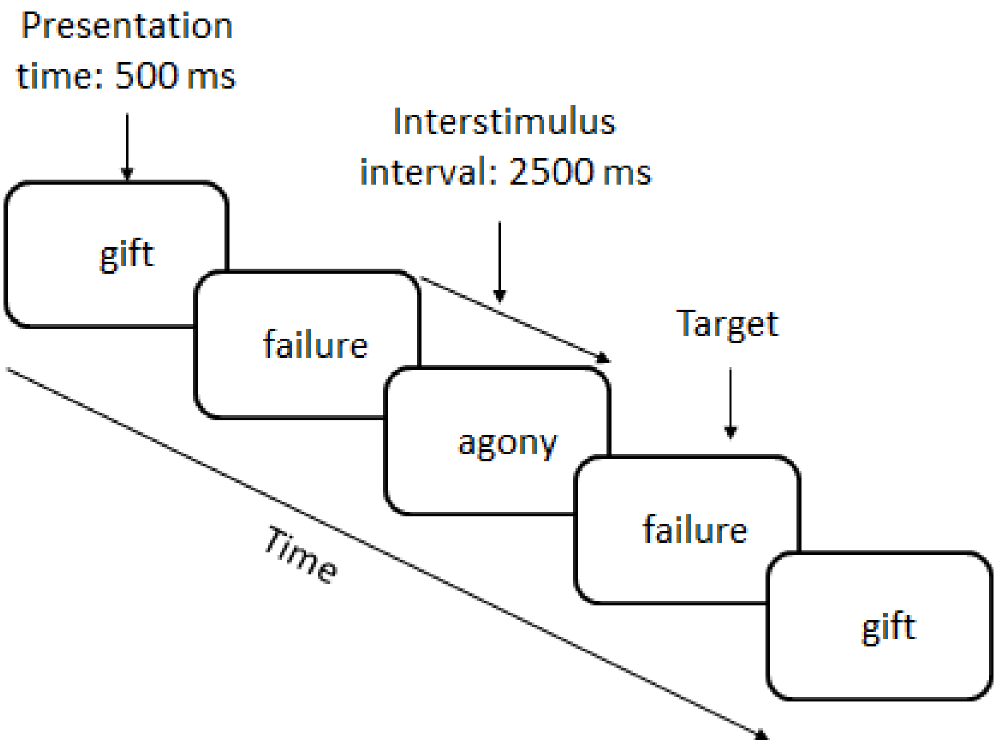
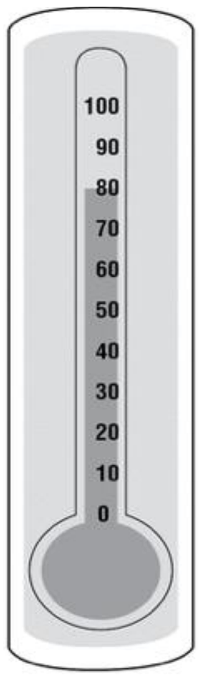


Figure 2. Series of trials in the n-back task. In this task, words are presented one at a time in the center of the screen and participants are instructed to identify whether or not each trial is a target trial. Target trials are those that match the word presented two trials previously. In this example, the 4th trial is the only target.

SUDS: The Subjective Units of Distress Scale



100 – Highest anxiety/distress that you have ever felt

90 – Extremely anxious/distressed

80 – Very anxious/distressed; can't concentrate. Physiological signs present.

70 – Quite anxious/distressed; interfering with functioning. Physiological signs may be present.

60 – Moderate-to-strong anxiety or distress

50 – Moderate anxiety/distress; uncomfortable, but can continue to function

40 – Mild-to-moderate anxiety or distress

30 – Mild anxiety/distress; no interference with functioning

20 – Minimal anxiety/distress

10 – Alert and awake; concentrating well

0 – No distress; totally relaxed

Note: "SUDS" stands for **"Subjective Units of Distress Scale."** Physiological signs may include, for example, sweating, shaking, increased heart rate or respiration, gastrointestinal distress.

Chapter: SUDS: The Subjective Units of Distress Scale
From: Concurrent Treatment of PTSD and Substance Use Disorders Using Prolonged Exposure (COPE): Patient Workbook

Downloaded from Oxford Clinical Psychology. © Oxford University Press, 2014

Figure 3. Subjective Units of Distress (SUDS) scale, from Oxford Clinical Psychology (2014).

Figure 4. Study Procedure Table

Condition	A. High-Stress + Control Intervention	B. Low-Stress + Control Intervention	C. High-Stress + ER Intervention
Session 1	**Baseline**		
REDCap	PHQ-9; PANAS; NLEQ	PHQ-9; PANAS; NLEQ	PHQ-9; PANAS; NLEQ
EXP 2	WASI-II: Vocab & MR	WASI-II: Vocab & MR	WASI-II: Vocab & MR
EXP 2	Executive Control task (Emotional n-back task)	Executive Control task (Emotional n-back task)	Executive Control task (Emotional n-back task)
Randomize			
EXP 1	Train Control Intervention (Healthy Living)	Train Control Intervention (Healthy Living)	Train ER Intervention (Mindfulness + Reappraisal)
Session 2	**One week later**		
REDCap	PANAS	PANAS	PANAS
EXP 1	Control Intervention review	Control Intervention review	ER Intervention review
EXP 2	Trier Social Stress Test	Low Stress Control	Trier Social Stress Test
	SUDS ratings	SUDS ratings	SUDS ratings
EXP 2	Executive Control task (Emotional n-back task)	Executive Control task (Emotional n-back task)	Executive Control task (Emotional n-back task)
	SUDS rating	SUDS rating	SUDS rating
Session 3	**End of the Semester**		
REDCap	PHQ-9; NLEQ	PHQ-9; NLEQ	PHQ-9; NLEQ

EXP = Experimenter; ER = Emotion Regulation; Vocab = Vocabulary; MR = Matrix Reasoning; PHQ-9 = Patient Health Questionnaire - 9; PANAS = Positive and Negative Affect Schedule; NLEQ = Negative Life Events Questionnaire; SUDS = Subjective Units of Distress Scale

Figure 5. *SUDS ratings by condition during session 2 stress tasks*

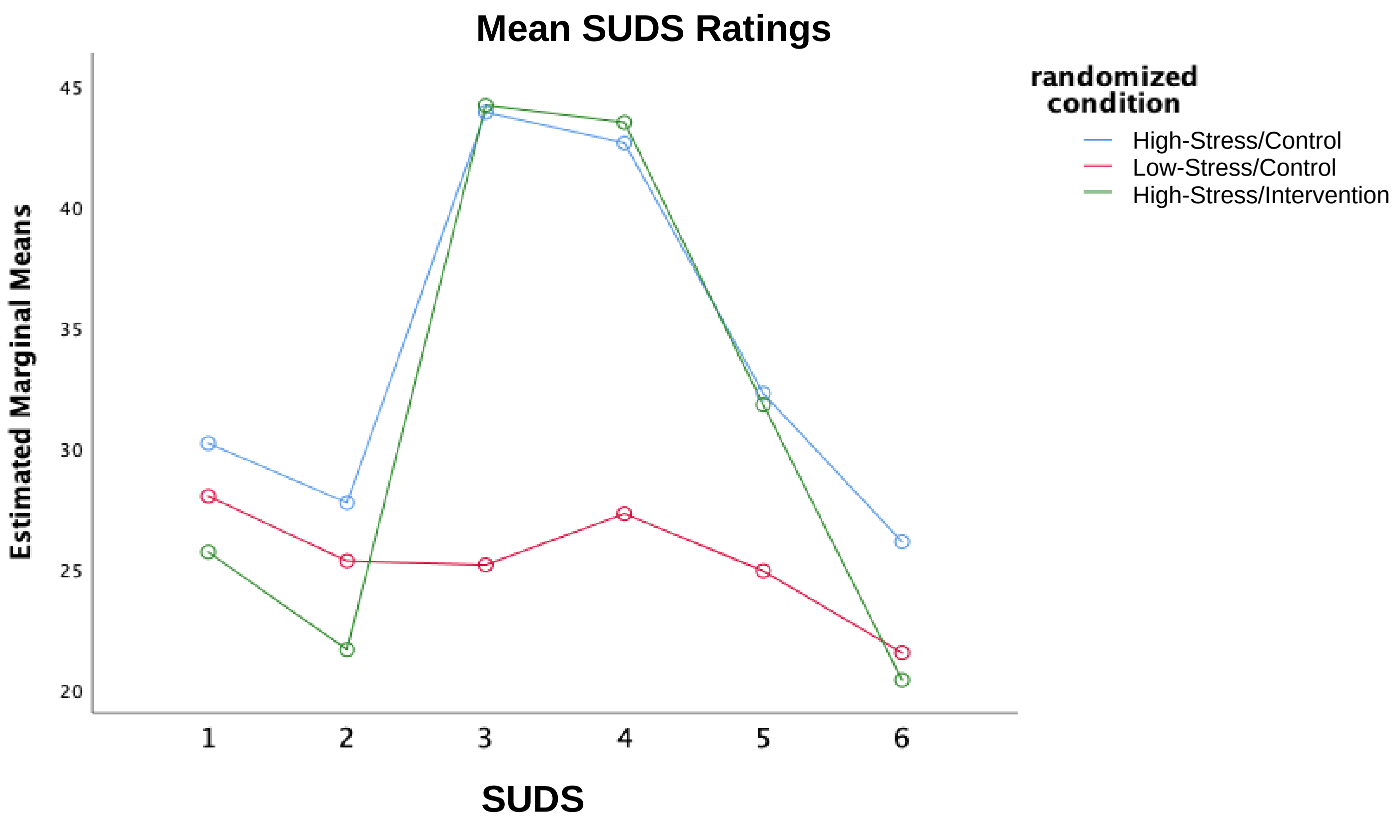
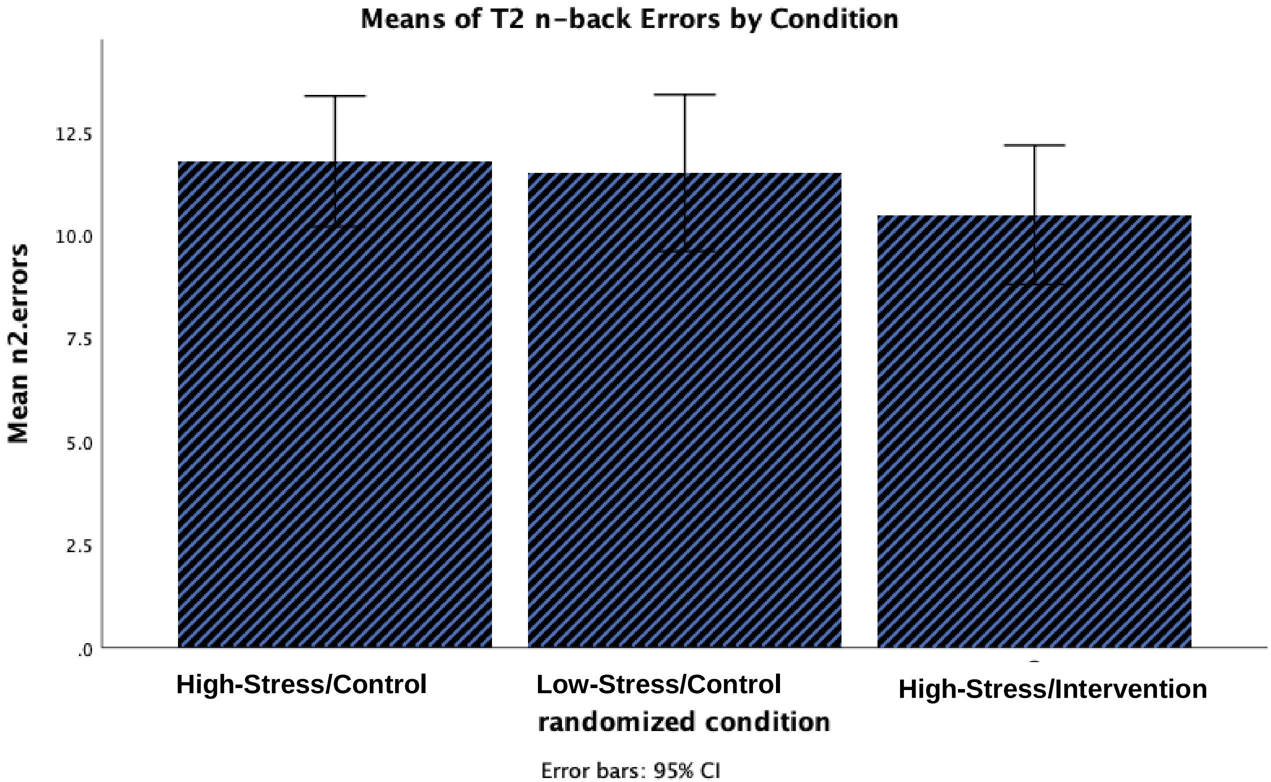


Figure 6.



Note: Differences between groups are not significant.

Appendix

Stimulus words included in the n-back task.

Negative	Positive
failure	heart
abuse	excitement
hatred	freedom
agony	cheer
fear	love
tragedy	reward
trauma	profit
dead	gift
victim	party
panic	paradise
stress	charm
funeral	leader
destruction	peace
anger	champion
jealousy	laughter

PATIENT HEALTH QUESTIONNAIRE (PHQ-9)

NAME:____________________________________ **DATE:**____________________

Over the last *2 weeks,* how often have you been bothered by any of the following problems? *(use "✓" to indicate your answer)*	**Not at all**	**Several days**	**More than half the days**	**Nearly every day**
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself—or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed. Or the opposite —being so figety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead, or of hurting yourself	0	1	2	3
	add columns		+	+

(Healthcare professional: For interpretation of TOTAL, please refer to accompanying scoring card). TOTAL:

10. If you checked off *any problems,* how *difficult* have these problems made it for you to do your work, take care of things at home, or get along with other people?	
	Not difficult at all ________
	Somewhat difficult ________
	Very difficult ________
	Extremely difficult ________

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PANAS

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate the extent to which you feel this way **TODAY**.

Use the following scale to record your answers.

	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
Interested	☐	☐	☐	☐	☐
Distressed	☐	☐	☐	☐	☐
Excited	☐	☐	☐	☐	☐
Upset	☐	☐	☐	☐	☐
Strong	☐	☐	☐	☐	☐
Guilty	☐	☐	☐	☐	☐
Scared	☐	☐	☐	☐	☐
Hostile	☐	☐	☐	☐	☐
Enthusiastic	☐	☐	☐	☐	☐
Proud	☐	☐	☐	☐	☐
Irritable	☐	☐	☐	☐	☐
Alert	☐	☐	☐	☐	☐
Ashamed	☐	☐	☐	☐	☐
Inspired	☐	☐	☐	☐	☐
Nervous	☐	☐	☐	☐	☐
Determined	☐	☐	☐	☐	☐
Attentive	☐	☐	☐	☐	☐
Jittery	☐	☐	☐	☐	☐
Active	☐	☐	☐	☐	☐
Afraid	☐	☐	☐	☐	☐

NLEQ

INSTRUCTIONS: In this questionnaire we are interested in whether certain events have happened to you over the **past month**. The questions can be answered by referring to the following scale:

A	B	C	D	E
NEVER	**RARELY**	**SOMETIMES**	**FREQUENTLY**	**ALWAYS**

Some questions do not follow this format. For these questions, a scale for answering will be provided after the question.

*****If no scale is provided for the question, use the scale at the top of the page.*****

Please be careful to mark your answers correctly and remember that you are to evaluate each question for only the **past month**.

SCHOOL

1. Did poorly on, or failed, an exam or major project in an important course (i.e. grade less than or equal to C.) ____

2. Received a negative reaction from family or friends about not doing well in school (e.g. got silent treatment, criticized, etc.) ____

3. Doing worse academically than usually did in previous semesters or than did in high school (difference of at least one grade; e.g. C rather than B.) ______

4. Negative consequences from studying for long periods of time (e.g. exhaustion, ill health, loss of friends, etc.) _____

5. Do not have time to do well in school or job (e.g. work long hours so have no time to study) _____

6. Dislike school in general, but have to stay (e.g. forced by parents to stay, have no skills to get a job, etc.) _____

7. Not doing as well in school as would like. _____

JOB

8. Laid off or fired from job. **A= NO B= YES**

9. Unable to find work and need a job very much for financial or other reasons. ____

10. Reprimanded at work. ______

11. Significant negative change in financial circumstances (e.g. large amount of money or valuables lost or stolen, significant decrease in financial support, etc.) _____

A	B	C	D	E
NEVER	**RARELY**	**SOMETIMES**	**FREQUENTLY**	**ALWAYS**

12. Did not have enough money for one or more necessities and had to do without them (or, when living with family, family did not have enough money for one or more necessities) (necessities are: health care, food, housing or necessary clothing.) _______

ACHIEVEMENT

13. Have not been achieving or accomplishing as much as would like. ________

14. Parents upset with me for not living up to their standards/expectations (e.g. not doing well in school, sports, etc.) __________

PARENTS AND FAMILY

15. Significant fight or argument with close family member that led to serious consequences such as self or family member crying, temporary loss of privileges, emotional distance, _________

16. Close family member became so upset with you that s/he ended the relationship. ________

17. Trying but can't seem to fully please mother and/or father. _________

18. Can't tell how family member really feels about you. ________

19. Trying but can't seem to get close to one or more family members. ________

20. Did something did not want to do in order to please family member. _______

21. Death of parent, brother or sister. **A= NO** **B= YES**

22. Found out that close family member has been criticizing you behind your back. _______

23. Fights or disagreements with one or more close family members. _________

24. Put down by parents or parents show dislike. _______

25. Parents disappointed in you. ________

26. Family member has significant medical or emotional problem (e.g. heart disease, depression, excessive use of alcohol or drugs) ____________

27. Family member has life threatening illness. _________

28. Conflicts with parents over (or parents do not support) personal goals, desires, or choice of friends. ________

29. Did not receive love, respect, or interest from parents (e.g. did not receive compliments or praise from parents, parents did not call or write, parents did not listen or show interest, etc.) __________

A NEVER	B RARELY	C SOMETIMES	D FREQUENTLY	E ALWAYS

30. Forced by parents to achieve things that could not or did not want to achieve (e.g. have to be a star athlete even though would rather concentrate on other interests, punished if do not excel in everything undertaken) ____________

31. Close family member has been withdrawing affection from you. ___________

ROOMMATES

32. Trying but can't seem to fully please roommate.____________

33. Criticized by one or more roommates. _______

34. Can't tell how one or more roommates really feel about you. _______

35. Trying but can't seem to get close to one or more roommates. ____________

36. Did something did not want to do in order to please roommate. _______

37. Found out that roommate has been criticizing you behind your back. _______

38. Fight or disagreement with one or more roommates. _______

39. Roommate has been withdrawing affection from you. _______

FRIENDS (OTHER THAN ROOMMATES)

40. Close friend becomes so upset with you that s/he ends relationship. _______

41. Trying but can't seem to fully please friend. ________

42. Criticized by one or more friends. ___________

43. Can't tell how one or more friends really feel about you. ________

44. Trying but can't seem to get close to one or more friends. _________

45. Found out that friend has been criticizing you behind your back. __________

46. Death of pet. **A= NO** **B= YES**

47. Death of friend. **A= NO** **B= YES**

48. Have hardly any friends. ____________

49. Not sought out by others for activities or friendships (e.g. not called by others and asked to do something fun, etc.) _______

50. Close friend has been withdrawing affection from you. ________

A	B	C	D	E
NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS

Boyfriend/Girlfriend/Spouse

51. Significant fight or argument with boyfriend/girlfriend/spouse that led to serious consequence(s) such as self or boyfriend/girlfriend/spouse crying, leaving common residence for one night, etc. ____

52. Boyfriend/girlfriend/spouse ends relationship. _____

53. Boyfriend/girlfriend/spouse says s/he is not sure whether wants relationship to continue. ____

54. Trying but can't seem to fully please boyfriend/girlfriend/spouse. ____

55. Criticized by boyfriend/girlfriend/spouse. _____

56. Trying but can't seem to get close to boyfriend/girlfriend/spouse. ____

57. Found out that boyfriend/girlfriend/spouse has been criticizing you behind your back. ____

58. Discovered boyfriend/girlfriend/spouse has been cheating on you. ____

59. Did something did not want to do in order to please boyfriend/girlfriend/spouse. ____

60. While still involved with boyfriend/girlfriend/spouse, s/he had a date with someone else. ____

61. Death of boyfriend/girlfriend/spouse. **A= NO B= YES**

62. Fight or disagreement with boyfriend/girlfriend/spouse. ______

63. Can't tell how boyfriend/girlfriend/spouse really feels about you. _____

64. Want a boyfriend/girlfriend/spouse but do not have one. ______

65. Did not receive love, respect or interest from boyfriend/girlfriend/spouse (e.g. did not receive compliments or praise, boyfriend/girlfriend/spouse did not listen or take interest in you, etc.) ____

66. Boyfriend/girlfriend/spouse withdrew affection from you. ______