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Exploring Executive Control as an Underlying Mechanism of Emotion Regulation and Stress Response

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EXPLORING EXECUTIVE CONTROL AS AN UNDERLYING MECHANISM OF EMOTION REGULATION AND STRESS RESPONSE

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Previous research has demonstrated a link among stress response, emotion regulation, and executive control, such that greater executive control is associated with ability to use emotion regulation strategies that may promote adaptive responding to stressors. However, evidence of this relation is correlational and it is therefore not clear whether the ability to adaptively respond to stressors is caused by executive control abilities. Recent research has found that changing cognitive biases through training results in changes in emotion regulation ability. Additional research indicates that executive control may also be trained in a similar manner. The current study employed a training design to explore whether training executive control affects emotion regulation as well as physiological and subjective responses to stress in a sample of undergraduate students. Results provide preliminary support for executive control as a process underlying individual differences in rumination and physiological stress response. Explanations and implications for future studies are discussed in order to continue the advancement of our understanding of executive control and its role in stress response.

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Chapter 1: Introduction

Research indicates that exposure to stressors places individuals at risk for numerous negative outcomes including depression (van Praag, 2004), anxiety (Barlow, 2002), and chronic health issues such as heart disease and hypertension (Taylor, 2010). Not all individuals exposed to stressors, however, will experience these negative outcomes (Bonanno, Galea, Bucciarelli, & Vlahov, 2006). The aim of the proposed study is to demonstrate that a set of cognitive processes, known collectively as executive control, underlies individual differences in the ability to respond adaptively to stressors.

Emotion Regulation and Stress Response.

Research investigating individual factors that contribute to the ability to respond adaptively to stressors implicates emotion regulation ability as a potential protective factor (Bonanno & Keltner, 1997; Bonanno, Papa, Lalande, Westphal, & Coifman, 2004). Emotion regulation, in its broadest form, is defined as a set of processes which alter emotion (Gross & Thompson, 2007). There are many ways in which emotions can be altered and one category of doing so, which relies on cognitive processes, is goal-oriented emotion regulation. This describes a method for changing emotions based on a specific goal (Koole, 2009). Goal-oriented emotion regulation involves holding a goal in mind, and using it to inform what one attends to and how one interprets an emotion eliciting situation (Koole, 2009). One frequently investigated goal-oriented emotion regulation strategy is reappraisal, which entails changing the interpretation of an emotion eliciting situation with the goal of altering the experienced emotion

(Gross, 1999). The ability to reappraise during a stressful event has been associated with more adaptive responses to stressors (Troy, Wilhelm, Shallcross, & Mauss, 2010).

In contrast to reappraisal, some responses to emotion eliciting situations are generally considered more passive. For example, rumination is a response that involves passively fixating on current negative emotions (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Rumination has been shown to predict factors associated with less adaptive responses to stress including increased levels of stress hormones (Zoccola & Dickerson, 2012) and increased negative affect (Genet & Siemer, 2012) following exposure to stressors. To better understand how emotion regulation is associated with individual differences in stress response, attention should be given to the processes that are associated with the use of various forms of emotion regulation.

Executive Control and its Role in Emotion Regulation

Cognition and emotion are intricately linked; appraisal theories of emotion posit that emotions do not exist independent of evaluations of the emotion-eliciting situation (Ellsworth & Scherer, 2003). This view of emotion is consistent with principles of cognitive therapy, which suggest that cognitions should be altered in order to change emotions (Beck, 1976). Due to the inextricable link between cognition and emotion, the cognitive processes involved in producing and changing emotions may provide critical insight into the ability to regulate emotions and respond adaptively to stressors.

Recent research has focused on investigating the association between emotion regulation ability and executive control (Joormann, Yoon, & Siemer, 2010; Ochsner & Gross, 2005). Executive control is broadly defined as a set of cognitive processes required to execute goal directed behavior (Miller, 2000). In other words, executive control is responsible for regulating automatic responses based on knowledge from experiences of past relevant situations.

Research investigating the process of regulating emotions demonstrates that goal oriented and passive emotion regulation are associated with executive control. For example, executive control has been associated with reappraisal ability (McRae, Jacobs, Ray, John, & Gross, 2012) and has been shown to moderate the relationship between and exposure to a stressful situation and rumination (De Lissnyder et al., 2012). These associations indicate that executive control is related to emotion regulation, which may promote or hinder adaptive responding to stressors.

Despite the established associations among executive control, emotion regulation, and stress response, a causal link among these processes has not been established. Demonstrating a causal relation is critical, not only to determine what underlies individual differences in stress response, but also because it may identify targets for preventing the incidence of negative outcomes associated with stress exposure.

The current study aims to identify a causal link among executive control, emotion regulation, and stress response. Before describing the current study, a more detailed review of executive control, including the tasks used to measure it are reviewed.

Measures of Executive Control

Executive control is responsible for regulating automatic responses based on knowledge from experiences of past relevant situations (Miller, 2000). Research indicates that three separate processes contribute to executive control ability: updating working memory, switching, and inhibition. Latent variable analysis indicates that, while these three factors are distinct, they are related to a general executive control ability (Miyake & Friedman, 2012; Miyake et al., 2000). Each of these three processes is described in detail below.

Working memory is a system that holds a limited number of representations which are the focus of current attention (Jonides & Smith, 1997; Miyake & Shah, 1999). The ability to update working memory, one of the three elements of executive control, involves appropriately and efficiently taking in new relevant information and discarding information that is no longer relevant (Miyake et al., 2000; Morris & Jones, 1990). The ability to efficiently utilize working memory is thought to be related to emotion regulation ability because working memory must be constantly updated in order to evaluate the emotion eliciting situation, consider one's goals, plan a response, and reevaluate each of these as the situation changes (Zelazo & Cunningham, 2007).

A task that has been used frequently to measure updating working memory is the n-back (Chatham et al., 2011; Kirchner, 1958). In the n-back, participants see a series of stimuli, presented one at a time, and must indicate whether the current stimulus is the same as the stimulus that was presented a specified number (*n*) of times earlier in the sequence. For example, if participants are completing a 2-back, they will have to decide whether the current stimulus is the same as the stimulus they saw two trials earlier. As the number for *n* increases, the difficulty of the task increases.

Another unique component of executive control is switching, which describes the process of shifting attention and resources from one task to another task (Miyake et al., 2000; Monsell, 2003). It is hypothesized that switching is related to emotion regulation ability because individuals must be able to flexibly switch between attending to emotional and non-emotional aspects of a situation in order to efficiently regulate emotions (Zelazo & Cunningham, 2007).

In a task used to measure switching ability, participants must alternate between classifying stimuli according to two separate rules (Monsell, 2003). For example, participants may see a series of numbers presented one at a time and on some trials determine whether the numbers are odd or even and on other trials determine whether the numbers are large or small. Switching ability is measured by how much longer it takes to respond when switching from one rule to the other rule, compared to the response latency when the rule remains the same.

The third primary component of executive control is inhibition, which is the deliberate suppression of automatic responses (Miyake et al., 2000). It is hypothesized that inhibition is required for individuals to override immediate emotional reactions of the emotion eliciting situation in order to implement an emotion regulation strategy (Zelazo & Cunningham, 2007).

Inhibition may be measured by a number of tasks including the Stroop task (Stroop, 1935) and Flanker task (Eriksen & Eriksen, 1974). In the Stroop task, participants are presented with a list of color words presented in ink of various colors. Participants are instructed to name the color of ink, which requires inhibiting the automatic process of reading the color word. In the Flanker task, participants are instructed to make a decision about the nature of a target stimulus (e.g., whether the target letter is a G or H) while three other distracting letters surround the target letter. Inhibition is measured by how much longer it takes to respond when the distracting letters are incongruent to the target compared to when they are congruent to the target.

Given the association between emotion regulation ability and executive control (Joormann et al., 2010; Ochsner & Gross, 2005), each of the executive control tasks outlined above have been adapted to more accurately measure how executive control is associated with emotion regulation by measuring the ability to update working memory with affective stimuli, switch between classifying stimuli based on an affective rule and a neutral rule, and inhibit distracting affective stimuli.

The role of switching in emotion regulation was supported by a task requiring the ability to switch from classifying stimuli by an affective rule (i.e., whether the picture was positive or negative) to classifying stimuli by a non-affective rule (i.e., whether the picture contained two or more, or one or fewer people). When the stimuli were negative, this type of switch predicted ability to reappraise during a sad film clip (Malooly, Genet, & Siemer, 2012).

Updating working memory was associated with emotion regulation ability in a study that employed an affective version of the n-back to investigate emotion dysregulation. Results demonstrated that depressed individuals experienced more difficulty discarding no longer relevant negative information from working memory compared to never depressed individuals (Levens & Gotlib, 2010).

Inhibition was linked to emotion regulation ability in a study that used an affective version of the flanker task. Results of this study established that individuals who tend to reappraise to regulate their emotions showed better inhibition when presented with negative stimuli, compared to individuals lower on a measure of trait reappraisal (Cohen, Henik, & Moyal, 2012). Taken together, these studies support the idea that each of the three elements of executive control ability, measured by affective versions of executive control tasks, are associated with the ability to implement emotion regulation strategies. However, the question still remains whether executive control plays a causal role in the ability to regulate emotions.

Training Executive Control.

A relatively recent area of research, cognitive bias modification, demonstrates that biases in cognitive processes, such as what one attends to and how one interprets a situation, can be modified (Brosan, Hoppitt, Shelfer, Sillence, & Mackintosh, 2011; Browning, Holmes, & Harmer, 2010). More importantly, research indicates that alterations in cognitive biases lead to changes in emotional responding following a stressor (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002).

Research paradigms similar to those used in cognitive bias modification have been employed to determine whether executive control processes can be altered and produce change in related domains. For example, executive control ability is associated with fluid intelligence (Carpenter, Just, & Shell, 1990) and it was hypothesized that if executive control abilities could be trained, improvements would be noticed in measures of fluid intelligence (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). This study included training sessions in which the participant practiced an n-back task. It also included a pre-training task, which measured fluid intelligence before training, and a post-training task, which was used to measure improvements in fluid intelligence after training. Four groups of participants engaged in the training task for approximately 25 minutes on each of 8, 12, 17, or 19 training days. Each of the four training groups, showed greater improvement from pre- to post-training on the measure of fluid intelligence, compared to a control group that did not complete a training task. Results indicate that training executive control led to improvement in fluid intelligence.

Integrating the findings from cognitive bias modification and executive control training provided the basis for research investigating the link between executive control and emotion regulation. The executive control training paradigm has been extended to investigate how executive control training may improve the ability to process emotional information (Schweizer, Hampshire, &

Dalgleish, 2011). This study included two training conditions in which participants completed either an n-back with affective stimuli or an n-back with neutral stimuli. The purpose of including both of these groups was to determine whether transfer to an affective context could only be achieved with an affective training task. Both conditions were compared to an active control condition in which participants determined whether or not a set of shapes contained identical shapes. All groups trained for a total of nineteen days. Two pre- and post-training tasks were used; one was a measure of fluid intelligence and the other was a version of the Stroop task containing affective stimuli. After completion of training, both training conditions showed improvements in the measure of fluid intelligence, while the control group did not improve. Further, only participants in the condition that trained with the n-back containing affective stimuli improved on the inhibition task with affective stimuli.

The results of this study indicate that training the updating working memory component of executive control using affective stimuli may improve the ability to process affective information (Schweizer et al., 2011). It is important to note, however, that a no-training control group exposed to affective stimuli was not used. Without this type of control group, it is impossible to say whether the improved ability to process affective stimuli was due to exposure to affective stimuli. Nevertheless, this research opened the door to possibilities of extending the training paradigm to investigate mechanisms underlying emotion regulation.

The Current Study.

Previous research provides support for a model of executive control as a factor with three overlapping core components: updating working memory, switching, and inhibition (Miyake et al., 2000). Executive control is related to processes involved in emotion regulation (Zelazo & Cunningham, 2007) and in fact, measures of each component have been associated with emotion regulation (Cohen et al., 2012; Levens & Gotlib, 2010; Malooly et al., 2012). Research also indicates that emotion regulation contributes to individual differences in stress response (Bonanno et al., 2006; Bonanno & Keltner, 1997). Despite the evidence linking executive control to emotion regulation and stress response, a causal relationship has not been established.

Recent research in cognitive bias modification has demonstrated a causal relationship between cognitive biases and emotional responses using a training paradigm (MacLeod et al., 2002). Additional research has demonstrated that executive control may be altered using similar methods to those employed in cognitive bias modification research (Jaeggi et al., 2008). Components of cognitive bias modification and executive control training were integrated by training executive control using affective stimuli in an effort to extend executive control training to affective applications (Schweizer et al., 2011). However, this extension leaves a number of important questions unanswered, each of which will be addressed by the proposed study.

One important question left unanswered by Schweitzer and colleagues is whether the improved ability to process affective information was due to improvements in executive control, improvements in executive control of affective material, or familiarity with affective material. Two important design changes would address this question. First, a control group exposed to affective stimuli, a training group exposed to neutral stimuli, and a training group exposed to affective stimuli should be used. Second, pre- and post-training tasks should measure each specific component of executive control rather than the general ability to process affective material.

Perhaps the most important question left unanswered by previous research is whether executive control training will transfer to emotion regulation ability and response to a stressor. This question has not yet been directly addressed and it will therefore be important to include more than one measure of stress response. Self-report of change in emotion, a physiological measure of stress reactivity, as well as a self-report of reappraisal use and rumination should be used to fully explore this question.

The proposed study will extend the existing literature to investigate the effect of training updating working memory on other components of executive control, stress response, and emotion regulation using three experimental conditions: (1) an affective working memory condition, in which participants will complete updating working memory training with a version of the n-back containing affective stimuli, (2) a neutral working memory condition, in which participants will complete updating working memory training with a version of the n-back containing neutral stimuli, and (3) a control condition, in which participants will complete an active control task containing affective stimuli.

The current study will measure pre-training to post-training differences in performance on tasks containing affective stimuli which measure the switching component of executive control (Switching task) and the inhibition component of executive control (Flanker task). Each of these tasks will measure executive control of affective material. Additionally, this study will use a well-validated laboratory stressor following the training to measure group differences in stress response via change in self-reported affect as well as change in stress hormone levels throughout the study session. Self-reported use of reappraisal and levels of rumination during the stressor will also be assessed to measure group differences in emotion regulation during the laboratory stressor.

Hypotheses.

I. *Transfer of training to executive control processes.* Engaging in an updating working memory training task will alter performance on the Flanker task and Switching task assessed using a pre- and post-training design.

   i. Following training, participants in the control condition will show improvement in the Flanker task and Switching task due to expected practice effects (Morrison & Chein, 2011).

   ii. Following training, participants in the neutral working memory condition will show greater improvement on the Flanker task and Switching task compared to participants in the control condition.

iii. Following training, participants in the affective working memory condition will show greater improvement on the Flanker task and Switching task compared to participants in the neutral working memory condition and control condition.

II. *Transfer of training to stress response.* Completion of an updating working memory training task will alter physiological and affective reactions to the laboratory stressor task.

i. Participants in the neutral working memory condition, compared to participants in the control condition, will show lower levels of physiological reactivity and lower levels of self-reported negative affect following the laboratory stressor.

ii. Participants in the affective working memory condition, compared to participants in the neutral working memory condition and control condition, will show lower levels of physiological reactivity and lower levels of self-reported negative affect following the laboratory stressor.

III. *Transfer of training to rumination and reappraisal.* Completion of the working memory training task will affect participants' use of reappraisal and levels of rumination during the laboratory stressor.

i. Participants in the neutral working memory condition, compared to participants in the control condition, will report less rumination and higher levels of reappraisal use during the laboratory stressor.

ii. Participants in the affective working memory condition, compared to participants in the neutral working memory condition and control condition, will report less rumination and higher levels of reappraisal use during the laboratory stressor.

Chapter 2: Method

Participants

Seventy (*N* = 70) participants were recruited from the University of Miami's Psychology 110 research pool. Participants signed up for the study using an online recruitment system and received six research credits for participating in the study. The average age of participants was 19.31 years (*SD* = 1.54). The sample was 62.9% (*n* = 44) male and 37.1% (*n* = 26) female. The sample was racially and ethnically diverse, with 57.1% (*n* = 40) identifying as White/Caucasian, 24.3% (*n* = 17) identifying as Hispanic or Latino, 7.1% (*n* = 5) identifying as Black/African American, 5.7% (*n* = 4) identifying as Asian, 1.4% (*n* = 1) identifying as American Indian/Alaska Native, and 4.3% (*n* = 3) identifying as "Other". The majority of participants (95.7%, *n* = 67) reported their marital status as single. One participant (1.4%) reported being married and two participants (2.9%) reported living with a domestic partner.

Symptoms of depression and anxiety were also assessed using the Beck Depression Inventory (BDI-II) and the Trait scale of the State Trait Anxiety Inventory (STAI-T). On the BDI-II, the mean score reported by participants was within the low range (*M* = 8.46, *SD* = 8.50). On the STAI-T, the mean score reported by participants was also within the low range (*M* = 40.93, *SD* = 11.43). BDI-II and STAI-T scores indicate that, on average, participants were not experiencing significant symptoms of depression or anxiety.

Affective Working Memory Training Task.

Task overview. The task was created and run with E-Prime 2.0 Software. The affective working memory training task is a version of the n-back task, which measures the updating working memory component of executive control. In the n-back, participants saw series of words, presented one at a time, and indicated whether the current word was the same as the word that was presented a specified number (*n*) of words earlier in the sequence. The specified number was one, two, three, or four, with higher numbers increasing the difficulty of the task. For example, when participants completed a 2-back, they had to decide whether the current word was the same as the word they saw two trials earlier (Figure 2.1).

Stimuli. The stimuli presented in the affective working memory training task were selected from the Affective Norms of English Words list (Bradley & Lang, 1999). Twenty-four positive and twenty-four negative words between four and eight characters were selected based on their valence and arousal ratings (Appendix A). As expected, the positive (M = 8.19, SD = 0.21) and negative (M = 1.82, SD = 0.22) words differed significantly in their mean valence, t (46) = -103.45, $p < .001$. In addition, the positive (M = 6.03, SD = 0.89) and negative (M = 6.07, SD = 0.84) words did not differ significantly in their rated arousal, t (46) = .179, p = .86.

Trials. Each trial consisted of a blank screen that appeared for 2000 ms followed by the word which was presented for 2000 ms. The word was presented in the center of the screen in size 18, bold, Courier New font. Participants were instructed to indicate, by pressing a key labeled with a red dot, when the current word matched the word from *n* steps earlier in the sequence (target trials). If the word did not match the word from *n* steps earlier in the sequence, participants were instructed to not respond (non-target trials).

Blocks. Trials were organized into blocks of 24 trials. At the beginning of each block, a message appeared indicating whether the following block would be a 1-, 2-, 3-, or 4-back. Three words were repeated within each block and consisted of either one positive and two negative words or one negative and two positive words. Half of the trials in each block were target trials.

Adaptive Design. The affective working memory training task was adaptive, meaning it became more or less difficult based on the performance of the participant. This type of task ensured that all participants had the ability to improve regardless of their initial ability (Dahlin, Bäckman, Neely, & Nyberg, 2009). Participants were not informed that the task was adaptive, but were informed that the number for *n* would change throughout the task. All participants started on a block with *n* equal to one. After the first block, the number for *n* was determined by the performance on the previous block. Participants advanced to the next level (*n+1*) when 95% or more of their responses were correct; this allowed for zero or one incorrect response. Participants moved to a new block on the same level (*n*) if between 75% and 95% of their responses on the previous block were correct; this allowed for two to five incorrect responses. Participants moved back to the previous level (*n-1*), if 75% or less of the responses were correct; this occurred if six or more mistakes were made. All participants completed a total of 19 blocks of 24 trials which resulted in a total of 456 trials.

Neutral Working Memory Training Task.

Task overview. The task, trials, blocks, and adaptive design of the neutral working memory training task were identical to the affective working memory training task described above, with the exception of the stimuli which were neutral words.

Stimuli. The stimuli presented in the neutral working memory training task were selected from the Affective Norms of English Words list (Bradley & Lang, 1999). Forty-eight neutral words between four and eight characters were selected based on their valence and arousal ratings (Appendix 1). Comparisons between the words used in the neutral working memory task and the words used in the affective working memory task were conducted to ensure that they differed in valence. As expected, the neutral (M = 5.24, SD = 0.16) and negative words differed significantly in their mean valence, $t(70) = 76.03$, $p < .001$. In addition, the neutral (M = 3.79, SD = 0.50) and negative words differed significantly in their rated arousal, $t(70) = -14.47$, $p < .001$. Also as expected, the neutral and positive words differed significantly in their mean valence, $t(70) = -66.83$, $p < .001$ as well as their mean arousal, $t(70) = -13.72$, $p < .001$.

Affective Control Task.

Task overview. The task was created and run with E-Prime 2.0 Software. The affective control task is a control version of the n-back task. It had low demand on the updating working memory component of executive control. In this version of the n-back, participants saw a series of words, presented one at a time, and indicated whether the current word was the same as a previously specified word. For example, participants were told that the target word was *merry*. They then had to decide whether the each word presented was *merry*.

Stimuli. The stimuli presented in the affective control task was the same as the words presented in the affective working memory training task.

Trials. Each trial consisted of a blank screen that appeared for 2000 ms followed by the word which was presented for 2000 ms. The word was presented in the center of the screen in size 18, bold, Courier New font. Participants were instructed to indicate, by pressing a key labeled with a red dot, when the current word matched the previously specified word (target trials). If the word did not match the previously specified word, participants were instructed to not respond (non-target trials).

Blocks. Trials were organized into blocks of 24 trials. At the beginning of each block, a message appeared indicating the target word. Three words were repeated within each block and consisted of either one positive and two negative words or one negative and two positive words. Half of the trials in each block were target trials.

Design. The affective control task was not adaptive. A different word was identified as the target word in each block.

Assessment of Effects of Working Memory Training: Flanker Task

Task overview. One of the tasks used to assess the effects of working memory training was the Flanker task, which is a measure of the inhibition component of executive control. This task was completed before and after the n-back task. The task was created and run with E-Prime 2.0 Software. In the Flanker task, participants had to determine whether a target word was positive or negative while ignoring three distractor words.

Stimuli. The words were selected from the Affective Norms of English Words list (Bradley & Lang, 1999). Words between four and eight characters were selected based on their valence and arousal ratings. Participants saw stimuli consisting of 25 positive, 25 negative, and 25 neutral words (Appendix A). As expected, the positive (M = 8.19, SD = 0.25) and negative (M = 1.83, SD = 0.22) words differed significantly in their mean valence, $t(48) = -96.46$, $p < .001$. Also as expected, the neutral (M = 5.24, SD = 0.20) and negative words differed significantly in their mean valence, $t(48) = 58.47$, $p < .001$, and the neutral and positive words differed significantly in their mean valence, $t(48) = -46.70$, $p < .001$. In addition, the positive (M = 6.09, SD = 1.18) and negative (M = 5.73, SD = 0.87) words did not differ significantly in their rated arousal, $t(48) = -1.22$, $p = .23$. The neutral (M = 4.25, SD = 0.76) and negative words differed significantly in their rated arousal, $t(48) = -6.36$, $p < .001$. The neutral and positive words also differed significantly in their mean arousal, $t(48) = -6.54$, $p < .001$.

Trials. Each trial began with a fixation cross, which participants were instructed to look at. This appeared on the screen for 1000ms. After the fixation cross, four words appeared on the screen. In each trial, three identical red distractor words and one green target word appeared in a two by two grid in the center of the screen. The target word sometimes appeared in the following four positions: top left, bottom left, top right, or bottom right. The valence of the target was positive or negative. The valence of the distractor words were positive, negative, or neutral. The participant was instructed to press a key labeled “P” if the target word was positive and a key labeled “N” if the word was negative (Figure 2.2). All participants completed 120 trials.

Measure of Inhibition. The purpose of the Flanker task was to assess how easily participants were able to inhibit the distracting words while responding to the target word. The reaction time for each trial was measured. Average reaction times for trials with positive targets and negative distractors were compared to average reaction times for trials with positive targets and neutral distractors. Similarly, average reaction times for trials with negative targets and positive distractors were compared to average reaction times for trials with negative targets and neutral distractors. These comparisons provided a measure of how well participants were able to inhibit the affective distractors.

Assessment of Effects of Working Memory Training: Switching Task

Task overview. The second task used to assess the effects of working memory training was the Switching task, which was a measure of the switching component of executive control. This task was also completed before and after the n-back task. The task was created and run with E-Prime 2.0 Software. In the Switching task, participants were asked to sort images according to two rules, and importantly, were required to flexibly switch between rules in order to quickly and accurately sort the pictures.

Stimuli. The Switching task included fourteen pictures in each of the following four different categories of images selected from the International Affective Picture System (IAPS; Lang & Bradley, 1999): negative pictures with no more than one person, positive pictures with no more than one person, negative pictures with two or more people, and positive pictures with two or more people.

The valence of the negative pictures with one or fewer people ($M = 2.59$, $SD = 0.66$) and negative pictures with two or more people ($M = 2.54$, $SD = 0.57$) did not significantly differ, $t(26) = .20$, $p = 0.85$. Also, the valence of the positive pictures with one or fewer people ($M = 7.66$, $SD = 0.40$) and positive pictures with two or more people ($M = 7.43$, $SD = 0.41$) did not significantly differ, $t(26) = 1.47$, $p = 0.15$. As expected, the valence of all positive pictures ($M = 7.55$, $SD = 0.41$) was significantly different from the valence of all negative pictures ($M = 2.57$, $SD = 0.61$), $t(54) = -35.93$, $p < 0.001$.

Trials. Each trial started with a blank screen presented for 250ms followed by a fixation cross which appeared for 250ms. An image was then presented at the center of the screen with either a grey or a white frame that indicated the sorting rule. One rule was to decide whether the picture was positive or negative. This rule was indicated by a white frame with a plus sign on the left and a minus sign on the right side of the frame. Participants were instructed to press a key labeled *L* when a positive picture was presented and a key labeled *R* when a negative picture was presented. The other rule was to decide whether the picture contained no more than one person or at least two people. This rule was indicated by a grey frame with *<=1* on the left and *>=2* on the right side of the frame. Participants were instructed to press a key labeled *L* when the picture contained no more than one person and a key labeled *R* when the picture contained at least two people (Figure 2.3). All participants completed 180 trials.

Measure of Switching. The purpose of the Switching task was to assess how easily participants were able to switch from sorting based on one rule to sorting based on the other rule. The reaction time for each trial was measured. Average reaction time for trials that were preceded by the same rule were compared to average reaction time for trials that were preceded by the other rule. This comparison provided a measure of how easily participants were able to shift to and from affective processing of information.

Assessment of Effects of Working Memory Training: Stress Induction

Stressor Task. A modified version of the Trier Social Stress Test was used to induce stress (Goeleven, De Raedt, Baert, & Koster, 2006; Kirschbaum, Pirke, & Hellhammber, 1993). The stressor consisted of two different tasks, a speech and an arithmetic task. Participants were told that both tasks measure aspects of their intelligence.

Participants first prepared a speech and were told that it would be evaluated according to flow, eloquence, and sophistication of word choice. They were also told that the speech would be videotaped so that the strength of the argument could be rated by other students. Participants were given three minutes to prepare and five minutes to complete the speech. They were told to build an argument supporting their position on the death penalty and to find scientific arguments rather than only emotional arguments. During the preparation time, the camera and the DVD recorder were positioned and turned on in sight of the participants. Participants were allowed to take notes while preparing for the speech, but were not able to use these notes during the speech. Participants were asked to stand in front of the camera while giving the speech. If participants stopped talking before five minutes was up, they were prompted to continue with the following phrases: “Can you please find some additional points?”, “You still have *X* minutes to fill.” and “Your performance will also be judged by whether you are able to fill up the entire five minutes.”.

The arithmetic task followed the speech task. Participants were told that the next task would be easier for them, as most UM students do well. While still facing the camera, they were asked to complete an arithmetic task in which they counted out loud backwards from 2083 to zero by increments of thirteen. If participants made a mistake, the experimenter said “Error, 2083” and participants had to start from the beginning.

Stress hormone levels. To assess the physiological response to the stressor, salivary cortisol samples were collected throughout the session. Two baseline samples were collected approximately 20 and 80 minutes after the start of the session. A sample measuring reactivity was collected 10minutes after the end of the stressor and three samples measuring recovery were collected 20, 30, and 40 minutes after the end of the stressor. Cortisol analysis was conducted at the lab of Clemens Kirschbaum in Dresden, Germany.

Affect ratings. To assess the emotional response to the stressor, participants’ affect was measured using eleven-point Likert-scales, ranging from not at all (0) to very much (10), at seven points throughout the session. Ratings for the following affective states were measured: amused, angry, anxious, depressed, happy, irritated, nervous, sad, tense, and upset.

Reappraisal and Rumination. Participants also filled out a questionnaire immediately following the stressor task assessing use of reappraisal and level of rumination during the stressor task. Rumination and reappraisal were each assessed with three items rated on a Likert-scale, ranging from strongly disagree (0) to strongly agree (6).

Self-Report Measures

Demographics Questionnaire. Data were collected on participants' gender, age, ethnic background, racial background, and marital status.

The Shipley Vocabulary Test (Shipley, 1940). The Shipley is a 40 item measure of crystallized intelligence. For each item, participants are instructed to decide which of four words are most similar to a prompted word. The Shipley correlates with other measures of crystallized intelligence (r = 0.66; Matthews, Orzech, & Lassiter, 2011). This measure was included to verify that mean intelligence scores did not differ between conditions.

Beck Depression Inventory, Second Edition (BDI-II; Beck, Steer, & Brown, 1996). The BDI-II is a 21-item self-report measure of depression symptoms. All responses range from 0 to 3 (e.g., I do not feel like a failure = 0, I feel I am a total failure as a person = 3). The BDI-II has demonstrated test-retest reliability (r = .91; Sprinkle et al., 2002) and high levels of internal consistency (α = .91; Dozois, Dobson, & Ahnberg, 1998) in an undergraduate sample.

Trait Scale of the State-Trait Anxiety Inventory (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The STAI is a 20 item self-report measure assessing stable personality tendencies toward anxiety on a Likert-scale ranging from almost never (1) to almost always (4). The STAI has demonstrated high levels of internal consistency (Rule & Traver, 1983).

Ruminative Responses Scale (RRS; Nolen-Hoeksema & Morrow, 1991; Treynor, Gonzalez, & Nolen-Hoeksema, 2003).The RRS assesses the tendency to respond to events with rumination and is divided into two subscales: brooding (RRS-B) and reflective pondering (RRS-R). The RRS-B contains five items (e.g., "Think what am I doing to deserve this?") and the RRS-R also contains five items (e.g., "Write down what you are thinking and analyze it") scored on a Likert-scale ranging from almost never (1) to almost always (4). The brooding subscale (α = .77) and the reflective pondering subscale (α = .72) has demonstrated good reliability (Treynor et al., 2003).

Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). The ERQ is a 10-item self-report measure assessing trait use of reappraisal and suppression. The ERQ is scored on a Likert-scale ranging from strongly disagree (1) to strongly agree (7). The reappraisal subscale (ERQ-R; α = .79) and the suppression subscale (ERQ-S; α = .73) has demonstrated good reliability (Melka, Lancaster, Bryant, & Rodriguez, 2011).

Cortisol Questionnaire. Participants completed a questionnaire asking about various factors (e.g., medication use, caffeine intake) that may affect cortisol levels. This questionnaire was used to exclude participants who may have been unable to provide meaningful cortisol samples.

Procedure

Participants signed up for the experiment using the online rEpr system and were asked to fill out a set of online questionnaires before arriving for their scheduled session time. Informed consent was obtained and participants were required to indicate that they read and understood the online consent form before beginning the questionnaires.

See Figure 2.4 for an overview of the study session. Upon arrival at the lab, informed consent was obtained from participants by a graduate student. Participants then completed the first of seven affect ratings on the computer. Next, participants completed the pre-training tasks: the Flanker task and then the Switching task. At the beginning of the Flanker task, participants saw a series of instruction screens that the experimenter read out loud (Appendix B). The experimenter made sure the participant understood the task before beginning the practice trials. Participants were then required to complete ten practice trials and were required to perform above 75% accuracy before moving on to the experiment trials. The length of the task was approximately seven minutes.

At the beginning of the Switching task, participants saw a series of instruction screens that the experimenter read out loud (Appendix B). The experimenter made sure the participant understood the task before beginning the practice trials. Participants were then required to complete eight practice trials and were required to perform above 75% accuracy to move on to the experiment trials. The length of the task was approximately nine minutes. After completing the pre-training tasks, a baseline cortisol sample was obtained while they completed the second affect rating.

Next, based on condition assignment, participants completed one training task. All participants saw a series of instruction screens that the experimenter read out loud (Appendix B). The experimenter made sure participants understood the task before beginning the practice trials. Participants were then required to complete four practice blocks containing a total of 19 practice trials which required 100% accuracy in order to move on to the experiment trials. The length of each task was approximately 35 minutes. The training task was followed by a third affect rating.

The post-training tasks were then completed, which were identical to those completed in pre-training. After both post-training tasks were completed, the stressor task began with an introduction the speech task. After the introduction to the speech task, participants completed a fourth affect rating. Participants used the next three minutes to prepare the speech, followed by five minutes of giving the speech. They then completed a fifth affect rating. Participants then completed the arithmetic portion of the stressor task. When this part of the stressor task was over, a sixth affect rating and the measure of reappraisal and rumination was completed while the second baseline cortisol sample was collected.

At this point, the experimenter told participants that they would be able to relax for the remaining 40 minutes of the session. Cortisol samples three through six were collected in 10 minute increments following the end of the stressor task. This allowed for a 40 minute recovery period, in which the participants watched a video about Australian parrots. After the final cortisol sample was collected, the cortisol questionnaire and a seventh affect rating was completed. Participants were then debriefed by the experimenter (Appendix B). Participants were asked if they had any questions about the study and whether they found any parts of the study odd or deceiving. This conversation took place to determine whether the participant may have been aware of the purpose of portions of the study session. Finally, participants were informed of why deception was necessary for the study. The participant was again given the opportunity to ask any questions and to contact the principal investigator.

Chapter 3: Data Analysis Plan and Data Preparation

Power analyses were conducted to determine the sample size for the proposed study. Results of the analyses indicated that a sample of 63 participants would yield an 80% chance of detecting effects, $d = .40$ when alpha is set to .05. Previous research has found effects of the same magnitude, $d = .40$ (Schweizer, Hampshire, & Dalgleish, 2011). A total of 63 participants would result in 21 participants in each condition, which is slightly more per condition than similar studies (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Schweizer et al., 2011). Therefore, it was anticipated that $N = 63$ would be large enough to detect the hypothesized effects of the proposed study. To examine each of the study hypotheses, the following analyses were proposed:

I. *Transfer of training to executive control processes.* It was expected that engaging in a working memory training task would alter performance on the Flanker and Switching tasks such that participants in the control condition would show improved performance; participants in the neutral working memory condition, compared to the control condition, would show greater improvement; participants in the affective working memory condition, compared to those in the neutral working memory or affective control conditions, would show greater improvement. To test this hypothesis, I examined performance on two measures of executive control (i.e., Flanker task and Switching task) as a function of training condition (affective working memory, neutral working memory, or control) and time (pre- and post- training) using 3 x 2 mixed-factorial ANOVAs. Results were expected to yield no main effect for condition, a significant main effect for time, and a significant condition x time interaction.

II. *Transfer of training to stress response.* It was expected that engaging in the working memory training task would alter responses to the laboratory stressor, such that participants in the neutral working memory condition, compared to participants in the control condition, would show lower levels of physiological reactivity and lower levels of self-reported negative affect; participants in the affective working memory condition, compared to participants in the neutral working memory condition and control condition, would show lower levels of physiological reactivity and lower levels of self-reported negative affect. To test the hypothesis regarding self-reported affect, 3 x 2 mixed-factorial ANOVAs were conducted, with condition as the between-subjects factor and time (affect ratings at baseline and post-speech task) as the within-subjects factor. It was expected that results would yield no main effect for condition, a significant main effect of time, and a significant condition x time interaction. Changes in physiological reactivity were examined using a 3 x 6 mixed-factorial ANOVA with condition as the between-subjects variable and time (cortisol samples 1 - 6) as the within-subjects variable. Results were expected to yield no main effect for condition, a significant main effect of time, and a significant condition x time interaction.

III. *Transfer of training to reappraisal and rumination.* It was predicted that completion of the working memory training task would affect participants' use of reappraisal and level of rumination during the laboratory stressor, such that participants in the neutral working memory condition, compared to participants in the control condition, would report higher levels of reappraisal and less rumination during the laboratory stressor, while participants in the affective working memory condition, compared to participants in the neutral working memory condition and control condition, would report higher levels of reappraisal and less rumination during the laboratory stressor. This hypothesis was examined by conducting one-way ANOVAs looking at group differences in the responses indicated on the Reappraisal and Rumination Questionnaire.

Data Preparation.

Switching Task. Switching task data was screened for participants performing worse than chance (accuracy < 50%). No participants performed worse than chance on the pre-training or post-training switching task. All participants were retained for analyses. To ensure that switch costs were computed only for accurate trials, reaction times for inaccurate trials were removed from further analyses. This led to 5.01% of the pre-training trials and 5.04% of the post training trials being removed from analyses. The data was also screened to identify outliers. Reaction times that were at least 2.5 standard deviations above or below the mean were replaced by the value 2.5 standard deviations above or below the mean. These values were computed separately for the pre-training and post-training tasks. This resulted in less than 3% of all trials being removed from analyses. This approach has been used previously for reaction time data from this task (Malooly, Genet, & Siemer, 2012).

Switch costs were computed for the pre- and post-training Switching task by subtracting the mean of the repetition trials from the mean of the switch trials. Change in the difference score from pre- to post- training was then screened for outliers. No participants were determined to be outliers and all participants were retained for analyses.

Flanker Task. Flanker task data was screened for participants performing worse than chance (accuracy < 50%). No participants performed worse than chance on the pre-training or post-training switching task. All participants were retained for analyses. To ensure that the flanker effect is computed only for accurate trials, reaction times for inaccurate trials were removed from further analyses. This led to 3.15% of the pre-training trials and 3.64% of the post training trials being removed from analyses. Finally, the data was screened to identify outliers. Reaction times that were below 300ms or above 2000ms were excluded from analyses. This resulted in less than 3% of all trials being removed from analyses. This approach has been used previously for reaction time data from this task (White, Brown, & Ratcliff, 2012).

A difference score for reaction times was computed for the pre- and post-training Flanker task by subtracting the mean of the control trials from the mean of the incompatible trials. Change in the difference score from pre- to post-training was then screened for outliers. One participant was determined to be an outlier and was removed from further analyses.

Measures of Stress Response. The levels of cortisol present in the participant's saliva samples were screened for outliers. One participant had cortisol levels above 60 nmol/L, with levels increasing at each time point following the stress induction. This participant indicated on the Cortisol Questionnaire that he did not sleep the night before the experiment. Since sleep deprivation has been shown to affect cortisol levels (Leproult, Copinschi, Buxton, & Van Cauter, 1997), this participant's cortisol data was not likely to be valid and was removed from further analyses.

Correlations between self-reported negative affect indicated that the individual items could be separated into two groups, one measuring fear and another measuring distress. Distress consisted of the following items: angry, depressed, irritated, sad, and upset; fear consisted of the following items: anxious, nervous, and tense. Chronbach's α was computed for each subscale. The distress subscale ($\alpha = .778$) and the fear subscale ($\alpha = .705$) were acceptable. The fear and distress subscales were used for analyses.

Measures of Reappraisal and Rumination. The questionnaire measuring use of reappraisal and levels of rumination during the stressor task consisted of three rumination items and three reappraisal items. To assess internal consistency, Cronbach's α was computed for each subscale. The rumination subscale (α = .776) and the reappraisal subscale (α = .630) were acceptable. The three items from each scale were then summed to form rumination and reappraisal subscales.

Chapter 4: Results

Group Characteristics

Demographic variables by condition are presented in Table 4.1. Participants in study conditions did not differ as a function of age, F (2, 67) = .97, p > .10, gender, X^2 (2, N = 70) = .10, p > .10, race/ethnicity X^2 (10, N = 70) = 12.66, p > .10, or marital status X^2 (4, N = 70) = 3.02, p > .10. Participants in study conditions did not differ in intelligence measured by the Shipley Vocabulary Test, F (2, 65) = 1.93, p > .10. Additionally, participants in study conditions did not differ in depression symptoms measured by the BDI-II, F (2, 66) = 1.42, p > .10 or anxiety measured by the STAI-T, F (2, 66) = 1.32, p > .10. Nor did participants in study conditions differ in trait emotion regulation measured by the RRS-B, F (2, 66) = .48, p > .10, RRS-R, F (2, 66) = .30, p > .10, ERQ-R, F (2, 66) = .79, p > .10, or ERQ-S, F (2, 66) = 1.45, p > .10. Participants in study conditions were also compared based on responses to the Cortisol Questionnaire to ensure that the groups did not differ in variables that may affect cortisol levels. Participants in study conditions did not differ in sleep duration, F (2, 65) = .784, p > .10, number of participants who drank caffeine the day of the session, X^2 (2, N = 68) = .13, p > .10, number of participants who smoked a cigarette the day of the session, X^2 (2, N = 64) = 1.99, p > .10, number of participants who take a daily medication, X^2 (2, N = 68) = .22, p > .10, or session time, X^2 (6, N = 68) = 1.28, p > .10. Cortisol Questionnaire variables by condition are presented in Table 4.2.

Preliminary Analyses

The Switching Task. To establish that switch costs were observed in the Switching task, a paired samples *t*-test comparing switch trial reaction times with repetition trial reaction times was conducted. On the pre-training Switching task, switch trial reaction times (M = 1539.17, SD = 334.80) were significantly greater than repetition trial reaction times (M = 1319.68, SD = 241.06), $t(69)$ =13.368, $p <$ .001. On the post-training Switching task, switch trial reaction times (M = 1167.10, SD = 247.03) were significantly greater than repetition trial reaction times (M = 1045.27, SD = 191.23), $t(69)$ =9.92, $p < .001$. This confirms the presence of switch costs at pre- and post-training. Descriptive statistics for Switching task reaction times per condition are presented in Table 4.3.

To ensure that the observed switch costs were not due to a speed accuracy trade off, a paired samples *t*-test comparing accuracy in switch and repetition trials was conducted. To indicate a speed-accuracy trade off was not present, the number of inaccurate switch trials would be greater than or equal to the number of inaccurate repetition trials. On the pre-training Switching task, the number of inaccurate switch trials (M = 4.82, SD = 4.42) was greater than the number of inaccurate repetition trials (M = 4.03, SD = 3.74), $t(67)$ =2.14, $p < .05$. On the post-training Switching task, repetition trial accuracy (M = 4.79, SD = 4.53) was not significantly different from switch trial accuracy (M = 4.28, SD = 4.25), $t(67)$ =1.25, $p > .05$. This indicates that the presence of switch costs at pre- and post-training is not due to a speed accuracy trade off.

The Flanker Task. To determine whether the flanker effect was observed in the Flanker task, a paired samples *t*-test comparing reaction times of trials with opposite-valenced distractors (incompatible trials) with reaction times of trials with neutral-valenced distractors (control trials) was conducted. On the pre-training Flanker task, incompatible trial reaction times (M = 855.57, SD = 123.19) were significantly greater than control trial reaction times (M = 842.17, SD = 128.62), $t(69) = 2.00$, $p = .05$. On the post-training Flanker task, incompatible trial reaction times (M = 821.64, SD = 116.42) were significantly greater than control trial reaction times (M = 804.76, SD = 115.05), $t(69) = 2.618$, $p < .05$. This confirms the presence of the flanker effect at pre- and post-training. Descriptive statistics for Flanker task reaction times per condition are presented in Table 4.4.

To ensure that the observed flanker effect was not due to a speed accuracy trade off, a paired samples *t*-test comparing inaccurate trials in incompatible and control trials was conducted. To indicate a speed-accuracy trade off was not present, the number of inaccurate incompatible trials would be equal to or greater than the number of inaccurate control trials. On the pre-training Flanker task, number of inaccurate incompatible trials (M = 1.47, SD = 1.67) was not significantly different from number of inaccurate control trials (M = 1.29, SD = 1.60), $t(69) = .869$, $p > .05$. On the post-training Flanker task, number of inaccurate incompatible trials (M = 1.83, SD = 2.40) was significantly greater than number of inaccurate control trials (M = 1.16, SD = 1.61), $t(69) = 3.16$, $p < .01$. This indicates that the presence of the flanker effect at pre- and post-training is not due to a speed accuracy trade off.

Manipulation check. Performance on the working memory training tasks was assessed to determine whether training on the tasks occurred. Because the tasks were adaptive and all participants started on a block of 1-back, it wasn't until the fourth block that block level indicated an individual's ability. As a result, the first 3 blocks of trials were eliminated from this analysis. The remaining 16 trials were divided into halves and performance on each block was measured by level of n-back (e.g., 1, 2, 3, or 4). Paired samples *t*-tests were conducted to determine whether performance in the second half was better than performance in the first half. For the affective working memory training task, level on the second half (M = 2.71, SD = 0.75) was significantly greater than level on the first half (M = 2.45, SD = 0.65), $t(23)$ =3.32, p < .01. For the neutral working memory training task, level on the second half (M = 2.79, SD = 0.769) was significantly greater than first half mean level (M = 2.589, SD = 0.679), $t(22)$ =2.289, p < .05. These analyses indicate that training on each task occurred (Figure 4.1).

Self-reported affect (Figure 4.2) and cortisol levels (Figure 4.3) were analyzed to determine whether the stressor task elicited a stress response from participants. Paired samples *t*-tests were conducted to determine whether there was a change in self-reported distress and fear from pre- to post-stressor task. Post-stressor distress (M = 1.61, SD = 1.51) was not significantly different from pre-stressor distress (M = 1.56, SD = 1.46), $t(68)$ =.308, p = .76. Post-stressor fear (M = 1.85, SD = 1.91) was significantly greater than pre-stressor fear (M = 1.42, SD = 1.59), $t(68)$ =1.91, p = .05. A paired samples *t*-test was conducted to determine whether there was a change in cortisol level from pre- to post-stressor task. Post-stressor cortisol (*M* = 11.02, *SD* = 8.17) was significantly higher than pre-stressor cortisol (*M* = 9.58, *SD* = 6.00), $t(68) = 3.14$, $p < .01$. These analyses indicate that the stressor task elicited a physiological stress response and self-reported increase in fear; however, the stressor task did not produce increases in self-reported distress.

Transfer of training to executive control processes.

Performance on the Flanker task was measured by an interference score, which was calculated by subtracting the mean of the control trials from the mean of the incompatible trials. An overall interference score, as well as interference scores for trials with positive and negative distractors were calculated. To test the hypothesis that engaging in an updating working memory training task would alter performance on the Flanker task, 3 x 2 mixed-factorial ANOVAs were conducted with condition (affective working memory, neutral working memory, or control) as the between subjects factor and time (pre- and post- training) as the within subject factor. Descriptive statistics for performance on the Flanker task per condition are presented in Table 4.5. Examination of overall interference scores yielded no main effect of condition, $F(2,65) = .28$, $p = .76$, time, $F(1,65) = .02$, $p = .90$, or time by condition interaction, $F(2,65) = .76$, $p = .47$. Examination of interference scores for trials with positive distractors yielded no main effect of condition, $F(2,65) = .60$, $p = .55$, time, $F(1,65) = .01$, $p = .91$, or time by condition interaction, $F(2,65) = .57$, $p = .57$. Examination of interference scores for trials with negative distractors yielded a trend for differences among conditions, $F(2,65) = 2.82$, $p = .07$. Examination of interference scores for trials with negative distractors yielded no main effect of time, $F(1,65) = .62$, $p = .43$ or time by condition interaction, $F(2,65) = .27$, $p = .77$ (Figure 4.4).

Performance on the Switching task was measured by switch costs, which were computed for the pre- and post-training Switching task by subtracting the mean of the repetition trials from the mean of the switch trials. To test the hypothesis that engaging in an updating working memory training task would alter performance on the Switching task, a 3 x 2 mixed-factorial ANOVA was conducted with condition (affective working memory, neutral working memory, or control) as the between subjects factor and time (pre- and post- training) as the within subject factor. Descriptive statistics for performance on the Switching task per condition are presented in Table 4.5. As expected, no main effect of condition was detected, $F(2,66) = .58$, $p = .56$. As expected, switch costs were significantly greater pre-training ($M = 219.22$, $SD = 138.37$) compared to post-training ($M = 123.05$, $SD = 102.97$), $F(1, 66) = 46.15$, $p < .001$. Contrary to study hypotheses, a time by condition interaction was not detected, $F(2,66) = .77$, $p = .47$(Figure 4.5).

Transfer of training to stress response.

To test the hypothesis that engaging in an updating working memory training task alters responses to the laboratory stressor task, 3 x 2 mixed-factorial ANOVAs were conducted, with condition as the between-subjects factor and time (affect ratings at pre- and post-speech task) as the within-subjects factor. Based on the correlations between affect ratings, ratings were split into two separate groups, distress and fear, and analyzed separately. Descriptive statistics for self-reported affect are presented in Table 4.6. Examination of distress ratings yielded no main effect of condition, F (2,66) = 1.30, p = .28. Contrary to study hypotheses, a main effect of time was not detected F(1,66) = .09, p = .76. Also contrary to study hypotheses, a time by condition interaction was not detected, F(2,66) = .59, p = .56 (Figure 4.6).

Examination of fear ratings yielded no main effect of condition, F(2,66) = .07, p = .93. As expected, a main effect of time was detected F(1,66) = 4.03, p < .05. Across all groups, participants reported higher levels of fear after the stressor (M = 1.85, SD = 1.91) compared to before the stressor (M = 1.42, SD = 1.59). Contrary to study hypotheses, a time by condition interaction was not detected, F(2,66) = 1.61, p = .21 (Figure 4.7).

To test the hypothesis that engaging in an updating working memory training task alters responses to the laboratory stressor task, a 3 x 6 mixed-factorial ANOVA was also conducted, with condition as the between-subjects factor and time (cortisol samples 1 - 6) as the within-subjects factor. Descriptive statistics for cortisol are presented in Table 4.7. As expected, no main effect of condition was detected, F(2,65) = .61, p = .55. Also as expected, a main effect of time was detected F(5,61) = 26.37, p < .001. A time by condition interaction was not detected, F(10,122) = 1.41, p = .19 (Figure 4.8).

To test the hypothesis that engaging in an updating working memory training task alters cortisol reactivity, a 3 x 2 mixed-factorial ANOVA was also conducted, with condition as the between-subjects factor and time (pre-stressor and post-stressor) as the within-subjects factor. As expected, no main effect of condition was detected, $F(2,66) = .776$, $p = .464$. Also as expected, a main effect of time was detected $F(1,66) = 10.16$, $p < .01$. Contrary to study hypotheses, a time by condition interaction was not detected, $F(2,66) = 1.99$, $p = .14$.

Transfer of training to reappraisal and rumination.

To test the hypothesis that completion of the working memory training task will affect participants' use of reappraisal and levels of rumination during the laboratory stressor, one-way ANOVAs investigating group differences in the responses indicated on the measure of reappraisal and rumination were conducted. Descriptive statistics for ratings of rumination and reappraisal are presented in Table 4.8. With regard to ratings of rumination, as expected, results indicated significant group differences, $F(2,66) = 4.22$, $p < .05$. As expected, participants in the neutral training condition ($M = 7.00$, $SD = 5.18$) reported significantly less rumination than participants in the control condition ($M = 11.48$, $SD = 5.57$), $t(44) = 2.82$, $p < .01$. However, participants in the affective training condition ($M = 9.00$, $SD = 4.94$) did not report significantly less rumination than participants in the neutral training condition, $t(44) = 1.25$, $p = .22$ or the control condition, $t(44) = 1.60$, $p = .12$ (Figure 4.9).

With regard to ratings of reappraisal, as expected, results indicated significant group differences, $F(2,66) = 3.68$, $p < .05$. The group differences, however, were not in the predicted direction. Participants in the control condition reported significantly more reappraisal ($M = 12.13$, $SD = 4.71$) than participants in the neutral training condition ($M = 9.39$, $SD = 3.68$), $t(44) = 2.20$, $p < .05$. Participants in the control condition also reported significantly more reappraisal than participants in the affective training condition (*M* = 8.83, *SD* = 4.78), *t*(44) = 2.36, *p* < .05. Participants in the affective and neutral training conditions did not differ in their reported use of reappraisal, *t*(44) = 0.67, *p* = .50 (Figure 4.9).

Exploratory effects of training.

Flanker task reaction times. Additional analyses were conducted to determine whether analysis of reaction times would yield results not seen with analyses of interference scores. Paired samples *t*-tests indicated that participants in the affective working memory condition had significantly faster reaction times from pre- to post- training for all trials, incompatible trials, and control trials (*p's* < .05). Paired samples *t*-tests indicated that participants in the neutral working memory condition did not have significantly faster reaction times from pre- to post- training for all trials, incompatible trials, or control trials (*p*'s > .10). Paired samples *t*-tests indicated that participants in the control condition had significantly faster reaction times from pre- to post- training for all trials and control trials (*p*'s < .05), but demonstrated only a trend for faster reaction times for incompatible trials (*p* = .07), Descriptive and test statistics are presented in Table 4.9.

Switching task reaction times. Additional analyses were conducted to determine whether analysis of reaction times would yield results not seen with analyses of switch costs. Paired samples *t*-tests indicated that participants in the affective working memory condition, neutral working memory condition, and control condition had significantly faster reaction times from pre- to post- training for all trials, switch trials, and repetition trials (*p's* < .001). Descriptive and test statistics are presented in Table 4.10.

Training effects for training responders. Additional analyses were conducted excluding participants who did not show improvement in performance on the training task. This resulted in exclusion of eight participants from the affective working memory condition and seven participants from the neutral working memory condition. To assess performance on the Switching task and performance on the Flanker task in this subset of participants, two 3 x 2 mixed-factorial ANOVAs were conducted with condition (affective working memory, neutral working memory, or control) as the between subjects factor and time (pre- and post- training) as the within subject factor. Results of these analyses were consistent with results including all participants, which demonstrated no significant time by condition interaction on performance on the Flanker task or performance on the Switching task. Test statistics are presented in Table 4.11.

Combining training groups. Because the two training conditions did not differ on cortisol levels and self-reported affect, additional analyses were conducted with the two training conditions collapsed into one training condition. An independent samples t-test indicated a trend for group differences in cortisol reactivity measured by change in cortisol levels from pre- to post- training, $t(66) = 1.67$, $p = .10$. Cortisol reactivity was greater for participants in the control condition ($M = 2.52$, $SD = 5.57$) compared to participants in the training condition ($M = .90$, $SD = 2.18$). Additionally, an independent samples t-test indicated a trend for group differences in change in self-reported fear from pre- to post-training, *t*(66) = 1.74, *p* = .09. Increase in fear was greater for participants in the control condition (*M* = .96, *SD* = 2.18) compared to participants in the training condition (*M* = .18, *SD* = 1.52). Test statistics are presented in Table 4.12.

Moderating role of rumination. A moderation analysis was then conducted to determine whether ruminative tendencies, measured by the RRS-B, moderated the relation between training and cortisol reactivity. Because the training groups did not differ in terms of cortisol reactivity, the training groups were again collapsed into one group for the following analyses. Regression analyses indicated that a model including training condition and rumination predicting cortisol reactivity was significantly improved by including the interaction between training condition and rumination, F_{change} (1,63) = 14.69, $p < .001$, $R^2 = .13$. Because the interaction between training condition and rumination was significant, post hoc probing was conducted to explore the interaction. For participants who scored one standard deviation below the mean on the RRS-B, training condition did not significantly predict cortisol reactivity, *B* = 1.45, *t* (63) = 1.36, *p* = .18. For participants who scored one standard deviation above the mean on the RRS-B, training condition significantly predicted cortisol reactivity, *B* = -4.14, *t* (63) = -3.97, $p < .001$ (Figure 4.10).

Exploratory correlations of relevant variables.

Psychopathology, emotion regulation and cortisol reactivity. Exploratory analyses were conducted to determine whether depression and anxiety symptoms, as well as trait emotion regulation were correlated with cortisol reactivity, measured by the change in cortisol level from pre- to post- stressor.

Across all conditions, cortisol reactivity was positively associated with BDI-II, STAI-T, RRS-B, RRS-R, and ERQ-S (*p*'s < .05). BDI-II, STAI-T, RRS-B, RRS-R, and ERQ-S were also positively correlated (*p*'s < .05). See Table 4.13 for correlations.

Rumination and reappraisal. Additional analyses were conducted to determine whether ratings of rumination and reappraisal during the stress induction were related to self-reported affect change during the stress induction. Across all conditions, rumination was correlated with increase in fear and distress (*p*'s < .01), whereas reappraisal was not significantly correlated with fear or distress (*p*'s > .10). See Table 4.14 for statistics. Additional analyses were also conducted to determine whether ratings of rumination and reappraisal during the stress induction were related to trait measures of rumination (RRS-B) and reappraisal (ERQ-R). Across all conditions, state rumination was correlated with trait rumination (*p* < .01), whereas state reappraisal was not significantly correlated with trait reappraisal (*p* > .10). See Table 4.15 for correlations.

Exploratory effects of relevant variables on cortisol.

Gender differences. To investigate whether there was a gender difference in cortisol reactivity a 2 x 3 x 2 mixed-factorial ANOVA was conducted with gender and condition as between subjects factors and cortisol sample (pre-stressor and post-stressor) as the within subject factor. The time by gender by group interaction was not significant, $F(2,62) = 1.16$, $p = .32$; however there was a trend for a time by gender interaction, $F(1,62) = 2.94$, $p = .09$. An independent samples *t*-test indicated a trend for greater increase in cortisol in males (*M* = 2.02, *SD* = 3.67) compared to females (*M* = .51, *SD* = 3.98), *t*(66) = 1.60, *p* = .12.

Session Time. An additional 4 x 3 x 2 mixed-factorial ANOVA was conducted with session time (9:00am, 12:00pm, 3:00pm, 6:00pm) and condition as the between subjects factors and cortisol sample (pre-stressor and post-stressor) as the within subject factor. There was a significant main effect of session time, *F*(3,56) = 4.837, *p* < .01. Independent samples *t*-tests indicated higher mean cortisol for participants with a 9:00 a.m. (*M* = 15.36, *SD* = 1.74) session time compared to participants with 12:00 p.m. (*M* = 10.38, *SD* = 1.33), 3:00 p.m. (*M* = 8.51, *SD* = 1.37) or 6:00 p.m. (*M* = 6.77, *SD* = 1.66) session times (*p*'s < .05). There was not, however, a significant session time by cortisol sample interaction, session time by condition interaction, or session time by condition by cortisol sample interaction (*p*'s > .10).

Chapter 5: Discussion

The aim of the current study was to examine whether a set of cognitive processes, known collectively as executive control, is a factor underlying individual differences in stress response. The current study employed a training design to determine whether engaging in an updating working memory training task leads to improved performance on other executive control tasks, decreased physiological and subjective responses to stress, decreased levels of rumination, and increased use of reappraisal.

Summary of Findings.

Performance on the working memory training tasks was assessed to determine whether participants in each condition improved on their trained task. Analyses indicate that training on each task occurred. Performance on tasks measuring switching (i.e., switch costs on the Switching task) and inhibition (i.e., interference scores on the Flanker task) were assessed before and after completing the training task to determine if transfer of working memory training occurred. A significant condition by time interaction was not observed for performance on the Switching task. This provides no support for the transfer of working memory training to a measure of switching.

Similarly, results of planned analyses demonstrate no significant condition by time interaction for performance on the Flanker task. However, additional analyses indicate that participants in the affective working memory condition had significantly faster reaction times on incompatible trials after training, compared to before training. This provides preliminary support for affective working memory training transferring to a measure of inhibition. Additionally, participants who were exposed to affective stimuli during the training period (i.e., participants in the affective working memory and control conditions) had faster reaction times on control trials after training, compared to before training.

Self-reported affect and salivary cortisol were assessed before and after the stress induction to determine whether working memory training had an effect on stress response. Results of planned analyses demonstrate no training condition by time interaction for self-reported affect. Similarly, no training condition by time interaction for cortisol was found. When participants in the affective working memory and neutral working memory conditions were combined and compared to participants in the control condition, a trend for greater increase in cortisol and self-reported fear from pre- to post- stressor in control participants emerged. Further, ruminative tendencies were found to moderate the relation between training and cortisol such that, for those with high ruminative tendencies, training led to lower cortisol reactivity. Taken together, these results provide preliminary support for the benefits of training transferring to stress response.

Following the stress induction, reported levels of rumination and use of reappraisal were assessed to determine whether working memory training impacted emotion regulation. Results of planned analyses demonstrate that participants in the affective working memory and neutral working memory conditions reported lower levels of rumination and less use of reappraisal during the stress induction compared to participants in the control condition. These results provide inconsistent support for the effect of training on emotion regulation during a stress induction.

The hypothesis that participants in the affective working memory condition would show the greatest improvement in executive control and that participants in both training conditions would show greater improvement in executive control than the control group was not supported by planned analyses. However, follow-up analyses examining reaction time data provided preliminary support for the transfer of affective working memory training to a measure of inhibition.

Planned analyses did not produce results supporting the hypothesis that, compared to participants in the control condition, participants in the affective and neutral working memory training conditions would demonstrate a dampened stress response, indicated by salivary cortisol and self-reported affect. Nor did results support the hypothesis that participants in the affective working memory condition would show the lowest levels of stress response. Additional analyses which combined training conditions, however, yielded preliminary support for the transfer of working memory training to stress response, indicated by salivary cortisol and self-reported fear.

The hypothesis that participants in the affective and neutral working memory training conditions, compared to participants in the control condition, would report less rumination during a stressor was supported; however, participants in the affective working memory condition did not report significantly less rumination than participants in the neutral working memory condition. Also contrary to study hypotheses, participants in each of the working memory training conditions, compared to participants in the control condition, reported less use of reappraisal during the stress induction.

Transfer of training to executive control.

Results of planned analyses did not provide support for the transfer of training to other measures of executive control. While contrary to study hypotheses, this finding is not surprising given that previous research on the ability of working memory training to produce improvements on other cognitive tasks has been mixed. Some research has supported the transfer of working memory training to untrained tasks (Dahlin, Bäckman, Neely, & Nyberg, 2009; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008), whereas other studies have found no evidence of transfer to untrained tasks (Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008; Owen et al., 2010).

A factor which may have contributed to the lack of transfer from training to other executive control tasks is that the design of the current study requires participants to complete the pre- and post- training tasks immediately before and after the training task. Previous research indicates that executive control is a limited capacity system, in which completion of tasks requiring executive control leads to decreased performance on subsequent executive control tasks (Schmeichel, 2007). The current study design required participants in each of the two training conditions to complete approximately one hour of executive control tasks; therefore, resource depletion may prevent training transfer to be observed in the training groups. Further evaluation of the data, however, does not support this explanation. Analysis of both training groups' performance on the n-back demonstrates improvement on the n-back from first half to second half, whereas a decline in performance would be expected if participants were fatigued. Thus, it appears unlikely that the null results are due to resource depletion.

Another aspect of our study that warrants discussion is that the sample included participants who did not show improved performance on the n-back. For these participants, it would be expected that no training occurred and therefore no transfer would be evident (Jaeggi, Buschkuehl, Jonides, & Shah, 2011). To investigate the possibility that such participants obscured any training effects, analyses were conducted including only participants who improved in their n-back performance. Performance on the Switching task and Flanker task was investigated using this subset of participants; however, findings were not different from results using the entire sample. Firm conclusions cannot be drawn since the smaller sample size resulted in reduced power; nonetheless, a preliminary investigation indicates that variable performance among participants on the training tasks did not impact the results.

While results of the planned analyses did not find that training transferred to performance on the Flanker task, measured by interference scores, and performance on the Switching task, measured by switch costs, additional analyses were conducted to determine whether training altered reaction times on each of these tasks. This approach was used in a study which determined that affective working memory training, but not neutral working memory training led to faster reaction times on a task with affective stimuli (Schweizer, Hampshire, & Dalgleish, 2011). The conclusion from this study was that affective working memory training led to improved processing of affective material; however, it is possible that exposure to affective stimuli is responsible for this effect. Consistent with these findings, the current study demonstrates that affective working memory training led to faster reaction times for control trials and incompatible trials of the Flanker task, whereas neutral working memory training did not lead to faster reaction times on either trial type. One of the critical ways the current study intended to extend previous research was by including a control group in order to determine whether such improvements in reaction time were due to training of executive control of affective material or exposure to affective material during the training task. In the current study, participants in the control group demonstrated faster reaction times on the post-training control trials, compared to the pre-training control trials. This indicates that exposure to affective material, independent of working memory training, was sufficient to produce improvement in reaction times. Interestingly, participants in the control group demonstrated only a trend for faster reaction times on the post-training incompatible trials, compared to the pre-training incompatible trials. Since incompatible trials require inhibition of incongruent affective material and only participants in the affective working memory training condition improved on these trials types, results suggest that affective working memory training may lead to improvements in executive control of affective material which cannot be attributed to exposure to affective material. Future research would need to replicate this finding to draw a firm conclusion.

Whereas preliminary support was found for the transfer of affective working memory training to a measure of inhibition, no support was found for this effect with neutral working memory training. An explanation for this finding may lie in the study design. Consistent with Schweizer et al. (2011), the pre- and post-training executive control tasks in the current study contained affective stimuli to assess training transfer to executive control of affective material. Because the current study did not include executive control tasks with neutral stimuli, we cannot say whether neutral working memory training was successful in training general executive control.

The current study also conducted reaction times analyses on the Switching task, by investigating reaction time improvements on switch trials and repetition trials; however, no support for transfer of working memory training to switching was found. Thus, the current study provides preliminary evidence that affective working memory training does not transfer to measures of switching, but does transfer to measures of inhibition. While the model of executive control advanced by Miyake et al. (2000) provided support for the hypothesis that working memory training would transfer to both switching and inhibition, our finding that working memory training may only transfer to inhibition is consistent with research demonstrating that updating working memory is more closely related to inhibition than it is to switching (Miyake & Friedman, 2012).

Transfer of training to stress response.

Initial results did not indicate that training transferred to stress response; however, additional analyses provided preliminary support for this hypothesis.

Consistent with previous research, which combined participants in neutral and affective working memory training groups (Schweizer et al., 2011), the current study combined participants from both training groups for additional analyses. This resulted in trends for greater cortisol reactivity and increase in fear from pre- to post- stress induction for participants in the control condition compared to participants in the combined training condition. While not conclusive, this provides preliminary evidence that training executive control may have an effect on stress reactivity. This is the first time that research has found such outcomes of executive control training and, therefore, follow-up research is needed to confirm these results.

Results of an exploratory analysis also indicates that working memory training leads to decreased cortisol reactivity, but only for participants with high ruminative tendencies. The finding that rumination moderates the relation between training and cortisol reactivity is consistent with the hypothesis that those who ruminate may benefit from interventions that improve executive control (De Lissnyder et al., 2012).

Transfer of training to reappraisal and rumination.

In line with study hypotheses, results indicated that executive control training led to less rumination during the stress induction, which is consistent with previous research demonstrating that rumination is associated with executive control (De Lissnyder et al., 2012). However, it was also found that executive control training led to less use of reappraisal during the stress induction. This unexpected finding highlights the distinction between attempted use of reappraisal and ability to successfully use reappraisal (Troy, Wilhelm, Shallcross, & Mauss, 2010). Correlations between use of reappraisal during the stressor and change in fear and distress were not significant, indicating that our measure of reappraisal did not measure ability to successfully use reappraisal. Previous research has found that reappraisal ability, but not frequency of reappraisal use, is associated with executive control (McRae, Jacobs, Ray, John, & Gross, 2012). Thus, it may be that our hypothesis was not supported because the measure of reappraisal did not measure ability to use reappraisal.

Another explanation for the unexpected finding that participants in the control condition reported using more reappraisal than participants in the training conditions may lie in the fact that the current study did not use a validated measure of rumination and reappraisal. Analyses indicate that while our measure of rumination was correlated with a validated measure of habitual rumination, our measure of reappraisal was not correlated with a validated measure of habitual reappraisal. This indicates that our findings regarding reappraisal during the stress induction may not be interpretable because the measure has poor construct validity.

General Discussion.

Results of the planned analyses did not support study hypotheses; however, closer evaluation of the data provided some support for each hypothesis. The data provide preliminary support for executive control as a process underlying individual differences in stress response and emotion regulation, as well as provide important considerations for future research.

Methodological limitations may explain why the planned analyses for each of the study hypotheses did not produce expected results. Limitations of the current study include the one-session training design. A one-session training has been shown to produce significant effects on intrusive thoughts (Bomyea & Amir, 2011) and emotional response to stress (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002); however, previous research also demonstrates a dose-dependent relation between training duration and transfer such that longer training duration leads to greater improvement in transfer tasks (Jaeggi et al., 2008). In line with this finding, many training paradigms employ a longer training period, ranging from 8 to 100 sessions (for a review, see Morrison & Chein, 2011). Thus, the duration of the current study's training period may have been too short to produce observable transfer effects. Future research should include at least several training sessions, which may be better suited to investigate the current study hypotheses.

Another limitation of the current study is that factors which may impact cortisol levels were not controlled for in the study design. Research indicates that men respond to stress inductions with greater increases in cortisol compared to women (for a review, see Kudielka & Kirschmbaum, 2005). A trend for greater cortisol reactivity in males compared to females was detected in the current study; however, there was not a significant interaction among cortisol reactivity, gender, and condition. Additionally, session time had a significant effect on cortisol levels with higher cortisol levels in the morning; however, session time did not significantly interact with cortisol reactivity or condition. The impact of time on cortisol in the current study is consistent with previous research (Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004) which demonstrates higher cortisol levels in the morning, but comparable cortisol response to a stressor in the morning and afternoon.

Together, these analyses indicate that although gender and session time did not interact with condition assignment, they increased the variability in the cortisol data which may have made it difficult to detect an effect of condition assignment on cortisol reactivity. A review of methodological considerations for measuring cortisol in response to stress recommends restricting collection time to the afternoon, in order to avoid introducing this variability (Kudielka, Hellhammer, & Wüst, 2009). Even though cortisol reactivity differs between men and women, it is recommended to include both genders in study samples and planned analyses should account for gender as a covariate in determining sample size (Kudielka et al., 2009). Thus, future studies investigating the effect of executive control training on stress response may benefit from restricting session times to one time point and including a sample large enough to account for gender differences.

Finally, as discussed previously, poor construct validity of our measure of reappraisal may have contributed to the lack of an observed training effect on reappraisal. Future studies should measure reappraisal ability and include a validated measure of reappraisal. Taken together, the methodological limitations of the current study provide important considerations for future research on the role of executive control in stress response.

Conclusions.

This study was successful in extending the research of executive control training in the two intended ways. First, the current study extended previous research by including a control group exposed to affective stimuli. Inclusion of the control group allowed the current study to provide preliminary support for the transfer of affective working memory training to a measure of inhibition. Second, and most importantly, the current study extended previous research by investigating the effect of working memory training on stress response. Results of these analyses provide preliminary evidence for executive control as a process underlying individual differences in stress response. Future studies should attempt to replicate these results in order to continue the advancement of our understanding of executive control and its role in stress response.

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Chapter 2 Figures

Figure 2.1. Sample of series of trials from the affective working memory task.

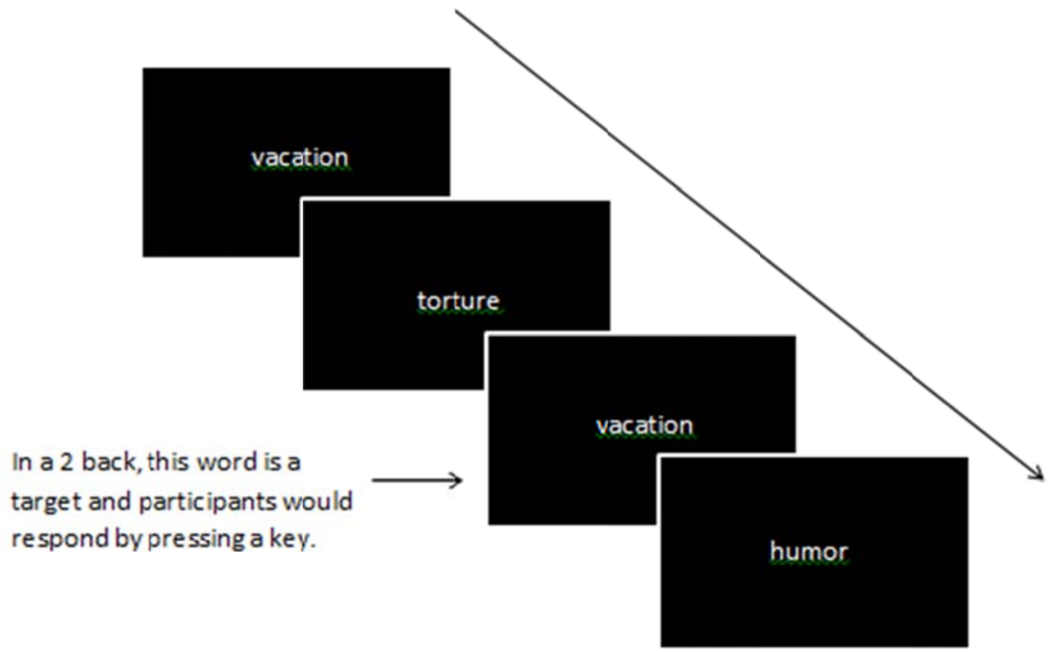


Figure 2.2. Sample trial from the Flanker task.

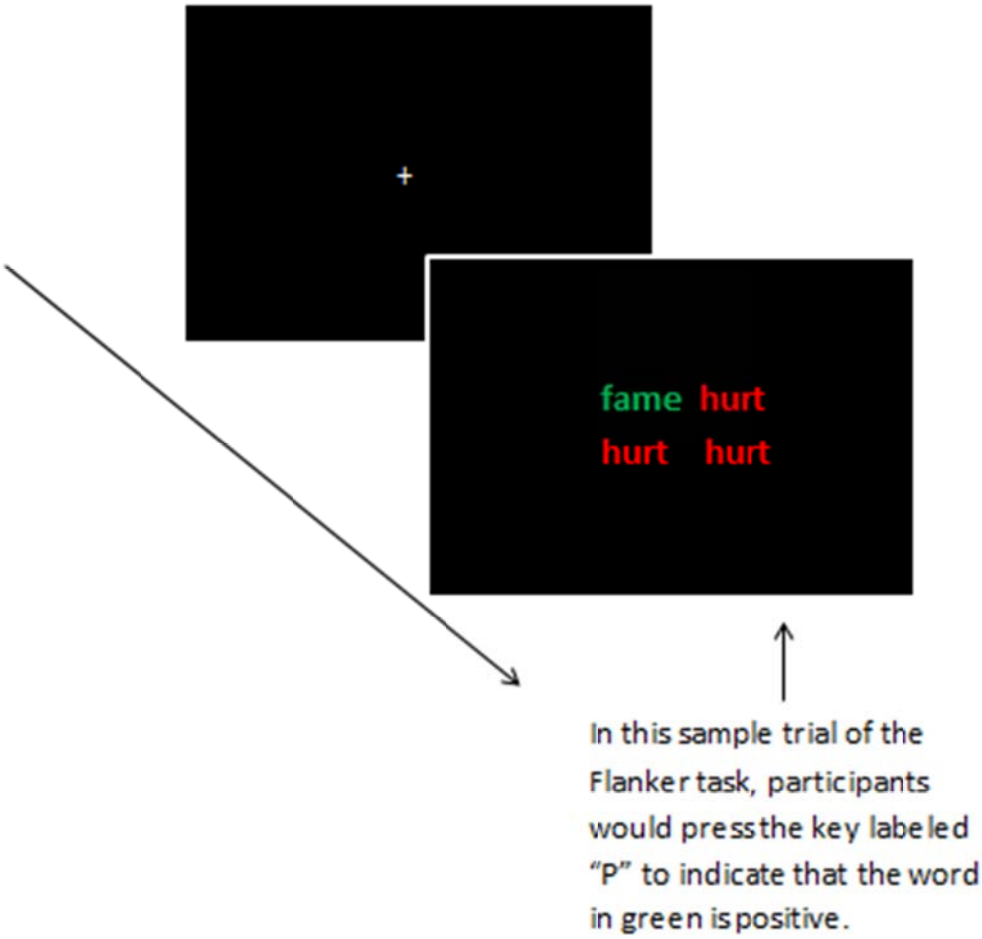


Figure 2.3. Sample trials from the Switching task.

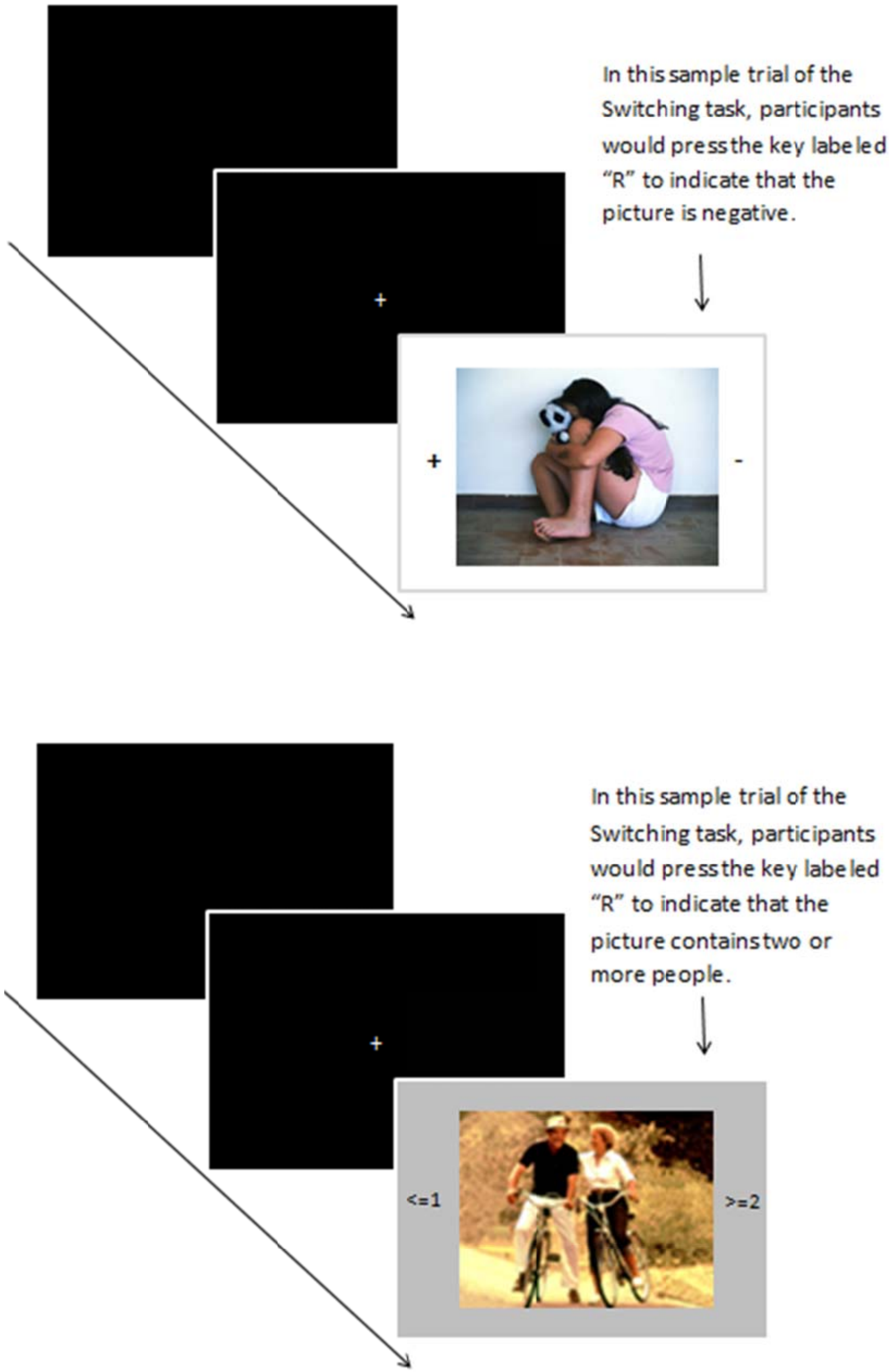
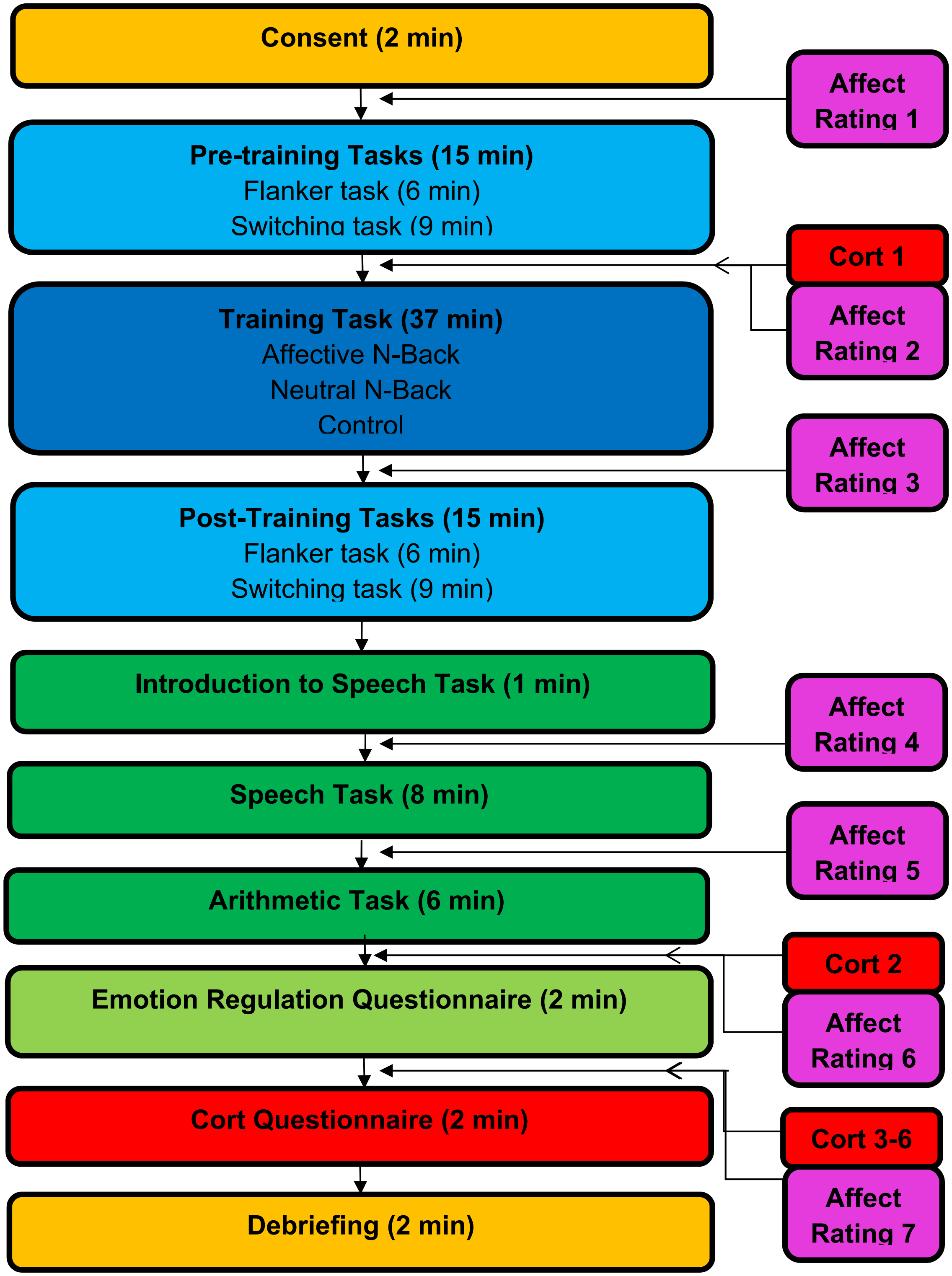


Figure 2.4. Overview of the study session.



Chapter 4 Tables and Figures

Table 4.1

Descriptive statistics, including means (standard deviations) and frequencies, for demographic variables and psychopathology symptoms as a function of training condition.

	Affective Working Memory	Neutral Working Memory	Control
Age	19.63 (1.74)	19.00 (1.35)	19.30 (1.49)
Gender			
Male	15	15	14
Female	9	8	9
Marital Status			
Single	23	22	22
Married	0	1	0
Domestic Partner	1	0	1
Race/Ethnicity			
White/Caucasian	12	11	17
Hispanic/Latino	6	8	3
Black/African American	3	0	2
Asian	2	2	0
American Indian/ Alaska Native	0	0	1
Other	1	2	0
Shipley	30.40 (3.33)	29.92 (4.28)	32.19 (4.54)

RRS-B	9.24 (3.63)	8.43 (2.43)	9.35 (4.10)
RRS-R	9.29 (3.29)	8.57 (3.42)	9.26(3.95)
ERQ-R	29.00 (6.69)	26.75 (7.59)	29.17 (7.15)
ERQ-S	16.09 (4.92)	13.43 (5.29)	15.57 (6.36)
BDI-II	10.68 (9.58)	6.41 (5.48)	8.30 (9.54)
STAI-T	42.94 (12.26)	42.18 (10.02)	37.84 (11.80)

Note. Shipley = Shipley Vocabulary Test; RRS-B = Brooding Subscale of the Ruminative Response Styles Questionnaire; RRS-R = Reflective Pondering Subscale of the Ruminative Response Styles Questionnaire; ERQ-R = Reappraisal Scale of the Emotion Regulation Questionnaire; ERQ-S = Suppression Scale of the Emotion Regulation Questionnaire; BDI-II = Beck Depression Inventory – Second Edition; STAI-T = Trait Scale of the State Trait Anxiety Inventory.

Table 4.2

Descriptive statistics, including means (standard deviations) and frequencies, for Cortisol Questionnaire variables as a function of training condition.

	Affective Working Memory	Neutral Working Memory	Control
Sleep Duration (hours)	7.17 (1.71)	6.54 (2.02)	6.59 (1.86)
Participants who had caffeine	5	6	5
Participants who smoked	2	1	0
Participants who take daily medications	5	4	5
Scheduled session time			
9:00am	3	5	5
12:00pm	7	7	7
3:00pm	6	7	7
6:00pm	6	4	4

Table 4.3

Descriptive statistics, including means (standard deviations), of Switching task reaction times as a function of condition.

	Affective Working Memory		Neutral Working Memory		Control	
	Pre-Training	Post-Training	Pre-Training	Post-Training	Pre-Training	Post-Training
Switch Trials	1458.64 (234.74)	1139.21 (177.10)	1617.06 (434.25)	1224.69 (296.53)	1538.68 (311.13)	1140.11 (261.26)
Repetition Trials	1263.66 (188.28)	1024.97 (138.35)	1385.59 (305.51)	1075.47 (233.83)	1312.59 (216.21)	1034.91 (200.60)

Note. Reaction times are listed in milliseconds (ms).

Table 4.4

Descriptive statistics, including means (standard deviations), of Flanker task reaction times as a function of condition.

	Affective Working Memory		Neutral Working Memory		Control	
	Pre-Training	Post-Training	Pre-Training	Post-Training	Pre-Training	Post-Training
Overall Incompatible	851.71 (100.27)	796.96 (70.81)	861.24 (139.47)	835.80 (136.73)	853.71 (135.31)	822.96 (124.93)
Overall Control	830.44 (108.81)	788.76 (75.43)	849.83 (142.35)	821.69 (135.28)	836.13 (131.56)	797.72 (129.70)
Positive Incompatible	859.37 (118.04)	807.21 (79.78)	857.61 (128.52)	852.23 (135.51)	852.34 (131.88)	821.31 (124.56)
Positive Control	820.77 (97.81)	801.10 (100.49)	833.09 (123.96)	813.49 (110.08)	851.58 (151.55)	804.60 (124.10)
Negative Incompatible	844.10 (94.88)	786.66 (78.52)	825.84 (121.66)	827.52 (135.99)	854.60 (152.74)	815.40 (137.30)
Negative Control	801.37 (90.90)	757.53 (67.90)	819.27 (125.55)	824.03 (126.80)	828.10 (142.81)	766.82 (109.69)

Note. Reaction times are listed in milliseconds (ms).

Table 4.5

Descriptive statistics, including means (standard deviations), of Flanker task interference scores and Switching task switch costs as a function of condition.

	Affective Working Memory	Neutral Working Memory	Control
Flanker Task			
Pre-Training			
Overall	21.27 (52.11)	11.41 (53.94)	17.58 (49.60)
Positive	20.04 (52.54)	24.69 (80.13)	0.60 (77.23)
Negative	42.72 (67.70)	9.77 (82.41)	33.45 (68.52)
Post-Training			
Overall	8.21 (57.29)	14.11 (53.58)	25.24 (34.44)
Positive	4.99 (70.22)	25.66 (73.01)	19.23 (54.39)
Negative	29.13 (78.20)	-8.94 (83.38)	36.27 (59.03)
Switching Task			
Pre-Training	200.08 (90.51)	231.47 (148.94)	226.09 (167.96)
Post-Training	114.73 (69.74)	149.21 (127.42)	105.20 (102.72)

Table 4.6

Descriptive statistics, including means (standard deviations) for self-reported affect as a function of condition.

	Affective Working Memory	Neutral Working Memory	Control
Pre-Stressor Rating			
Fear	1.65 (1.51)	1.55 (1.76)	1.06 (1.49)
Distress	1.95 (1.46)	1.47 (1.37)	1.25 (1.50)
Post-Stressor Rating			
Fear	1.75 (2.16)	1.77 (1.61)	2.02 (2.00)
Distress	1.93 (1.58)	1.34 (1.25)	1.55 (1.67)

Table 4.7

Descriptive statistics, including means (standard deviations) for cortisol as a function of condition.

	Affective Working Memory	Neutral Working Memory	Control
Cortisol Sample 1	14.06 (9.52)	14.33 (7.55)	18.37 (12.49)
Cortisol Sample 2	9.83 (5.08)	9.04 (6.02)	10.16 (6.92)
Cortisol Sample 3	11.33 (6.26)	9.34 (6.74)	12.67 (10.74)
Cortisol Sample 4	10.68 (5.60)	8.77 (6.98)	11.80 (10.70)
Cortisol Sample 5	9.92 (5.84)	8.30 (7.11)	9.77 (7.61)
Cortisol Sample 6	8.66 (5.46)	7.80 (7.47)	8.08 (5.84)

Note. Cortisol is listed in nmol/L.

Table 4.8

Descriptive statistics, including means (standard deviations) for self-reported rumination and reappraisal as a function of condition.

	Affective Working Memory	Neutral Working Memory	Control
Rumination	9.00 (4.94)	7.00 (5.18)	11.47 (5.57)
Reappraisal	8.83 (4.78)	9.39 (3.68)	12.13 (4.71)

Table 4.9

Descriptive and test statistics, including means (standard deviations), df, t, and p values for Flanker task reaction times.

	Reaction Time (ms)	Pre- to Post- Reaction Time Difference	*df*	*t*	*p*
Affective Working Memory					
All trials					
Pre-training	838.36 (101.26)	48.51 (84.89)	21	2.68	.014
Post-training	789.85 (71.23)				
Incompatible trials					
Pre-training	851.71 (100.27)	54.74 (92.33)	21	2.78	.011
Post-training	796.96 (70.81)				
Control trials					
Pre-training	830.44 (108.81)	41.68 (92.59)	21	2.11	.047
Post-training	788.76 (75.43)				
Neutral Working Memory					
All trials					
Pre-training	846.79 (137.56)	22.43 (100.52)	22	1.07	.296
Post-training	824.36 (127.68)				
Incompatible trials					
Pre-training	861.24 (139.47)	25.44 (123.22)	22	.99	.333
Post-training	835.8 (136.72)				
Control trials					
Pre-training	849.83 (142.35)	28.14 (91.13)	22	1.48	.153
Post-training	821.69 (135.27)				
Control					
All trials					
Pre-training	844.27 (133.88)	37.87 (66.08)	22	2.75	.012
Post-training	806.4 (123.04)				
Incompatible trials					
Pre-training	853.71 (135.31)	30.75 (78.04)	22	1.89	.072
Post-training	822.96 (124.93)				
Control trials					
Pre-training	836.13 (131.56)	38.41 (73.66)	22	2.50	.020
Post-training	797.72 (129.70)				

Table 4.10

Descriptive and test statistics, including means (standard deviations), df, t, and p values for Switching task reaction times.

	Reaction Time (ms)	Pre- to Post-Reaction Time Difference	*df*	*t*	*p*
Affective Working Memory					
All trials					
Pre-training	1362.41 (208.52)	280.24 (102.35)	21	12.84	.00
Post-training	1082.17 (154.47)				
Switch trials					
Pre-training	1458.64 (234.74)	319.44 (132.69)	21	11.29	.00
Post-training	1139.21 (177.10)				
Repetition trials					
Pre-training	1263.66 (188.28)	238.69 (87.76)	21	12.76	.00
Post-training	1024.97 (138.35)				
Neutral Working Memory					
All trials					
Pre-training	1500.19 (365.71)	350.77 (212.47)	22	7.92	.00
Post-training	1149.41 (257.12)				
Switch trials					
Pre-training	1617.16 (434.25)	392.37 (243.41)	22	7.73	.00
Post-training	1224.69 (296.53)				
Repetition trials					
Pre-training	1385.59 (305.51)	310.11 (196.99)	22	7.55	.00
Post-training	1075.47 (233.83)				
Control					
All trials					
Pre-training	1425.89 (255.86)	338.49 (114.40)	22	14.19	.00
Post-training	1087.4 (226.15)				
Switch trials					
Pre-training	1538.68 (311.13)	398.57 (136.04)	22	14.05	.00
Post-training	1140.11 (261.26)				
Repetition trials					
Pre-training	1312.59 (216.21)	277.68 (127.97)	22	10.41	.00
Post-training	1034.91 (200.60)				

Table 4.11

ANOVA summary table examining the effects of time (pre- and post- training) and training condition on performance on the Flanker task and Switching task, excluding participants who did not improve on the training task.

	df	*F*	*p*
Flanker task			
Condition	2,50	.53	.59
Time	1,50	1.80	.19
Condition x Time	2,50	1.65	.20
Switching task			
Condition	2,50	.46	.64
Time	1,50	32.35	<.001
Condition x Time	2,50	.77	.47

Table 4.12

Descriptive and test statistics, including means (standard deviations), df, t, and p values assessing differences between the control condition and combined training condition on salivary cortisol and self-reported affect change from pre- to post-stressor.

	Pre- to Post- Cortisol Change	***df***	***t***	***p***
Control Condition	2.52 (5.57)	66	1.67	.10
Combined Training Condition	.90 (2.44)			
	Pre- to Post- Fear Change	***df***	***t***	***p***
Control Condition	.96 (2.18)	66	1.74	.09
Combined Training Condition	.18 (1.52)			
	Pre- to Post- Distress Change	***df***	***t***	***p***
Control Condition	.30 (1.63)	66	.97	.34
Combined Training Condition	-.04 (1.20)			

Table 4.13

Correlations between measures of psychopathology symptoms, trait emotion regulation, and cortisol reactivity.

	Cortisol Reactivity	RRS-B	RRS-R	ERQ-S	ERQ-R	BDI-II
Cortisol Reactivity	--	--	--	--	--	--
RRS-B	.52***	--	--	--	--	--
RRS-R	.32**	.57***	--	--	--	--
ERQ-S	.37**	.29*	.20	--	--	--
ERQ-R	.09	-.09	.12	.29*	--	--
BDI-II	.27*	.67***	.43***	.36**	-.13	--
STAI-T	.24*	.62***	.34**	.28*	-.21	.74***

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. RRS-B = Brooding Subscale of the Ruminative Response Styles Questionnaire; RRS-R = Reflective Pondering Subscale of the Ruminative Response Styles Questionnaire; ERQ-R = Reappraisal Scale of the Emotion Regulation Questionnaire; ERQ-S = Suppression Scale of the Emotion Regulation Questionnaire; BDI-II = Beck Depression Inventory – Second Edition; STAI-T = Trait Scale of the State Trait Anxiety Inventory.

Table 4.14

Correlations of measures of affect change during the stress induction with rumination and reappraisal during the stress induction.

	Rumination During Stressor	Reappraisal During Stressor	Fear Change
Rumination During Stressor	--	--	--
Reappraisal During Stressor	.20	--	--
Fear Change	.31**	.03	--
Distress Change	.31**	-.12	.42***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.15

Correlations of measures of trait rumination and reappraisal with rumination and reappraisal during the stress induction.

	RRS-B	RRS-R	ERQ-R	Rumination During Stressor
RRS-B	--	--	--	--
RRS-R	.57***	--	--	--
ERQ-R	-.09	.12	--	--
Rumination During Stressor	.37**	.23	-.08	--
Reappraisal During Stressor	-.10	.09	.15	.20

* $p < .05$, ** $p < .01$, *** $p < .001$

Note. RRS-B = Brooding Subscale of the Ruminative Response Styles Questionnaire; RRS-R = Reflective Pondering Subscale of the Ruminative Response Styles Questionnaire; ERQ-R = Reappraisal Scale of the Emotion Regulation Questionnaire.

Figure 4.1. N-back performance across task blocks by training condition.

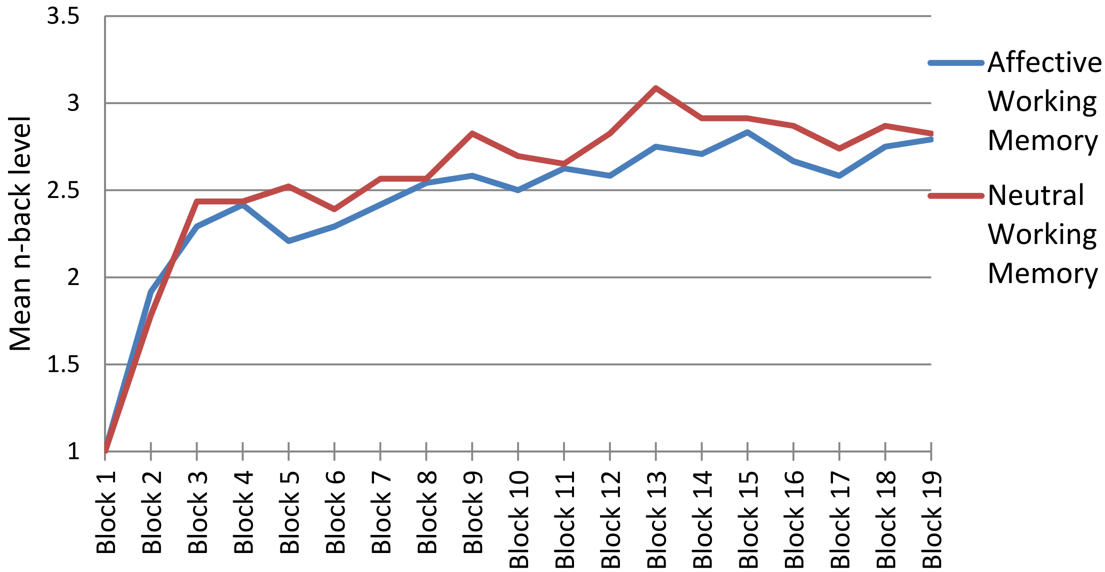


Figure 4.2. Change in self-reported affect from pre- to post- stressor for all participants.

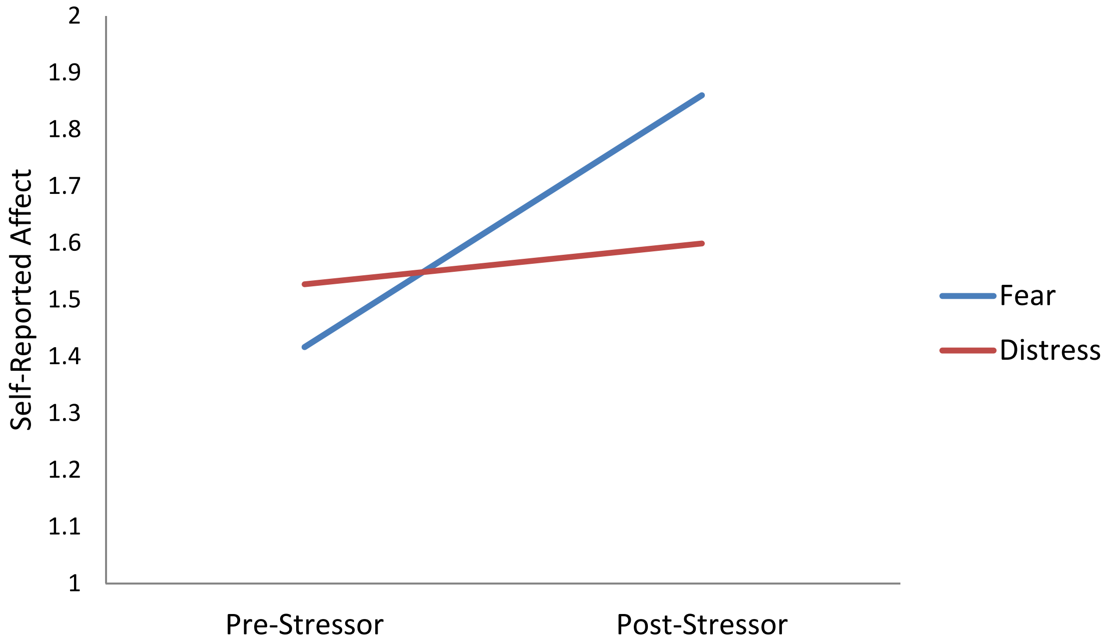


Figure 4.3. Change in salivary cortisol from pre- to post- stressor for all participants.

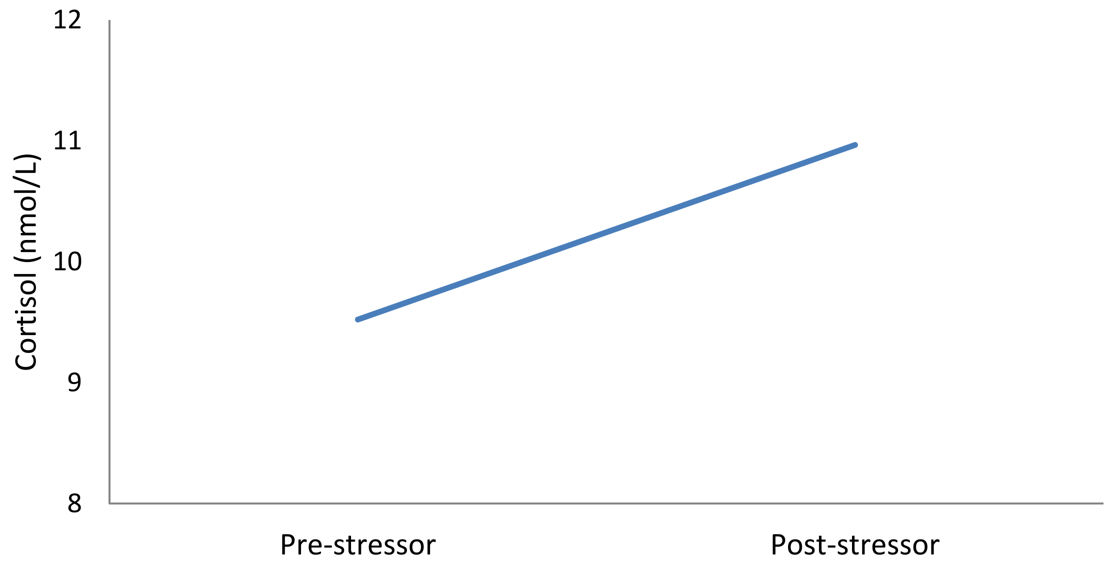


Figure 4.4. Interference scores on Flanker task by condition.

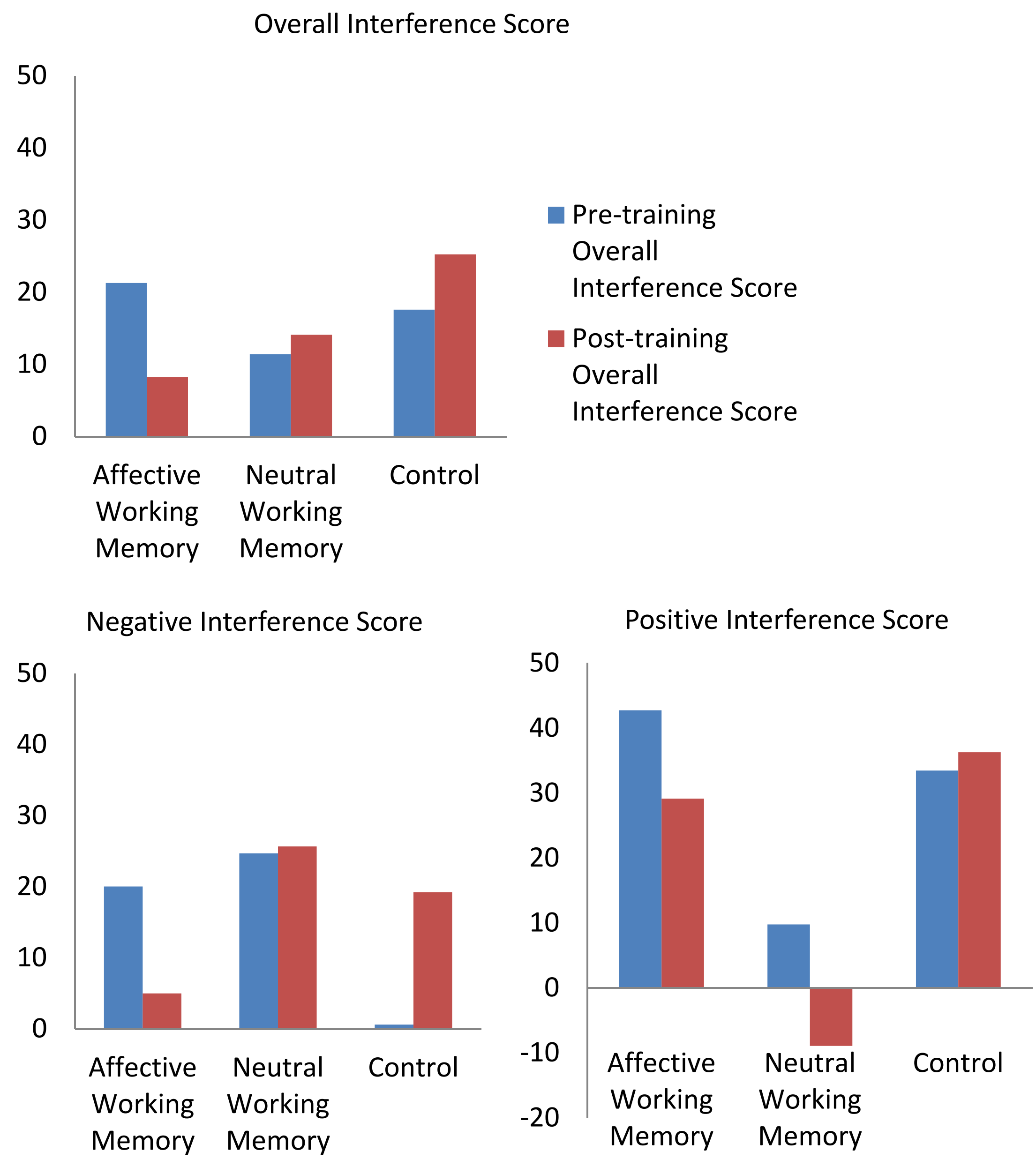


Figure 4.5. Switch costs on the Switching task by condition.

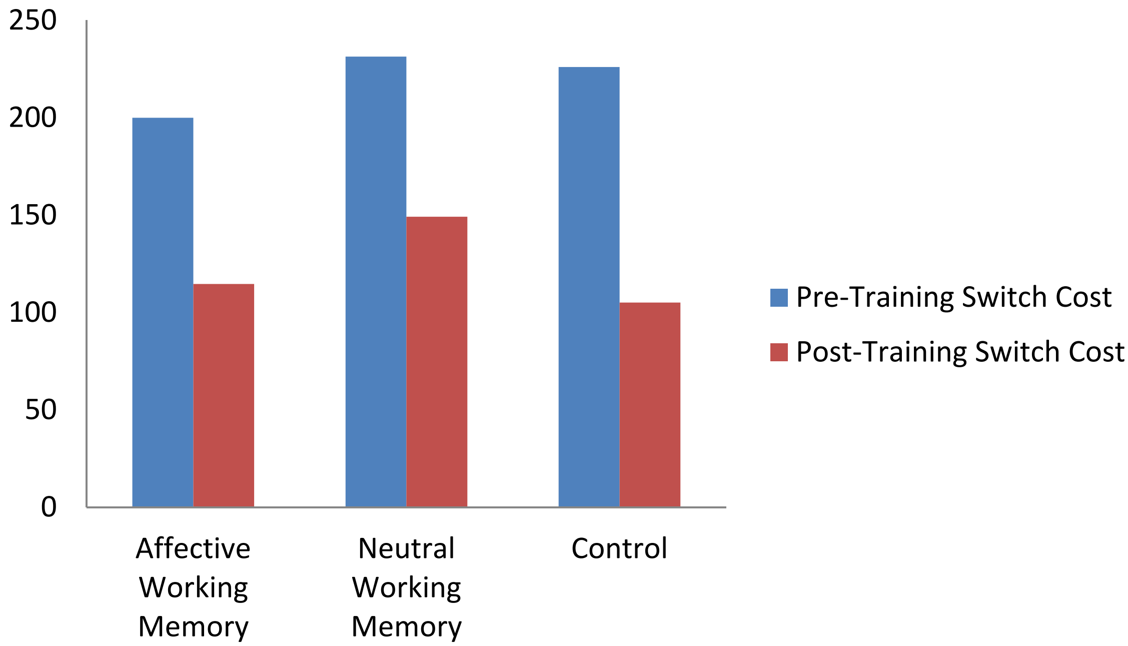


Figure 4.6. Change in distress from pre- to post- stressor by condition.

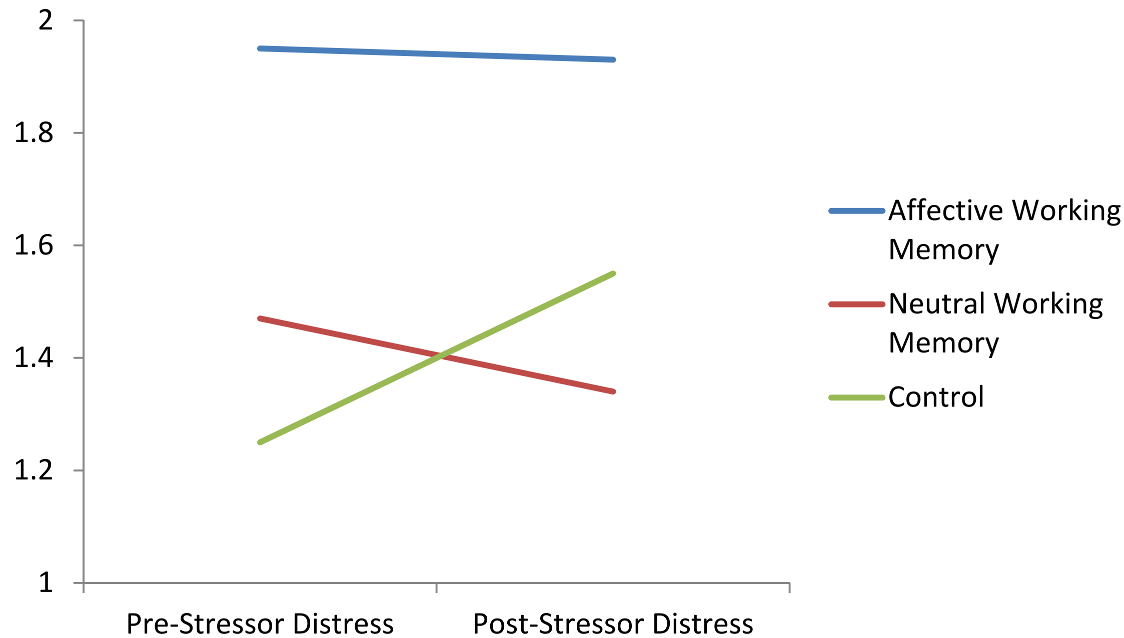


Figure 4.7. Change in fear from pre- to post- stressor by condition.

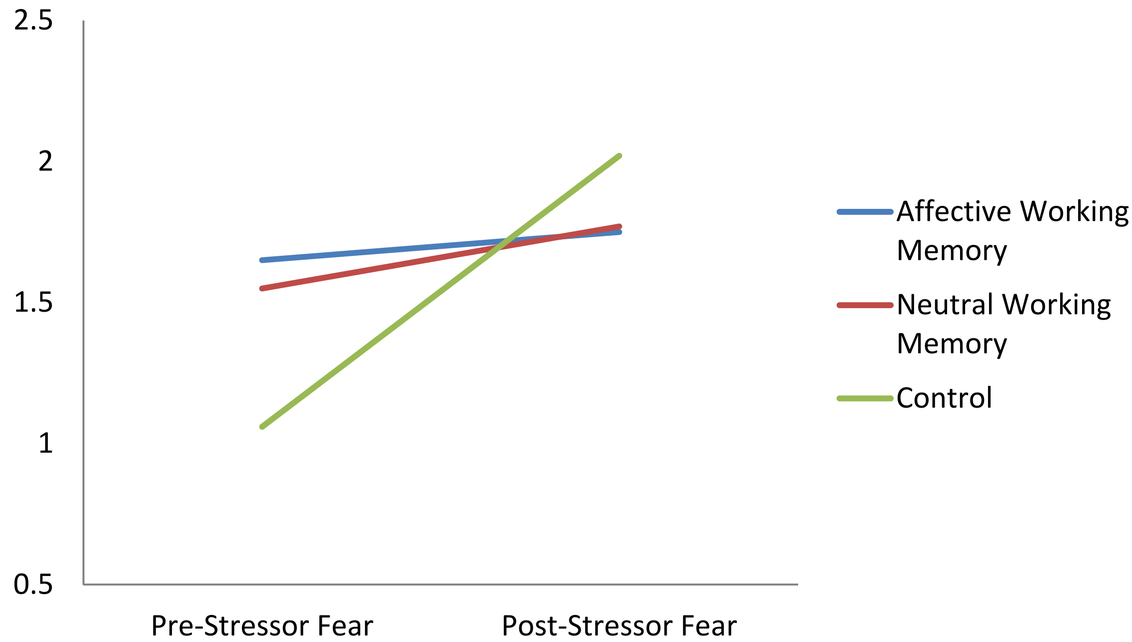


Figure 4.8. Change in salivary cortisol by condition.

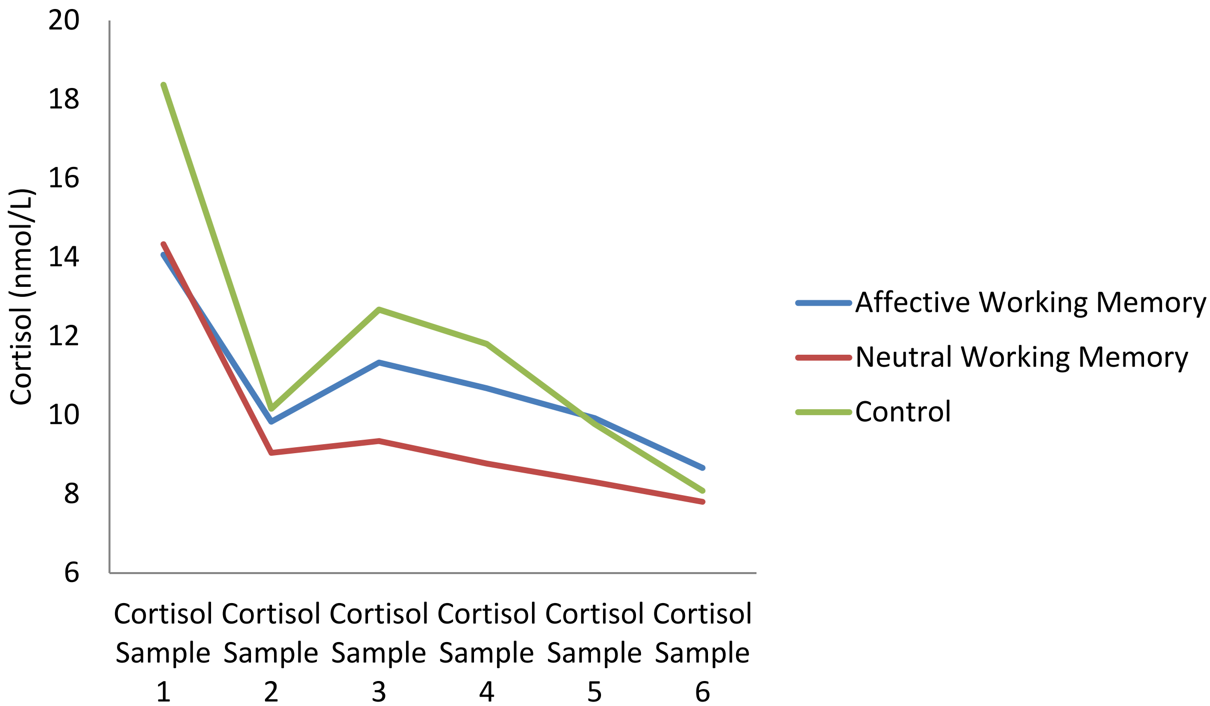


Figure 4.9. Levels of rumination and reappraisal during the stressor task by condition.

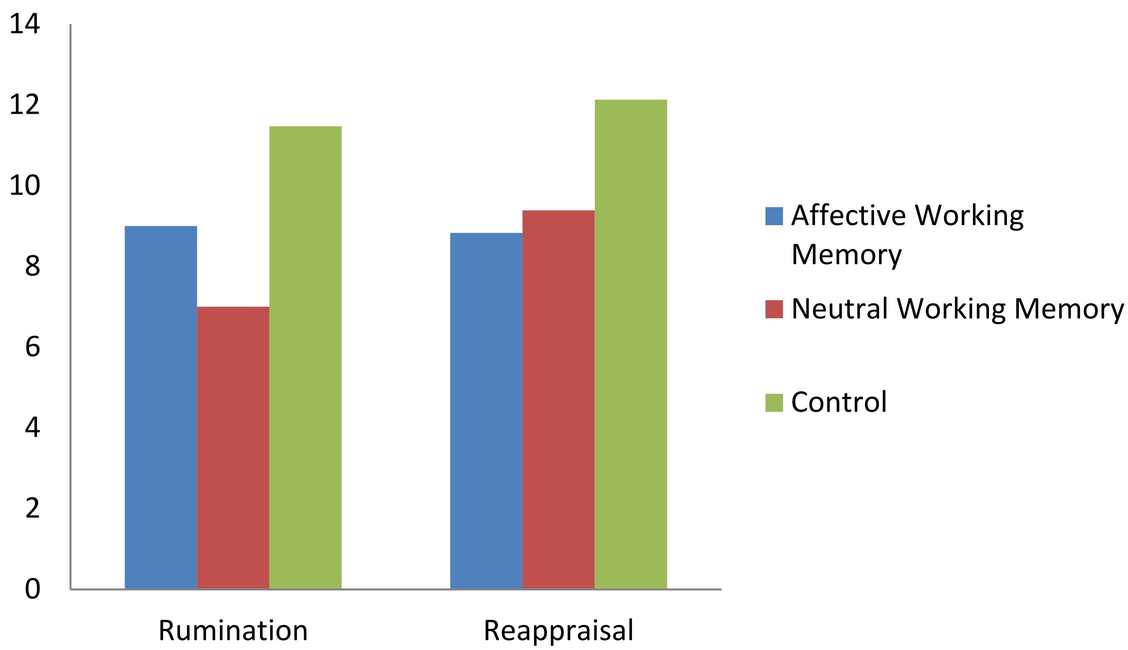
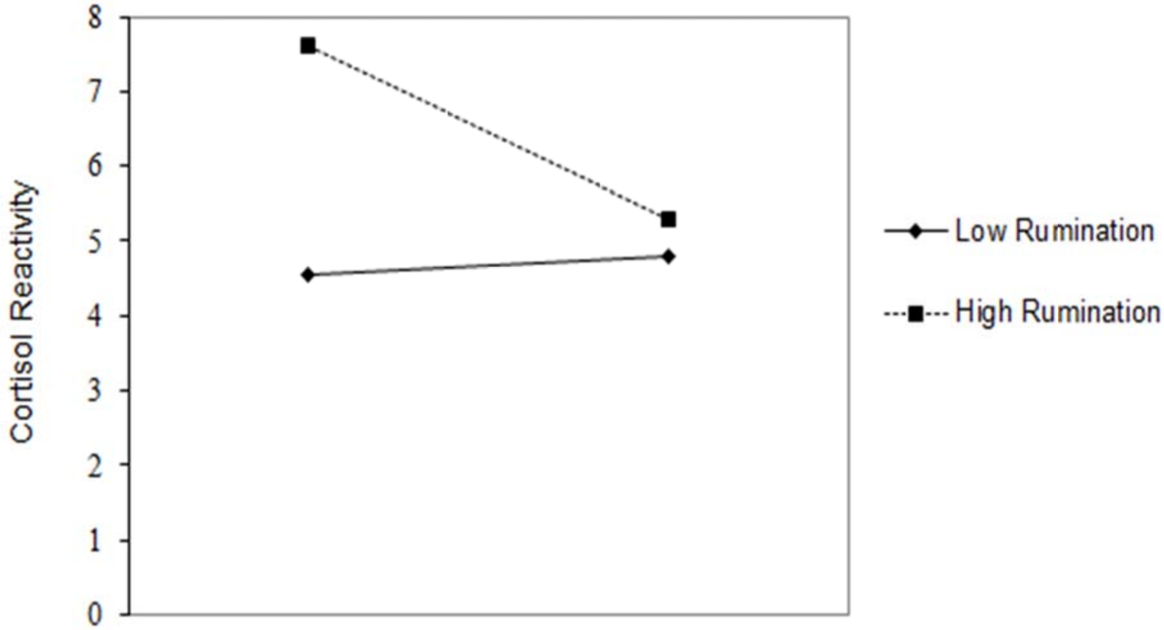


Figure 4.10. Trait rumination moderates the relation between training and cortisol reactivity.



Appendix A

Table 1

Stimuli selected for inclusion in the training tasks.

Neutral:	Neutral:	Negative:	Positive:
part	pencil	death	joke
door	street	drown	baby
tool	finger	abuse	kiss
cork	theory	slave	love
lawn	butter	ulcer	merry
item	poster	rabies	music
clock	violin	betray	happy
month	basket	hatred	humor
phase	hydrant	afraid	joyful
paper	cabinet	burial	luxury
table	machine	prison	snuggle
wagon	journal	maggot	aroused
spray	utensil	suicide	diploma
tower	context	torture	engaged
boxer	hairpin	assault	passion
quiet	passage	failure	rainbow
mantel	glacier	unhappy	delight
icebox	kerchief	pollute	success
rattle	umbrella	leprosy	terrific
barrel	material	murderer	vacation
column	building	terrible	treasure
statue	elevator	bankrupt	romantic
locker	activate	syphilis	friendly
engine	windmill	accident	laughter

Table 2
Stimuli selected for inclusion in the Flanker task.

Neutral:	Negative:	Positive:
reserved	rejected	handsome
contents	disaster	graduate
hospital	mutilate	pleasure
busybody	disloyal	champion
industry	headache	paradise
serious	funeral	diamond
history	poverty	sunrise
patient	tragedy	liberty
lantern	despise	victory
ketchup	seasick	miracle
fabric	cancer	pillow
sphere	killer	thrill
banner	morgue	orgasm
writer	misery	comedy
museum	poison	mother
noisy	grief	beach
chair	gloom	proud
ennui	cruel	cheer
trunk	upset	lucky
elbow	vomit	loved
hard	rape	home
vest	hurt	fame
chin	sick	sexy
fork	dead	free
news	jail	cash

Appendix B

Instructions for Flanker task.

In this task your job will be to decide if a certain word is a positive or a negative word. You will see four words on the screen, one green word and three red words. Your task is to decide if the green word is a positive or a negative word.

If the green word is a positive word, press the button marked >P<. If the green word is a negative word, press the button marked >N<. Please place your right index and middle finger on the keys marked >P< and >N<. Rest your fingers on these keys throughout the experiment.

Both, speed and accuracy are important. So, make sure you decide and respond as quickly and as accurately as possible. Please remember, you should only respond to the green word and ignore the red word. If you are unsure of the answer, guess!

Before each set of words you will see a cross in the middle of the screen. You should look at the cross after each trial. This is because the target word may appear anywhere on the screen, so looking at the center will help you respond more quickly.

Do you have any questions? If any of the instructions are unclear, please contact the experimenter now! We will start with a couple of practice trials. Please, press the space bar when you are ready to begin.

Remember: Only respond to the green word!
>P< positive word
>N< negative word
There won't be any feedback for the test trials. When you are ready to begin the test trials, please press the space bar!

Instructions for Switching task.

This task examines how people process images they see. Your job is to rapidly and accurately sort images that will appear in the center of the screen. The images will each be displayed several times, across many trials.

Each trial will start with a "fixation cross." Look directly at it. Then a picture will appear, with a frame that tells you what rule to use for sorting the picture. There will be 2 rules.

One rule is to decide whether the picture is happy or sad. If a white frame appears with the symbols "+" and "-" on the sides, then press the "L" key if the picture is happy and the "R" key if the picture is sad.

The other rule is to decide whether the picture has no more than one person in it, or whether it has two or more people in it. If a grey frame appears with the symbols "1<" and "2>" on the sides, then press the "L" key if there is one person or no one, and the "R" key if there are two or more people.

At this time, place your right-hand pointer finger on the key labeled "L" for left. Place your right-hand middle finger on the key labeled "R" for right.

Let's practice. You will soon see a fixation cross in the center of the screen, followed by a picture. If the frame around the picture is white with the symbols "+" and "-" then press the "L" key if the picture is happy and press the "R" key if the picture is sad. Remember to work quickly but try to be as accurate as possible.

Here is another practice set. As before, you will see a fixation cross in the center, followed by a picture. If the frame around the picture is gray with the symbols "1>" and "2<" then press the "L" key if there is no more than one person in the picture and press the "R" key if there are two or more people in the picture. Remember to work quickly but try to be as accurate as possible.

Now you are ready to get started. Like before, you will see a fixation cross in the center of the screen, followed by a picture. If the frame around the picture is white, with the symbols "+" and "-" then press the "L" key if the picture is happy and press the "R" key if the picture is sad.
If the frame around the picture is gray, with the symbols "1>" and "2<" then press the "L" key if the picture has no more than one person and press the "R" key if the picture has two or more people. Remember to work quickly but try to be as accurate as possible.

Instructions for affective and neutral working memory task.

In this task, you will be asked to accurately monitor and respond to a series of words that will be presented one at a time.

Your job is to respond when you see a word that matches a word presented earlier in the sequence. Sometimes you will have to respond when the word matches the word from 1 time earlier in the sequence. Other times you will have to respond when the word you see matches the word from 2, 3, or 4 times previously. When this happens, you should respond by pressing the key with the red dot.

Next, you will do practice sets of 1-back, 2-back, 3-back, and 4-back. After that, you may move on to the rest of the task. Remember, during the task, you will sometimes do sets of 1-back, 2-back, 3-back, or 4-back, but you will always be told which type you are doing at the beginning of each set. The duration of the task will be about 35 minutes. Let me know if you have any questions.

Example of instructions before each section: The following section will be a 1-back. Remember to press the red dot when the word you see matches the word from 1 word back.

Instructions for affective control task.

In this task, you will be asked to accurately monitor and respond to a series of words that will be presented one at a time.

Your job is to respond when you see a certain word. We will show you which word you should respond to. When this word appears, you should respond by pressing the key with the red dot. After a certain number of trials, we will tell you to start responding to a new word. Next, you will do a couple of practice sets. After that, you may move on to the rest of the task.

The duration of the task will be about 35 minutes. Do you have any questions?

Example of instructions before the start of each section:
For the next set of trials, respond when you see the word:
torture
Remember to press the red dot when the word appears.

Stress task script.

“The following tasks measure different aspects of your intelligence. The first task will be a speech, which I will evaluate according to flow, eloquence, and sophistication of word choice. In addition, we will videotape the speech so that a panel of your peers can rate the strength of your argument. I will provide the topic for your speech, and the details about the other tests in a moment. But first, I need you to complete another set of questions on the computer.”

“You will be given 3 minutes to prepare, and then 5 minutes to complete your speech. During this time, you should build an argument supporting your position on the death penalty. Rather than providing an emotional argument or opinion, you should provide a scientific argument supporting your position. You can use this piece of paper to take notes while you prepare; however, you will NOT be allowed to use your notes when you give your speech. Your time starts now.”

“Your time limit is up. I need to collect your paper. Please stand up and face the camera. You have five minutes to make your argument. I’ll let you know when the time is up or if you have failed to fill up the entire 5 minutes. Start now.”

“Your time limit is up.”

Debriefing Script.

You have now completed the session. Do you have any questions? If so, write down questions on session form. Tell the participant you will give them more information in a moment. *Was the experiment entirely clear?* If not, write down comments on the session form. *Did all aspects of the procedure make sense?* If not, write down comments on the session form. *Everyone reacts to things in different ways and it would be helpful to hear about your feelings about and reactions to the experiment. Did you find any aspect of the procedure odd, confusing, or disturbing?* If so, write down comments on the session form. *Do you think there may have been more to the experiment than meets the eye?* If so, have the participant elaborate and write down comments on the session form.

We all get anxious or nervous in stressful situations, and we experience some physiological changes (such as faster heart beat) as a result of it. However, some people may be particularly prone to feeling anxiety or other negative emotions in response to stress. This study was interested in examining how cognitive processes such as working memory can contribute to such emotional reactions. Given this goal, there were some aspects of the study that we could not discuss with you in advance For example, we had to create a minor stressful situation without your knowledge. To do this, we told you that your speech would be presented to a panel of undergraduate and graduate students and faculty so they can evaluate the quality of your speech; however, we will not be presenting the recording to anyone. The task was necessary to create some anxiety. Similarly, the arithmetic task that asked you to count backwards in 13-step increments was also designed to produce some anxiety. This is an incredibly difficult task that is designed for people to have difficulty with.

If we could have told you about how you were actually performing on these tasks, we would have. However, as I explained earlier, it is critical that we put you in these situations in order to produce minor anxiety. This was important to our ability to see differences in people's reactions to it. We regret that we had to present this false and stressful information to you, but this really was our only option to be able to interpret our results. We realize that this might induce feelings of frustration but we hope that our explanation clears up any negative feelings you might have. We really appreciate your participation in this study.

How are you feeling right now that you learned more about our study? Write down comments on the session form. If they are ok: *Your participation really helps us understand stress responses better, and we are really thankful that you* *participated. In order for this study to work successfully, it is extremely important that you not mention the details of it to anyone that you know.*

If they are upset of have questions: Discuss further and offer relaxation tapes if participants seem anxious or nervous. If the participants have any questions or comments, please ask them to contact Jutta Joormann at jjoormann@psy.miami.edu, or (350) 284-2641.