The Impact of Attention Bias Modification Training and Attentional Control on the Salivary Cortisol and Alpha Amylase Response to Acute Psychosocial Stress

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ABSTRACT

The Impact of Attention Bias Modification Training and Attentional Control on the Salivary Cortisol and Alpha Amylase Response to Acute Psychosocial Stress

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Attention bias modification (ABM) training has demonstrated potential in decreasing symptoms of anxiety, particularly in clinical populations. However, there is a paucity of research examining the impact of this training on physiological adaptation to stress, important for health. The objective of this dissertation was to examine whether ABM training can attenuate the salivary cortisol and alpha amylase (sAA) response to an acute psychosocial stressor. In study 1, university students were randomly assigned to one of three conditions: ABM training with supraliminal stimuli, ABM training with masked stimuli, or a control task with no ABM training. The ABM training was a spatial cueing task where participants were implicitly trained to shift attention towards happy faces and away from angry ones. Following the training intervention, participants underwent the Trier Social Stress Test (TSST). Unexpectedly, the two ABM training interventions were associated with higher rather than lower salivary cortisol and sAA responses to stress post-intervention. Moderation analyses indicated that participants with high baseline attentional control exhibited elevated cortisol responses to stress following both ABM trainings, relative to those with low attentional control.

Study 2 aimed to determine whether the heightened stress response to the ABM training could be attributed to the type of ABM paradigm used (spatial cueing) and/or the type of control task used. The spatial cueing ABM training with supraliminal stimuli employed in study 1 was compared to the more frequently used dot probe training, which fosters change by training participants to allocate attention to positive relative to negative stimuli when they are presented simultaneously. Participants also underwent a second TSST approximately two months post-training. Consistent with study 1, spatial cueing ABM training led to elevated cortisol levels during the first TSST relative to a no training control condition. Both ABM interventions however, reduced cortisol reactivity at the follow-up TSST relative to the first one. Importantly, those in the active training groups with lower baseline attentional control showed greater cortisol attenuation during the follow-up TSST compared to those with higher attentional control. Overall, this work suggests that the use of ABM interventions to reduce stress reactivity should be pursued with caution.

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Study 1:

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Relative contribution:

Kamala Pilgrim conducted the literature review, tested the majority of participants, undertook the statistical analyses, interpreted the results, and wrote the manuscript.

Kamala Pilgrim and Mark Ellenbogen developed the research question and study protocol. Mark Ellenbogen supervised the statistical analyses and revised the manuscript.

As an Honour's Psychology student, Karine Paquin was trained by Kamala Pilgrim to recruit, screen and test several study participants.

Study 2:

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Relative contribution:

Kamala Pilgrim conducted the literature review, tested the majority of participants, conducted the statistical analyses, interpreted results, and wrote the manuscript. Kamala Pilgrim and Mark Ellenbogen developed the research question and study protocol. Mark Ellenbogen supervised the statistical analyses and revised the manuscript. In her capacity as a research volunteer, Vanessa Zappitelli was trained by Kamala Pilgrim to recruit, screen and test several of the study participants. As a graduate level tutor, Christopher Cardoso helped with the statistical analyses.

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LIST OF RELEVANT ABBREVIATIONS

ABM	Attention Bias Modification
ANT	Attention Network Test
ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
M	Mean
MANCOVA	Multivariate Analysis of Covariance
MANOVA	Multivariate Analysis of Variance
RT	Response Time
sAA	Salivary Alpha Amylase
SD	Standard Deviation
Tukey's HSD	Tukey’s Honest Significant Difference

CHAPTER 1. GENERAL INTRODUCTION

Selective Attention and Self-Regulation

Humans preferentially allocate attention toward features of the environment that are consistent with their dominant belief systems (Bargh & Pietromonaco, 1982; Ferguson & Bargh, 2004). Selective attention is the ability to focus on relevant external information, internal memories and thoughts as opposed to maladaptive distractors (Raz, 2004). From an evolutionary perspective, early identification of physical (LeDoux, 1995; Mineka & Öhman, 2002; Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001) and social threats (Dickerson, Gruenewald, & Kemeny, 2004; Gruenewald, Kemeny, Aziz, & Fahey) is beneficial, at least in the short term, as it facilitates immediate responses to potentially harmful stimuli or situations (Gilbert, 1998; Mineka & Öhman, 2002; Öhman & Mineka, 2001; Öhman, 2005; Vuilleumier, 2005). In contrast, an attentional bias is an excessive, inflexible focus on negative or threatening information (Beck & Clark, 1997; MacLeod, Mathews, & Tata, 1986; Mogg & Bradley, 1998) which undermines goal attainment and the ability to efficiently self-regulate responses to stress (Derryberry & Rothbart, 1997; Gross, 2002; Ochsner & Gross, 2005; Posner & Rothbart, 2000).Thus, highlighting the attentional processes involved in adaptive self-regulation is critical to a better understanding of resiliency in the face of stress as well as the development of psychopathology (Posner & Rothbart, 2000).

Rationale for Attention Bias Modification (ABM) Training

Elucidating the causal nature of the relationship between attentional biases and emotional vulnerability for disorders such as anxiety and depression has become an important focus of many researchers in this area. To support the existence of this etiological relationship researchers have highlighted two basic conditions that must be met (Clarke, Notebaert, & MacLeod, 2014; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). First, systematically training individuals to focus towards or away from specific emotional valences using an attention bias modification (ABM) training program must modify the attentional bias (Clarke et al., 2014; MacLeod et al., 2002; Mathews & MacLeod, 2002). Second, this must be accompanied by a corresponding change in the clinical symptoms, mood responses and/or physiological markers under investigation (Clarke et al., 2014; Heeren, De Raedt, Koster, & Philippot, 2013; MacLeod et al., 2002). Thus, it is posited that changing the focus of attention using ABM training interventions can foster a more efficient emotional and physiological response to stress and reduce symptoms of anxiety (Clarke et al., 2014; MacLeod et al., 2002; Mathews & MacLeod, 2002).

In contrast to the large body of research on ABM training and clinical symptoms (Hakamata et al., 2010; Mogoaşe, David, & Koster, 2014), few studies have examined the impact of this intervention on the physiological response to acute stress, particularly within a healthy sample. It is well documented that the ability to efficiently initiate and self-regulate the physiological response to acute stress is central to long-term physical and emotional health (McEwen, 1998, 2005; Pruessner et al., 2010). Thus, clarifying the impact of ABM training on stress reactivity in this population may shed light on the specific attentional processes that support adaptive coping.

The established correlational link between attentional biases and the magnitude of the physiological response to acute stress provides good reason to predict that ABM training would be successful in altering this response (Ellenbogen, Schwartzman, Stewart, & Walker, 2006; Ellenbogen, Schwartzman, Stewart, & Walker, 2002; Fox, Cahill, & Zougkou, 2010; Pilgrim, Marin, & Lupien, 2010). Of the few studies that have used an ABM training task to experimentally investigate this hypothesis in healthy individuals, results have been promising (Dandeneau, Baldwin, Baccus, Sakellaropoulo, & Pruessner, 2007). However, the use of different ABM training tasks and variable methodological procedures such as, the measurement of distinct physiological biomarkers and the assessment of basal versus acute stress or recovery rates, hinders comparisons across studies (Baert, Casier, & De Raedt, 2012; Dandeneau et al., 2007).

There is also a limited understanding of the mechanisms underlying the positive outcomes of ABM training. A growing body of research shows that ABM training activates brain networks associated with higher order attentional control, resulting in changes at later stages of information processing which presumably promote better emotion regulation (Browning, Holmes, Murphy, Goodwin, & Harmer, 2010; Clarke, Browning, Hammond, Notebaert, & MacLeod, 2014; Eldar & Bar-Haim, 2010; Suway et al., 2013). These findings support theoretical models that ABM training interventions work by sharpening attentional control. However, there is also research consistent with the view that ABM training primarily alters the initial detection and appraisal of incoming cues rather than attentional control (Heeren et al., 2013; O'Toole & Dennis, 2012).

Purpose and Outline of Current Dissertation

To shed light on these issues, this dissertation examines the impact of two frequently used ABM training interventions on the physiological and mood response to stress in healthy, university students. It also investigates the role of baseline attentional control in predicting different physiological outcomes following ABM training. What follows is an introductory chapter beginning with an overview of the mechanisms underlying the normal physiological response to stress in healthy humans and a discussion of the role of attentional biases in predicting these responses. The extant literature examining the effects of ABM training on symptoms of distress and anxiety in subclinical and clinical populations is then reviewed, followed by a discussion of the research investigating the impact of ABM training on different physiological markers of stress in both disordered and non-clinical groups. The final section describes two main theories proposed to underlie the positive outcomes of ABM training: The attentional control and valence specific models (Heeren et al., 2013).

Neuroendocrine Changes Elicited by Acute Stress

Real or perceived challenges reliably trigger a cascade of emotional and neuroendocrine events as a means of providing adequate energy to handle the stressor and to restore homeostatic equilibrium. This system underlies the maintenance of several functions such as, body temperature, heart rate, blood pressure and hormone levels in the face of challenging circumstances (McEwen, 1998, 2008; Sapolsky, 2007). The acute biological response to stress has two stages. The immediate response is initiated by the sympathetic nervous system (SNS). Activation of the SNS stimulates pre-ganglionic neurons located in the locus coeruleus of the brain stem triggering a robust increase in circulating catecholamines, epinephrine and norepinephrine, from the adrenal medulla (Kvetnansky, Lu, & Ziegler, 2013; Tsigos & Chrousos, 2002). This facilitates the rapid reactions typically observed immediately following an acute stressor such as, the narrowing of attentional focus, increased alertness, elevated heart rate, accelerated breathing, pupil dilation, suppression of digestive functions, etc. (Tsigos & Chrousos, 2002).

Salivary alpha amylase (sAA), a digestive protein synthesized by the acinar cells of the parotid gland, has been identified as a potent marker of SNS activity based on its correlations with plasma norepinephrine (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996; Nater & Rohleder, 2009; Rohleder, Nater, Wolf, Ehlert, & Kirschbaum, 2004; Thoma, Kirschbaum, Wolf, & Rohleder, 2012) and acute cortisol in response to stress (Engert et al., 2011). Both “passive drooling” or “direct spitting” of unstimulated whole saliva have been identified as reliable methods for sAA concentration determination allowing for the concurrent assessment of both cortisol and sAA levels from a single saliva sample (Bosch, Veerman, de Geus, & Proctor, 2011).

The SNS response to stress is followed by the activation of the hypothalamic-pituitary-adrenal (HPA) axis which occurs approximately 20-40 minutes post-stressor onset (Dickerson & Kemeny, 2004; Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004). Activation of this system leads to a robust rise in corticotropin-releasing hormone from the paraventricular nucleus of the hypothalamus (De Kloet, 2004; Hsu, Kirouac, Zubieta, & Bhatnagar, 2014), adrenocorticotropic hormone from the anterior pituitary (Herman & Cullinan, 1997; Stevens & White, 2010), and cortisol from the adrenal cortex (Brown, 2000). Each of these hormones functions in a negative feedback loop, which under normal, healthy conditions, efficiently shuts down system activation to reinstate balance (Brown, 2000). In the short term, stress hormones exert positive effects on a host of metabolic, immune, cardiovascular and central nervous system processes which have a profound impact on overall physical, cognitive and emotional well-being (Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; McEwen, 2008). In addition, both cortisol and norepinephrine follow an inverted U-shaped function with either excessively high or low levels associated with negative consequences for the brain and body (Arnsten, 2000, 2009; Chamberlain & Robbins, 2013; Lupien et al., 2007; Lupien & McEwen, 1997; Lupien et al., 2002; Lupien, McEwen, Gunnar, & Heim, 2009; McEwen & Sapolsky, 1995). Cortisol also follows a daily circadian rhythm, with peak levels during the first hour after awakening which diminish over a 24-hour period until they reach the lowest trough in the late evening (Akerstedt & Levi, 1978; Pruessner et al., 1997).

The acute cortisol (Foley & Kirschbaum, 2010; Grissom & Bhatnagar, 2009; Wüst, Federenko, van Rossum, Koper, & Hellhammer, 2005) and SNS response to stress (Howard & Hughes, 2012; Minkley, Schröder, Wolf, & Kirchner, 2014) also tend to habituate following repeated exposure to the same type of challenge. Failure to habituate in response to a previously encountered stressor is associated with negative outcomes (McEwen & Lasley, 2003) such as job-related exhaustion (Kudielka et al., 2006), vulnerability to major depression (McEwen, 2005; Morris & Rao, 2014; Sapolsky, 2000; Waugh, Muhtadie, Thompson, Joormann, & Gotlib, 2012), clinical anxiety (Raskin, 1975; Watson, Gaind, & Marks, 1972) and specific personality traits (e.g., trait dominance: Lee & Hughes, 2014, low self-esteem: Kirschbaum et al., 1995; Pruessner et al., 1997). Based on these findings, it is suggested that a moderate rise in stress hormones is an adaptive response to acute stress, provided that it is followed by a timely and efficient diminishment of activity (Dickerson & Kemeny, 2004; Juster, Perna, Marin, Sindi, & Lupien, 2012; Linden, Earle, Gerin, & Christenfeld, 1997).

Attentional Bias and Acute Stress Reactivity

In humans, a stress response is initiated when the challenge is appraised as being beyond the person's capacity to cope (Lazarus & Folkman, 1984). Specific situational factors such as, novelty, unpredictability, feeling a low sense of control, perceiving a threat to the 'social self' and/or having an overall negative self-image predict elevated HPA axis reactivity in response to acute psychological forms of stress (Andrews et al., 2007; Dickerson et al., 2004; Gruenewald et al., 2004; Mason, 1968; Pruessner et al., 2005; Wadiwalla et al., 2010). These findings suggest that attentional biases play some role in the development and maintenance of emotional disorders as well as in triggering and regulating physiological responses to psychosocial stress.

Attentional biases for negative information have been robustly reported across a range of anxiety spectrum and mood disorders (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Bradley, Mogg, & Millar, 2010; MacLeod et al., 1986; Mathews & MacLeod, 2005; Mogg & Bradley, 1998; Mogg et al., 2000; Williams, Mathews, & MacLeod, 1996). Similarly, an attentional bias for threatening emotional information (e.g., anger, disgust, fear, rejection) has also been shown to predict greater cortisol elevations (Applehans & Luecken, 2006; Dandeneau et al., 2007; Ellenbogen, Carson, & Pishva, 2010; Fox et al., 2010; Pilgrim et al., 2010; Roelofs, Bakvis, Hermans, van Pelt, & van Honk, 2007) and acute SNS responses to stress (Kreher, Powers, & Granger, 2012).

In addition, a number of studies have shown that attentional biases particularly at early stages of processing (e.g., stimulus presentations ranging from approximately 13 ms to 200 ms) are stronger predictors of acute cortisol reactivity in response to both naturalistic and laboratory stressors than such factors as self-reported neuroticism, trait-anxiety, or depression (Ellenbogen et al., 2010; Fox et al., 2010). Attentional biases for words presented with limited conscious awareness have also been shown to predict a negative mood response to naturalistic stressors (MacLeod & Hagan, 1992; Najström & Jansson, 2007; Osinsky, Lösch, Hennig, Alexander, & Macleod, 2012; van den Hout, Tenney, Huygens, Merckelbach, & Kindt, 1995; Verhaak, Smeenk, van Minnen, & Kraaimaat, 2004). These findings suggest that early stage attentional biases may be more reliable indicators of maladaptive stress reactivity than biases which occur at later stages of emotional information processing.

Bottom Up versus Top Down Pathways

The extent to which attention remains fixated on relevant stimuli versus negative or threatening information is thought to be determined by the bottom up ‘alarm’ systems of the brain or the higher order, top down control mechanisms, which each vie for control over attention (Bishop, 2008, 2009). Bush, Luu, & Posner, (2000) propose that the anterior cingulate cortex acts as a key regulator of these systems by either facilitating or impairing top down control over emotional centers. Thus, the anterior cingulate cortex can lead to greater activation of the bottom up subcortical circuitry including the amygdala, or increase activity of the higher order attentional control regions such as the dorsolateral prefrontal cortex which can dampen the response of the lower centers (Vanderhasselt, De Raedt, Leyman, & Baeken, 2009; Wang et al., 2010).

Dual processing frameworks (Barrett, Tugade, & Engle, 2004; Strack & Deutsch, 2004) posit that, in healthy individuals, acute stress triggers a switch from the top down, slow, reflective system of stress regulation to the bottom up, reflexive network mediated by the subcortical pathways (Arnsten, 2009). Although this is often beneficial in helping an individual handle an acute stressor, according to attentional control models, emotion dysregulation develops when either there is a failure of the top down systems to adequately diminish the response of the underlying emotional circuitry or when the influence of the bottom up pathway overpowers the activity of the higher order regions (Bishop, Duncan, Brett, & Lawrence, 2004; Bishop, 2008, 2009; Posner & Rothbart, 1998, 2000). Importantly, these networks also facilitate emotional information processing therefore exerting a critical role not only in stress reactivity and regulation, but also in the development and maintenance of attentional biases (Pessoa & Ungerleider, 2004; Phelps & LeDoux, 2005).

Assessment of Attentional Bias

Different computerized tasks are used to evaluate the nature and magnitude of attentional biases (Bar-Haim et al., 2007; Grafton & MacLeod, 2014). Tasks assessing attention bias tend to examine responses to emotional stimuli that have only been presented for brief stimulus durations in order to measure processes that operate automatically (Cisler & Koster, 2010; Grafton & MacLeod, 2014). The two main tasks used to measure attentional biases are the dot probe and the spatial cueing paradigm (Mogoaşe et al., 2014). The dot probe task (MacLeod et al., 1986) is a competitive processing task because it simultaneously presents two words or facial stimuli of different valences which can each attract attention. Each stimulus is presented either above or below, or on the left and right side of a centrally-placed fixation point for a short duration (typically ranging from very brief, e.g., 13 ms, to moderate, e.g., 500 ms, exposure times). One stimulus cue typically depicts a negative, sad or angry emotion and the other a neutral or positive one. Once these cues disappear, a target (e.g., a dot or single letter) appears in the previous location of one of the words or facial expressions. Participants are required to identify the presence of the probe (i.e., detection task), the type of target presented (i.e., horizontal or vertically positioned dots, the letter *E* or *F*, for example), or the location of the probe (i.e., discrimination task), as quickly and accurately as possible. Relative to trials with neutral pictures, faster response times (RTs) on "congruent" trials (i.e., where a negative cue and target appear on the same side of the screen) suggest that attention was rapidly engaged toward the location of the affective stimulus. Relative to trials with neutral pictures, longer RTs on "incongruent" trials in contrast, (i.e., where the target appears on the opposite side of the negative cue) indicate impaired disengagement of attention away from the negative cue, which presumably absorbed attention.

The modified spatial cueing paradigm (Fox, Russo, Bowles, & Dutton, 2001; Posner, Snyder, & Davidson, 1980; Stormark, Nordby, & Hugdahl, 1995) is similar to the dot probe task, but differs in one fundamental way. The spatial cueing task is an attentional shifting paradigm in which attentional engagement toward and disengagement away from a single stimulus is examined more distinctly (Koster, Crombez, Verschuere, & De Houwer, 2004). To accomplish this, participants are presented with one positive, negative, or neutral picture or word stimulus on the right or left side of a centrally placed fixation point, in contrast to the presentation of two stimuli simultaneously as in the dot probe task. Next, participants respond when they detect a target which appears after the initial emotional or neutral word or face cue disappears. Initial cues are considered "valid" when presented in the same spatial location as the target and "invalid" when they are shown on the opposite side of the target (Posner et al., 1980). Valid cues are believed to measure shifts of spatial attention from the fixation point to the facial cue and target, referred to as “attentional engagement.” Invalid cues, in contrast, assess the movement of attention toward the location of the target after disengaging away from the cue presented in the contralateral hemifield. This disengagement process usually exerts a cost reflected by slower RTs on invalid trials relative to valid ones (Posner et al., 1980).

In this task attentional disengagement biases are operationalized by subtracting responses on neutral invalid trials from negative invalid trials. Attentional engagement is assessed by subtracting negative valid trials from neutral valid trials. This strategy is postulated to assess differences in the ability to engage toward and disengage away from negative stimuli compared to neutral information. Another way to analyze responses is to subtract RTs on valid threat trials from invalid threat trials (Baert, De Raedt, Schacht, & Koster, 2010). This technique measures the cost of disengaging attention away from the prior location of a negative cue (i.e., negative disengagement trials) compared to trials where attention was not required to disengage away from one region to shift to another (e.g., negative engagement trials).

Based on these or similar tasks, researchers have operationalized three types of attentional biases that can develop (Cisler & Koster, 2010; Ellenbogen et al., 2002; Grafton, Watkins, & MacLeod, 2012; Koster, Crombez, Verschuere, & De Houwer, 2006). Hypervigilance is characterized as rapid attentional engagement toward maladaptive stimuli, while delayed disengagement involves slower shifting of attention away from certain material. The third, avoidance, is a more prolonged focusing of attention away from specific stimuli (Cisler & Koster, 2010; Grafton & MacLeod, 2014; Grafton et al., 2012).

Modification of Attentional Bias

To establish evidence of a causal relationship between attentional biases and markers of stress reactivity or symptoms of clinical psychopathology, recent studies have focused on experimentally altering the attentional bias and examining consequent changes in these outcomes. The standard ABM procedure implicitly trains individuals to focus on positive or neutral information rather than on negative stimuli (Bar-Haim, 2010; MacLeod et al., 2002; Van Bockstaele et al., 2014).

In this manner it is posited that ABM fosters greater processing of adaptive information via incidental learning (Bar-Haim, 2010; Clarke et al., 2014). Incidental learning is indirect, unorganized, unplanned, and unintentional learning that occurs while engaging in repetitive activity and which typically operates without conscious awareness that learning is taking place (Reber, 1967; Reber, 1989).

In addition, fostering attentional disengagement away from negative information and toward positive or neutral information at an early stage of attentional processing is considered to be an “early selection strategy” (Van Dillen & Koole, 2007). Similar to distraction, this technique blocks the processing of emotion at an early stage before it gathers greater force (Sheppes & Gross, 2011; Sheppes et al., 2014; Sheppes, Scheibe, Suri, & Gross, 2011). Cognitive reappraisal in comparison, is considered a “late selection strategy” since it involves first paying attention to an emotional stimulus or situation and taking time to reinterpret the meaning of the information in an adaptive way that modifies the impact on one’s emotional experience (Sheppes & Gross, 2011). Although each are considered antecedent processes compared to other maladaptive strategies like suppression of emotion, cognitive reappraisal requires a longer period of emotion processing compared to attentional disengagement or distraction.

Using the dot probe or spatial cueing paradigms, ABM is achieved by generating a contingency between the location of the target and the valence of the emotional cue (MacLeod et al., 2002). When the goal is to examine the effects of refocusing attention toward positive or neutral information as opposed to negative stimuli (i.e., an intervention aimed at *decreasing* negative emotions or stress reactivity) on the majority or all of the trials, the target consistently appears in the same location as the cue depicting positive or neutral affect. In contrast, when the objective is to focus attention toward threat (i.e., a manipulation to *increase* negative affect or stress reactivity) the target will be shown in the same region as the cue depicting negative emotion. To control for non-specific effects of exposing participants to repetitive words or pictures, control training sessions typically present the same type and number of words or facial expressions but remove the contingency between the location of the target and the location of the affective cue, allowing targets to appear after each stimulus cue type with equal frequency (Amir, Weber, Beard, Bomyea, & Taylor, 2008).

MacLeod and colleagues (2002) were first to use a dot probe ABM training task to try to alter the attentional bias of subjects with moderate levels of anxiety and to examine subsequent emotional vulnerability to a stressor which immediately followed this training. Participants were randomly assigned to either an "*attend threat*" ABM training condition or to an "*attend neutral"* condition, and were subsequently exposed to a stressful anagram task. As expected, the "*attend threat"* group developed faster engagement toward negative words presented with full conscious awareness and had a more negative mood response to the stressful anagram task. This study was the first to provide empirical evidence that a single session of ABM training aimed at modifying underlying implicit attentional associations can result in a corresponding change in mood reactivity.

Although this was a groundbreaking study, there were some limitations that needed to be addressed in future research. First, only words were used as threatening cues. Therefore, it could not be known whether the reported effects would extend to other types of social information such as facial expressions. Second, since there was no active control group in which either no training was performed at all, or where participants completed a control computerized task which lacked the contingencies between the location of the emotional cue and the target, it was difficult to discern the magnitude of these effects (Amir et al., 2008).

In an effort to shed light on some of these factors, researchers have since set out to replicate and extend these findings with an emphasis on the assessment of self-reported anxiety and emotional distress following training within clinical or subclinical populations (Mogoaşe et al., 2014).

Impact of ABM Training on Subjective Measures of Distress and Anxiety

There is now a substantial body of evidence supporting the effectiveness of ABM training particularly in attenuating subclinical or clinical symptoms of anxiety in both children (Bar-Haim, Morag, & Glickman, 2011; Bechor et al., 2014; Cowart & Ollendick, 2011; Eldar et al., 2012; Lowther & Newman, 2014; Rozenman, Weersing, & Amir, 2011; Waters, Pittaway, Mogg, Bradley, & Pine, 2013) and adults (Mathews & MacLeod, 2002; See, MacLeod, & Bridle, 2009). In particular, a number of studies in subjects with generalized anxiety disorder and social phobia have shown positive effects of ABM training on attentional biases for negative information and clinical symptoms (Amir, Beard, Burns, & Bomyea, 2009; Amir et al., 2008; Amir, Beard, Taylor, et al., 2009; De Voogd, Wiers, Prins, & Salemink, 2014; Hazen, Vasey, & Schmidt, 2009; Li, Tan, Qian, & Liu, 2008; Schmidt, Richey, Buckner, & Timpano, 2009). Importantly, the change in attentional bias has often been shown to mediate the modification of symptoms (Amir et al., 2008; Amir, Beard, Taylor, et al., 2009; Kuckertz, Gildebrant, et al., 2014).

ABM training has also reduced symptoms of PTSD (Kuckertz, Amir, et al., 2014) contamination fear in those with subclinical levels of obsessive compulsivity (Najmi & Amir, 2010), mild dysphoria (Baert et al., 2010), and depression (Browning, Holmes, Charles, Cowen, & Harmer, 2012; Wells & Beevers, 2010; Yang, Ding, Dai, Peng, & Zhang, 2014). In healthy subjects, ABM training decreased the attentional bias (Dandeneau & Baldwin, 2004; Suway et al., 2013) and the emotional response to a stressful task encountered following training (Dandeneau et al., 2007; Dandeneau & Baldwin, 2009; Sharon Eldar, Ricon, & Bar-Haim, 2008). Thus, a large body of research has demonstrated that ABM training can reduce subjective markers of distress, anxiety and other symptoms in clinical samples and to some extent in healthy populations as well.

Recently, meta-analyses have been used to quantify the magnitude of these effects. In a rigorous meta-analysis of 12 studies which only included randomized controlled designs that used a dot-probe training intervention in anxious populations, Hakamata et al., (2010) found that ABM induced a large impact on the change in attentional bias (*d* = 1.16), and a medium effect on both anxiety symptoms (*d* = 0.61) and emotional reactivity following a stressor completed after training (*d* = 0.77). In contrast, other meta-analyses have reported less compelling findings (Beard, Sawyer, & Hofmann, 2012; Hallion & Ruscio, 2011). Including 21 studies in their analysis, Hallion & Ruscio, (2011) reported only a small effect of ABM on the attentional bias (*g* = 0.29), symptoms of psychopathology (*g* = 0.13) and the emotional response to a stressor (*g* = 0.023). Similarly, in a meta-analysis which incorporated both clinical and healthy populations, Beard et al., (2012) reported a large effect size for the change in attentional bias (*g* = 1.06), a relatively smaller effect on emotional reactivity to stress (*g* = 0.40), and a negligible effect of ABM on self-reported subjective symptoms post-training (*g* = 0.03). Thus, despite the consistent positive effects of ABM on the attentional bias and on subjective markers of distress and anxiety, there is substantial variation in the magnitude of these effects across studies. In addition, there are fewer studies examining the impact of ABM training on physiological markers of stress reactivity.

ABM Training and Acute Physiological Reactivity to Stress

One of the first studies to assess physiological reactivity to stress following ABM training in a clinical population was carried out by Heeren et al., (2012). The authors recruited participants with social phobia and randomly assigned them to either an "*attend threat"*, "*attend positive*" or to a control task. The results showed that only the "*attend positive*" group demonstrated a change in attentional biases as well as a significant reduction in self-reported anxiety, emotional, behavioral and skin conductance responses to a speech task. However, McNally, Enock, Tsai, & Tousian, (2013) recently found that university students with social phobia underwent the same reduction in attentional bias, behavioral signs of anxiety (i.e., gaze, vocal quality, discomfort, conversational fluidity, and speech duration) as well as heart rate, diastolic and systolic blood pressure responses following a speech task as a control computer intervention suggesting that ABM had no unique effect on outcomes of interest. Thus, in contrast to Heeren et al., (2012) who reported specific benefits of ABM training on skin conductance responses compared to a control task, the results of McNally et al., (2013) suggest that an ABM intervention which aimed to train participants to focus toward specific emotional information can lead to the same outcomes as a control computer task that was not designed to change the attentional bias.

To shed light on the impact of ABM on heart rate variability in healthy participants, Baert et al., (2012) randomly assigned 32 individuals actively seeking employment to do a series of dot probe ABM training sessions at home. Following training participants performed a mock job interview 1-2 days prior to an actual interview. The results indicated that the ABM training was successful in improving disengagement away from stimuli depicting threat and heart rate variability was also enhanced but only during the recovery phase of the acute stressor. These contrasting findings underscore the need for more replications of these studies in similar populations and assessing comparable physiological markers.

In one of the few studies to examine the effects of ABM on cortisol levels in the natural environment, Dandeneau et al., (2007, study 3b) trained healthy participants working as telemarketers to focus attention toward a smiling face which was embedded within a matrix of facial expressions depicting disgust in a visual search paradigm. In a control condition, participants were required to identify the five-petaled flower as quickly as possible from an array of seven-petaled flowers. Interestingly, participants who underwent training over a five day period reported a significant decrease in basal cortisol levels. These results are similar to the findings of Browning et al., (2012) who reported lower morning cortisol levels in depressed individuals following ABM training which fostered processing of positive faces. These results suggest that ABM training may be capable of reducing daytime cortisol levels but it remains to be seen whether it can also attenuate the acute cortisol response to psychosocial stress.

Taken together, there is some preliminary evidence that ABM training can have a positive influence on stress reactivity, but there are few studies examining physiological markers and the results obtained from those that have assessed these variables have been mixed. In an attempt to clarify the impact of ABM training on both the emotional and physiological response to stress, Mogoaşe et al., (2014) included studies that examined physiological markers along with investigations which assessed emotional reactivity following a psychosocial challenge. Similar to Beard et al. (2012), the authors reported a larger effect size ($g = 0.40$), in both healthy and anxious populations, in studies examining stress reactivity post-training compared to effect sizes obtained from studies that did not include exposure to a stressor following training ($g = 0.16$; Mogoaşe et al., 2014). This suggests that ABM training may be more effective in reducing reactivity to an acute stressor as opposed to symptoms occurring outside of a stressful context.

Despite the number of studies demonstrating positive effects following ABM interventions, there is an accumulating body of research, similar to the aforementioned findings of McNally et al., (2013), which fails to show a change in the attentional bias or subsequent clinical symptoms following ABM training across diagnoses such as, social phobia (Boettcher, Berger, & Renneberg, 2012; Carlbring et al., 2012; Heeren, Mogoaşe, McNally, Schmitz, & Philippot, 2015; Neubauer et al., 2013), depression (Baert et al., 2010) and health anxiety (Lee & Hughes, 2014). However, rather than providing evidence that refutes the effectiveness of ABM training, studies that were not able to modify the attentional bias following an ABM intervention may actually provide support for the theory that the change in the attentional bias mediates the beneficial outcomes of ABM (Clarke et al. 2014). Following this reasoning, studies that cannot change the attentional bias would be expected to produce null effects (Clarke et al., 2014). Clarke et al. (2014) suggest that a critical avenue for future research will be to, a) identify the specific methodological factors that reliably induce a change in the attentional bias following ABM training and, b) highlight the moderating variables that tend to improve or impair outcomes of training.

Methodological Inconsistencies in the ABM Training Literature

First, different ABM training paradigms may be superior to others in their ability to alter the attentional bias thus differentially impacting clinical symptoms and stress reactivity. Although the majority of research has used a variant of the dot probe task, some have used the modified spatial cueing paradigm to train attention or a visual search paradigm which embeds a positive word or face within a matrix of negative stimuli to train attention (Mogoaşe et al., 2014). Although these tasks are similar in theory, the dot probe and visual search tasks both aim to change the attentional bias by training people to selectively process specific valences through competitive processing of two or more emotional stimuli presented at the same time, while the spatial cueing task in contrast, facilitates shifting of attention toward or away from one valence at a time. No studies to date have compared these ABM tasks to one another within the same investigation.

Second, most studies have trained individuals to focus on neutral stimuli rather than positive information. There is some evidence that training attention to focus toward positive stimuli also reduces emotional vulnerability following stress thus more studies should examine the effects of this valence on outcomes (Baert et al., 2012, 2010; Heeren et al., 2012; Taylor, Bomyea, & Amir, 2011). Third, no studies to date have examined the impact of ABM on the acute cortisol or sAA response to stress following training. This is important given that these are key markers of stress reactivity that can provide important insight into the functioning of the HPA axis. Finally, the role of moderating variables is still poorly understood although there is mounting evidence that ABM may be impaired or improved by specific baseline individual differences between subjects.

Role of Moderators in ABM Training

Shedding light on moderating variables in ABM is becoming an increasingly critical focus of research (Clarke et al., 2014). Meta-analyses have revealed that increasing the number of ABM training sessions results in larger effects post-training (Beard et al., 2012; Hakamata et al., 2010). Individuals who demonstrate an attentional bias for negative information at baseline respond in the intended direction of ABM training better than those who do not show this initial attentional bias (Amir, Taylor, & Donohue, 2011; Heeren et al., 2013; Kuckertz, Gildebrant, et al., 2014; O'Toole & Dennis, 2012; Suway et al., 2013). Even generating an attentional bias prior to performing an ABM training procedure (i.e., via fear induction) has been shown to improve outcomes following training (Kuckertz, Gildebrant, et al., 2014).

Individual differences in personality at baseline can also predict different responses following ABM training (Higgins & Hughes, 2012). Higgins & Hughes, (2012) for example, reported that those with low a priori levels of neuroticism, who completed an ABM intervention that aimed to foster attentional disengagement away from negative information, had paradoxically elevated cardiovascular reactivity following training. Those with higher neuroticism evidenced lower responses following the same intervention.

In sum, the moderating role of specific factors such as neuroticism and baseline attentional biases may have a positive influence on outcomes following ABM interventions while other variables may impede or lead to paradoxical outcomes. The mechanisms underlying these different outcomes of ABM remain less well understood.

Proposed Theoretical Models

Heeren et al., (2013) suggest that ABM can induce changes in attentional biases, as well as mood, behavior or physiological responses, by modifying either a valence specific system (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 2002) or a later stage attentional control system (Eysenck & Derakhshan, 2011; Eysenck, Derakshan, Santos, & Calvo, 2007). According to attentional control system theories, attentional biases are due to a widespread deficit in the ability to activate top down regulation of emotional information processing rather than to an excessive attentional bias for negative information at the stimulus level (Bishop, 2009; Compton, 2003; Derryberry & Reed, 2002; Eysenck et al., 2007). The theory postulates that anxiety is experienced when there is increased functioning of the valence driven attentional system that is not effectively diminished by the goal directed, top down attentional control centers. Stress or anxiety can thus lead to greater processing of threatening information by increasing activity of the valence driven system which in turn dampens the impact of the top down attentional control system.

Valence specific theories (Beck & Clark, 1997; Mogg & Bradley, 1998; Todd, Cunningham, Anderson, & Thompson, 2012) in contrast, propose that ABM modifies the early processing of emotional information, either making it more likely that stimuli will be appraised as threatening and/or by increasing the extent to which attention is allocated toward threatening content. According to this theory, the valence evaluation system quickly assesses the threatening nature and salience of incoming information and this initial assessment *determines* whether the top down systems facilitate processing of the information or instead, foster disengagement away from it. This theory highlights the importance of the initial allocation of attention towards threat and/or the appraisal of incoming stimuli, in determining emotional, behavioral and physiological reactivity to the information. Evidence that the automatic, pre-attentive processing of threat predicts physiological (Ellenbogen et al., 2006; Fox et al., 2010; Öhman & Soares, 1993, 1994) and emotional reactions to stress (MacLeod & Hagan, 1992) are used to formulate this theory.

In summary, the valence specific model holds that solely improving attentional control does not modify the early attentional bias or symptoms (Heeren et al., 2013). The attentional control model predicts that the attenuation of symptoms *requires* enhanced attention control without necessarily impacting the valence specific bias (Heeren et al., 2013). A final viewpoint is that both the valence specific and the attentional control systems are causally involved in the reduction of attentional biases and symptoms of interest (Heeren et al., 2013).

Evidence in Support of the Valence Specific Theory

Support for the valence specific model in ABM comes from a study which showed that ABM training can influence brain activation at early stages of processing (O'Toole & Dennis, 2012). O'Toole & Dennis, (2012) measured P1 (early stage) and P2 (later stage, elaborate, strategic processes) EEG amplitudes in healthy, non-disordered individuals. Participants in the disengage from threat group evidenced reductions in P1 amplitudes to all cues presented at early stages of processing (100 ms) following training. This suggests that ABM training in healthy individuals can diminish automatic processing of threatening cues as well.

Further evidence for this theory comes from a recent study by Heeren, Philippot, & Koster, (2014). In a university sample of students with mid-range levels of self-reported anxiety, the authors distinguished between either a stable component of attentional bias and a dynamic aspect which assesses the ease with which attentional biases change over time. For the stable component of attentional bias, the variance shared between the first assessment, taken two weeks before the ABM procedure at time 1, and at time 2, measured just prior to ABM intervention, were combined. For the dynamic aspect, the influence of either time point alone was measured. Interestingly, the results indicated that the dynamic feature of the attentional bias, (i.e., the variance specific to each of the time points), was most predictive of performance gains on the ABM training task. Taken together, these findings suggest that the benefits of ABM training are pronounced when the baseline attentional bias is already flexible to change before the intervention, especially at early stages of processing, and within-sessions.

Evidence in Support of the Attentional Control Theory

Support for the role of attentional control in ABM training comes from studies showing that ABM increases activity in regions of the brain which underscore attentional control (Browning et al., 2010; Clarke et al., 2014; Eldar & Bar-Haim, 2010). Browning et al., (2010) randomly assigned participants to an "*attend-threat*" training which increased attentional biases for negative information, or to an "*avoid-threat*" training which diminished attentional biases for this information. Interestingly, when participants were later trained to focus their attention in a manner that was opposite to the original direction of the ABM training, they underwent greater activity in the lateral prefrontal cortex suggesting that this higher order attentional control region mediates the positive effects of ABM (Browning et al., 2010). Similarly, Clarke et al., (2014) randomly assigned young adults with moderate trait anxiety to ABM training that promoted attention towards negative words or disengagement away from these stimuli. Participants also underwent either an active treatment which included direct current stimulation of the dorsolateral prefrontal cortex during the ABM procedure or a SHAM intervention. Only participants in the active condition who underwent an enhancement in areas responsible for attentional control during ABM training demonstrated a change in attentional bias consistent with the direction of training, suggesting that the improvement in attentional control mediates the effects of ABM training.

To investigate the role of attentional control in ABM training, Klumpp & Amir, (2010) randomly assigned moderately socially anxious individuals to one of three different ABM training conditions: 1) "*attend to neutral*", 2) "*attend to threat*", or 3) a control condition in which there was no contingency between the emotional cues and probes. After one session, both the "*attend to threat"* as well as "*attend to neutral"* groups reported a reduction in state anxiety following an impromptu speech task compared to individuals in the standard control condition. The authors suggested that regardless of the direction of training, ABM may improve attentional control in a manner that strengthens the ability to attenuate anxiety in response to stress. However, since attentional control was not measured in this study these observations remained speculative.

Recent studies have used objective measures of attentional control to examine the effects of ABM training on attentional control and heart rate reactivity to a stressor following either a standard ABM training or a control computerized intervention (Heeren et al., 2015; McNally et al., 2013). In speech anxious students, McNally and colleagues (2013) conducted an ABM intervention using two measures of attentional control as outcome measures to test the attentional control theory. Assessment measures for attentional control included a self-report measure of attentional control developed by Derryberry & Reed, (2002) and a computer task termed, the Attention Network Test (ANT), an RT task which examined how rapidly the direction of a central arrow is accurately identified when it is flanked by other arrows pointing in the same (congruent) or a different direction (incongruent) (Fan, McCandliss, Sommer, Raz, & Posner, 2002). The results showed that following an, "*attend to joy"* ABM training, an "*attend to threat"* ABM training, or a control training, all groups underwent significant improvements in self-reported and RT-based attentional control. All groups also underwent similar reductions in symptoms over time irrespective of training type. Recently, Heeren et al., (2015) replicated this finding showing that both a no-contingency control task and an ABM intervention lead to comparable increases in attentional control as well as outcome measures. Notably, in both studies there was little to no change in the attentional bias following the ABM training or the control intervention. These results provide preliminary support for the attentional control theory in showing that an increase in attentional control is associated with reductions in physiological reactivity to stress whether or not the computer task performed was aimed at changing the attentional bias.

In sum, there is a growing body of evidence that supports the hypothesis that improvements in attentional control mediate the positive effects of ABM on clinical symptoms as well as markers of stress reactivity following a challenge.

Summary and Conclusions from the Literature on ABM Training

ABM training has potential as an alternative treatment to anxiety disorders, or more appropriately as a putative adjunct to standard interventions used in the treatment of anxiety disorders. However, there are discrepant findings and the mechanisms underlying the effects of ABM training on different outcomes are unclear. The evidence thus far appears to provide greater support for the role of attentional control (i.e., top down effects on the processing of emotional information) as a key mechanism enabling change through ABM programs, but there is also evidence that ABM can alter early stage emotional processing as well. ABM training also tends to attenuate the mood response to stress, but its effect on biological stress systems is less understood. Recent evidence has shown that ABM can diminish heart rate variability, skin conductance responses to an acute stressor, and daily cortisol rhythms, but no study to date has examined the salivary cortisol or sAA response to an acute psychosocial stressor.

Aims of the Current Research

The purpose of the current dissertation was to further shed light on the impact of ABM training on the physiological response to stress by measuring both the acute salivary cortisol and sAA response to stress. In a series of two studies, the hypothesis that ABM training could reduce neuroendocrine activity in response to stress was tested. We also sought to shed light on the role of attentional control in ABM by measuring this construct through the use of a validated RT task, i.e., the ANT. In order to examine differences between different forms of ABM training, the current research examined the impact of ABM training using a standard dot probe training protocol and a less common spatial cueing training protocol. Last, follow-up effects of ABM training were examined by investigating whether the results of training would be maintained or improved approximately two months after the end of the training protocol.

Study 1 tested the hypothesis that three days of ABM training designed to foster disengagement of attention away from threatening faces and engagement toward positive facial expressions would lead to reduced salivary cortisol levels, sAA levels, and negative mood ratings to a psychosocial challenge. It also examined whether baseline attentional control would moderate the association between ABM training and the physiological and mood response to psychosocial stress.

Study 2 was conducted to follow-up the findings of study 1. Participants completed an initial psychosocial stressor followed by a second, identical stressor approximately 8 weeks post-ABM training. Only the cortisol response to stress was examined in study 2. In addition, two ABM training programs, one based on the dot probe task and another on the spatial cueing paradigm, were compared. To explore the possibility that our “control” training might have had effects on stress reactivity, two control groups, a gender identification task (requiring no shifts of attention) and a no-training condition, were compared. Study 2 also examined the role of attentional control in moderating these outcomes.

CHAPTER 2. STUDY 1:

The Impact of Attentional Training on the Salivary Cortisol and Alpha Amylase Response to Psychosocial Stress: Importance of Attentional Control

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Abstract

Introduction: This study examined the effects of three consecutive days of attentional training on the salivary alpha amylase (sAA), cortisol, and mood response to the Trier Social Stress Test (TSST). The training was designed to elicit faster disengagement of attention away from threatening facial expressions and faster shifts of attention toward positive ones.

Method: Fifty-six healthy participants between the ages of 18 and 30 participated in a double-blind, within-subject experiment. Participants were randomly assigned to one of three attentional training conditions - supraliminal training: pictures shown with full conscious awareness, masked training: stimuli presented with limited conscious awareness, or control training: both supraliminal and masked pictures shown but no shifting of attention required. Following training, participants underwent the TSST. Self-reported mood and saliva samples were collected for the determination of emotional reactivity, cortisol, and sAA in response to stress post-training.

Results: Unexpectedly, participants in both attentional training groups exhibited a higher salivary cortisol response to the TSST relative to participants who underwent the control training, $F(4, 86) = 4.07$, $p = .005$, $\eta_p^2 = .16$. Supraliminal training was also associated with enhanced sAA reactivity, $F(2, 44) = 13.90$, $p = .000$, $\eta_p^2 = .38$ and a more hostile mood response ($p = .021$), to the TSST. Interestingly, the effect of attention training on the cortisol response to stress was more robust in those with high attentional control than those with low attentional control ($\beta = -0.134$; $t = -2.24$, $p = .03$).

Conclusion: This is among the first experimental manipulations to demonstrate that attentional training can elicit a paradoxical increase in three different markers of stress reactivity. These findings suggest that attentional training, in certain individuals, can have iatrogenic effects.

Keywords: Attention Modification; Attentional Control; Attentional Training; Executive Attention; Salivary Alpha Amylase; Salivary Cortisol; Stress

Introduction

It is well known that anxiety disorders and other mental illnesses such as depression are associated with abnormalities in the selective processing of emotional stimuli (MacLeod et al., 1986; Mathews & MacLeod, 2005; Peckham, McHugh, & Otto, 2010; Williams et al., 1996). It is not known, however, whether alterations in emotional information processing represent a correlate or symptom of the disordered state, or contribute to the development or maintenance of these disorders. Recently, randomized-control studies attempting to experimentally modify the focus of attention, known as attentional training, have been conducted in an effort to clarify the issue of causality. If the relationship between attentional abnormalities and anxiety is etiological, then changes in attention should elicit a decrease in anxiety and symptom relief. Indeed, attentional training has been effective in reducing symptoms of anxiety (Bar-Haim, 2010; Hakamata et al., 2010; Li et al., 2008), as well as emotional reactivity to stress (Amir et al., 2008; MacLeod et al., 2002). Less is known, about the link between attentional biases, attentional training, and physiological markers of stress, as well as the role of attentional control in these associations.

Several studies have shown that baseline, early stage attentional biases predict cortisol responses to stress (Ellenbogen et al., 2006; Fox et al., 2010; Pilgrim et al., 2010; Roelofs et al., 2007). Fox et al., (2010) showed that baseline attentional biases predict cortisol reactivity eight months later while controlling for neuroticism, trait anxiety, and depression. Similarly, faster shifts of attention toward masked angry faces during stress, a marker of automatic processing, was associated with higher cortisol in response to the Trier Social Stress Test (TSST; Ellenbogen et al., 2010). These findings suggest that attention training, particularly at early stages, may influence physiological indices of stress in important ways. Although techniques such as cognitive behavioral stress management (Gaab et al., 2003, 2006) and meditation (Lutz, Slagter, Dunne, & Davidson, 2008; Sood & Jones) may also attenuate cortisol levels (Brand, Holsboer-Trachsler, Naranjo, & Schmidt, 2012; Fan, Tang, & Posner, 2014; Gaab et al., 2003, 2006; Regehr, Glancy, & Pitts, 2013) and heart rate (Nyklíček, Mommersteeg, Van Beugen, Ramakers, & Van Boxtel, 2013), attentional training, which specifically aims to change attentional biases, may shed light on the causality of the relationship between attention and stress.

Few studies have examined the impact of attentional training on physiological markers of stress (Baert et al., 2012; Dandeneau et al., 2007; Heeren et al., 2012; Higgins & Hughes, 2012). Training toward happy faces increased self-esteem and lowered basal cortisol in young adults working in a stressful environment (Dandeneau et al., 2007), while six days of training facilitated disengagement away from threat and improved heart rate variability (a marker of autonomic system functioning) during the recovery phase of a simulated job interview (Baert et al., 2012).

Despite these results the exact mechanism by which attentional training occurs, remains largely unknown (Heeren et al., 2013). Attentional biases may be the result of a valence-specific system which modifies initial threat detection (Heeren et al., 2013) and/or sharpens attentional control (Heeren et al., 2013; Klumpp & Amir, 2010; Paulewicz, Blaut, & Kłosowska, 2012) which, rather than reducing early threat processing, would modify responses to incoming threat. According to this view, attentional control regulates bottom up emotional responses. This is supported by evidence that attentional control moderates the link between trait anxiety and fear during exposures to biological challenge (i.e., a single inhalation of 35% CO2 enriched gas; Richey, Keough, & Schmidt, 2012). Derryberry & Reed, (2002) also showed that strong attentional control predicts faster disengagement from threat and/or engagement toward non-threatening information, irrespective of trait anxiety. Similarly, the strength of the relationship between trait anxiety and amygdala activation in response to stress was moderated by attentional control (Bishop, 2009).These findings suggest that attentional control may play a role in the top down regulation of stress.

Taken together, there is some evidence that attentional training influences stress reactivity, but more research is necessary. Given the link between rapid threat processing and cortisol reactivity observed across several studies (Ellenbogen et al., 2006, 2010; Fox et al., 2010), it is possible that training early attentional processes may influence stress reactivity in unique ways. The present study compared training of early versus later stages of attention on the stress response as indexed by the subjective emotional response and two major biological stress systems - the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis. The SNS is triggered immediately following stress, representing an early stage of the stress response, while the HPA axis, which responds 20-30 min later (Chrousos, 2009) reflects a later stage of reactivity or adaptation to an ongoing challenge. Both salivary alpha amylase (sAA), a digestive enzyme and marker of SNS activity (Nater & Rohleder, 2009), and cortisol, the major human glucocorticoid stress hormone secreted by the HPA axis, will be collected in the present study. It is important to determine if attentional training has specific effects on the HPA axis, consistent with some past correlational research (Ellenbogen et al., 2006), or whether it influences stress reactivity across all systems (mood state, cortisol, and sAA).

In the present study, healthy participants were randomly assigned to one of three attention training manipulations: a masked condition using briefly presented stimuli (17 ms) followed by a mask (733 ms; limited conscious awareness), a supraliminal condition using pictures displayed for 750 ms (full conscious awareness), and a control condition where participants were exposed to both picture types but not required to shift attention.

Attentional training took place over three days and was aimed at facilitating attentional disengagement away from threat (angry faces) and promoting shifts of attention toward positive stimuli (happy faces). The hypotheses were: (1) attention training will elicit faster disengagement from threat, (2) attention training will attenuate mood, cortisol, and sAA reactivity post-training, (3) attention training with masked stimuli will have a more robust effect on the cortisol response to stress than supraliminal training, and (4) baseline attention control will moderate the association between attentional training and parameters of stress reactivity.

Method

Participants

Fifty-six healthy (30 female; 26 male) participants between the ages of 18 and 30 years were recruited via advertisements posted online and on the campuses of McGill and Concordia Universities (Montréal, Canada). All potential participants were screened using an in-house questionnaire which was completed via the Internet. Individuals were excluded from the study for the presence of past or current psychopathology, any severe medical condition, use of glucocorticoid medication, use of cigarettes (i.e., more than 10/week), excessive recreational drug use (i.e., cannabis use more than once a month), pregnancy, poor English language proficiency and/or previous exposure to the psychosocial stressor used in the present study (see below for details). Of the 56 participants who took part in the investigation, 18 (10 female) were randomly assigned to the supraliminal training condition, 18 (9 female) to the masked training condition, and 20 (11 female) to the control condition.

Materials

The Profile of Mood States – Bipolar Form **(Lorr & McNair, 1988)** is a 72-item, self-report questionnaire that was designed to measure six bipolar mood states. Each mood state corresponds to a scale composed of 12 adjectives. Participants rate how they currently feel on a 4 point Likert scale ranging from “much unlike this” to “very much like this”. For this study, only four of the six dimensions were examined: (1) Composed-Anxious; (2) Elated-Depressed; (3) Agreeable-Hostile; and (4) Confident-Unsure. Internal consistency (Cronbach's alpha) ranges from .75 to .92 (Lorr & McNair, 1988).

The Beck Depression Inventory_II **(Beck, Steer, Ball, & Ranieri, 1996a; Beck, Steer & Brown,1996b)** consists of 21 items to assess the severity of depressive symptoms. Test-retest reliability (Pearson r = .93) and internal consistency ($\alpha = .91$) have been shown to be high (Beck et al., 1996a, 1996b).

The Liebowitz Social Anxiety Scale **(Liebowitz, 1987)** is a 24-item questionnaire which is designed to measure levels of both fear and avoidance of social and performance situations. Each of the items is rated from 0 to 4, with high scores representing more fear and/or avoidance. Combining the total scores for fear and avoidance provides an overall score with a maximum of 144 points. The scale also provides six scores representing: total fear, total avoidance, fear of social situations, fear of performance situations, avoidance of social situations and avoidance of performance situations. Alpha coefficients for all scores were found to be in the high range (Heimberg et al., 1999).

The Fear of Negative Evaluation **(Watson & Friend, 1969)** questionnaire is a 30-item instrument which assesses levels of discomfort and distress in interpersonal interactions. The questionnaire is designed to measure the degree to which apprehension is felt in subjects when negatively evaluated. Items appear in a true-false response format. Test-retest reliability (r = .78–.94) and internal consistency (α .94–.96) have been shown to be satisfactory according to Watson & Friend (1969).

The Modified Spatial Cueing Paradigm **(Posner et al., 1980)** is an adapted stimulus detection task used in previous studies (Stormark et al., 1995; Ellenbogen et al., 2002). To examine baseline attentional biases as well as changes in the attentional bias, this task was administered on Day 1 prior to attentional training (pre-training) and again three days after the attentional training procedure was completed on Day 5 (post-training).

In this task participants fixated on a gray "+" sign placed in the center of a black background, which was flanked on both sides by a gray rectangle (3.7 cm × 3.2 cm). Participants pressed a single key as quickly and as accurately as possible when the target (a black dot) appeared in one of the rectangles. Preceding all target presentations, an emotionally valenced cue (i.e., a picture of a sad, angry, or neutral facial expression) appeared in one of the rectangles, signaling the probable location of the target on the majority of trials. Following Posner et al. (1980), valid or engagement trials (i.e., cue and target in same hemifield), and invalid or disengagement trials (i.e., cue and target in opposite hemifields) represented 75% and 25% of all trials, respectively. There were a total of 380 trials, divided into 15 blocks (5 blocks for each picture category) of 24 trials, and an additional 72 “catch” trials (48 valid, 24 invalid). Catch trials were meant to prevent participants from developing an automatic response due to the fixed cue-target intervals in this experiment and were excluded from statistical analyses. Cues (pictures) were presented for 750 ms, 200 ms, or 17 ms followed by a masking stimulus. For masked trials, the mask was presented for 183 ms immediately at the offset of the cue. At 83 ms following the offset of the cue or mask, targets were presented for 600 ms.

Subjects performed the task, using a chin rest, 57 cm away from the monitor. The center of each rectangle was 2.2° of visual angle from the fixation point. Pre-target cues were pictures selected from the MacArthur Network Face Stimuli Set (http://www.macbrain.org/resources.htm; Tottenham et al., 2009). Pictures were scaled to the same size as the background rectangles (3.7 cm × 3.2 cm) using a graphic editing software. Masks were made by cutting pictures into small pieces and randomly reassembling them. The backward masking procedure with pictures has been effectively used in other studies of automatic or pre-attentive processing (Öhman & Soares, 1998). The modified spatial cueing task was performed on a PC computer, with a 17-in. NEC color monitor. The task was programmed using the STIM Stimulus Presentation System software (version 7.584) developed by the James Long Company (Caroga Lake, NY).

The Attention Network Task **(ANT; Fan et al., 2002)** was designed to isolate three attentional networks: alerting, executive attention (i.e., attentional control) and orienting. The ANT is a combination of a flanker paradigm using arrows (Eriksen & Eriksen, 1974) and a cued RT task similar to the stimulus detection task used in this study (Posner et al., 1980). Participants indicate the direction of a centrally placed arrow that is flanked by four arrows (two on each side) which point either in the same direction as the central arrow (congruent condition) or in the opposite direction (incongruent condition). In the neutral condition, straight lines flank the central arrow.

The arrows are also preceded by one of three types of cues: a central cue, double cue or location cue. The center and double cues indicate that the arrow stimulus will occur soon, and the location cue is 100% predictive of target location. The task provides two measures of performance, RT and error rate, and the three network scores can be calculated from these measures using established formulas (see Fan et al., 2002).

The Attentional Training and Control Tasks were supraliminal and masked training paradigms based on a stimulus detection spatial cueing paradigm (Baert et al., 2010) similar to the task used at pre and post-training. The training programs were designed to facilitate attentional disengagement away from stimuli depicting threat and promote shifts of attention toward positive stimuli. To accomplish this, on all valid trials (336), the pre-target cue was a happy facial expression. For all invalid trials (336), the pre-target cue was an angry facial expression.

The supraliminal and masked training conditions differed in the exposure duration of the pre-target cue. In the former condition, facial cues were presented for 750 ms. In the masked condition, facial cues were shown for 17 ms followed by a mask for 733 ms. To ensure that participants were attending to the stimuli during these conditions, the cue-target delay varied between 100 or 500 ms. Moreover, “catch trials” (32), wherein no target was presented after the pre-target cue, were included.

In the control condition, participants viewed the same facial stimuli as shown in the other conditions, but no attentional shifting was required. That is, participants were presented with a single happy or angry facial expression on either the right or left side of a fixation point, and were required to identify the sex of the model by pressing an *M* or *F* key. Supraliminal and masked pictures were presented equally in the control condition.

The Trier Social Stress Test **(TSST; Kirschbaum, Pirke, & Hellhammer, 1993)** is a well-validated psychosocial stressor which required participants to perform a speech and mental arithmetic in front of two “expert” evaluators, one male and one female, while being recorded by audio-visual recording equipment (Kirschbaum et al., 1993). Panelists were actually well-trained confederates. Participants were asked to perform a 5 min speech discussing why they felt they are the best candidate for a job position of their choosing and were given 10 min to organize their thoughts. They were also informed that they would be given a second task by the committee after their speech, which consisted of completing a 5 min mental arithmetic challenge where they had to serially subtract 17 from 2023 as fast and as accurately as possible.

Salivary Cortisol and Alpha Amylase were assessed by having subjects express saliva directly into 6 mm polypropylene vials. Saliva samples were frozen at −20 °C until cortisol and sAA concentration determination. Cortisol levels, in µg/dl, were determined using an enzyme immunoassay (EIA) kit from Salimetrics LLC (State College, PA). The sensitivity of the cortisol assay was set at 0.012 µg/dl. The inter-and intra-assay coefficient of variation for the cortisol assays were 2.2% and 4.6% (on a range of 0.01–10 µg/dl dose), respectively. Levels of sAA, in U/ml, were determined using a commercially available kinetic reaction assay without modification to the manufacturer’s protocol from Salimetrics LLC (State College, PA; Granger, 2006). All assays were conducted in the laboratory of Dr. Dominique Walker at the Douglas Hospital Mental Health Institute, Montréal, Canada.

Procedure

This study was run across five consecutive days (Figure 1).

Day 1. Participants initially completed a battery of questionnaires to assess current levels of depression and anxiety (Table 1). They then completed the baseline (pre-training) modified spatial cueing paradigm and were randomly assigned to either the masked, supraliminal, or control condition.

Days 2–4. Participants completed their assigned attentional training or control protocol at the laboratory. The task lasted approximately 30 min.

Day 5. Participants returned to the laboratory for the final session to undergo the TSST. Testing occurred between 12:30 pm and 5:30 pm. Participants refrained from eating and drinking caffeinated or acidic beverages one hour prior to arrival at the laboratory as well as during the experimental procedures. In order to obtain a post-training assessment of attention, participants first completed the modified spatial cueing paradigm. Next, they rested on a comfortable chair in a dimly lit room listening to soft music or reading for 30 min. Following the relaxation phase participants underwent the TSST. A total of six saliva samples were collected during the session: 15 min prior to the TSST (Time −15; S1), 5 min prior to the TSST (Time −5; S2), immediately post-TSST (Time +10; S3), and in 10 min intervals after the TSST at +10 min (Time +20; S4), +20 min (Time +30; S5), +30 min (Time +40; S6) post-stress.

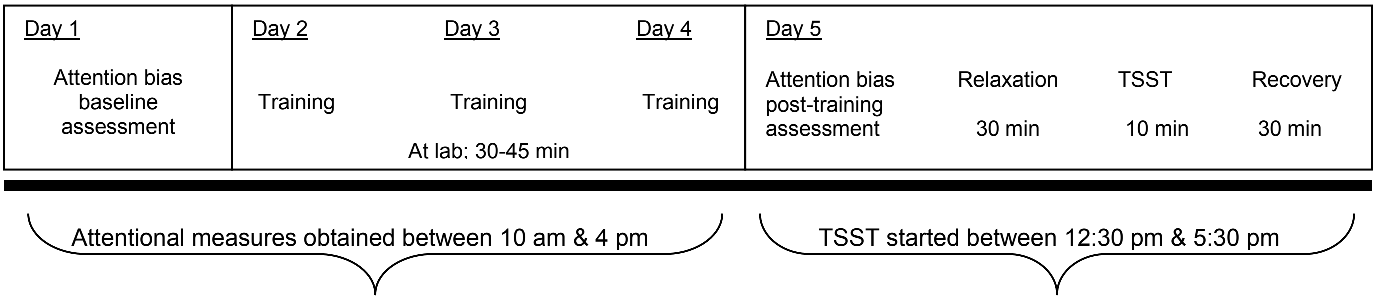

Figure 1. Sequence, timing and duration of tasks. TSST: Trier Social Stress Test.

Table 1.
Baseline measures, attention bias and mood change scores
(±standard deviation = *SD*).

Variable	Supraliminal	Masked	Control
Beck Depression Inventory_II	11.4 ± 10.1	5.1 ± 5.9	5.4 ± 4.4
Liebowitz Social Anxiety Scale	40.7 ± 20.9	28.2 ± 15.3	33 ± 18.2
Fear of Negative Evaluation	13.2 ± 4.1	13.5 ± 5.1	12.5 ± 5.5
Spatial cueing (Post-training − Pre-training; means (*SD*))			
Engagement toward threat			
750 ms threat	. 013 ± .034	−.001 ± .029	.013 ± .031
200 ms threat	−.016 ± .035	−.003 ± .030	.009 ± 046
Masked threat	−.017 ± .018	−.009 ± .023	.015 ± .034
Disengagement away from threat			
750 ms threat	.002 ± .038	.005 ± .051	−.009 ± .061
200 ms threat	−.014 ± .038	−.005 ± .043	.005 ± .046
Masked threat	.022 ± .043	−.011 ± .041	−.005 ± .068
Engagement toward sad			
750 ms sad	.002 ± .038	−.005 ± .024	.002 ± .037
200 ms sad	−.007 ± .035	−.001 ± .023	.006 ± .043
Masked sad	−.005 ± .035	−.003 ± .027	.013 ± .031
Disengagement away from sad			
750 ms sad	.006 ± .048	.021 ± .061	−.009 ± .047
200 ms sad	−.020 ± .047	−.006 ± .074	.008 ± .048
Masked sad	−.019 ± .058	.004 ± .046	.005 ± .067
Profile of Mood States Bipolar Form mood change (PostTSST − PreTSST; mean (*SD*))			
Composed-anxious	−6.78 ± 7.98	−8.18 ± 9.21	−2.73 ± 5.11
Angry-Hostile	−6.70 ± 7.25	−2.37 ± 4.34	−.473 ± 4.73
Elated-Depressed	−3.41 ± 6.80	−3.37 ± 6.25	.368 ± 5.26

Three mood assessments were also taken 5 min before the TSST (Time −5; Mood 1), directly after the TSST (Time +10; Mood 2) and 10 min after the TSST (Time +20; Mood 3). Participants were compensated 50$ CAN for their involvement and were followed up approximately one to two months later (data not reported). Procedures for this study were approved by the Concordia university Research Ethics Committee (Montréal, Canada), and all subjects provided written informed consent to participate in the study.

Statistical Analyses

RTs less than 150 ms or greater than 850 ms were considered outliers and excluded from the modified spatial cueing data. Distribution normality was assessed for all RT, questionnaire, cortisol and sAA data. The distributions for cortisol and sAA were positively skewed with substantial positive kurtosis and were therefore log transformed. For clarity of interpretation, figures depict original data. All within-subject ANCOVAs used Greenhouse Geisser corrected values where appropriate.

An index score of the speed of disengagement from angry faces was computed by subtracting RTs for invalid trials with neutral faces from RTs for invalid trials with angry faces hereafter referred to as a “disengagement score”. An index score of the speed of attentional shifting toward angry faces was computed by subtracting RTs for valid trials with angry faces from RTs for valid trials with neutral faces hereafter referred to as an “engagement score”. Positive scores on both indices indicate greater selective attention to angry faces relative to neutral faces. To examine changes in selective attention following training, difference scores were computed by subtracting disengagement and engagement scores obtained at baseline on Day 1 from Day 5 scores for each of the exposure durations (750 ms, 200 ms, and masked). Engagement and disengagement scores were also computed for valid and invalid trials with sad faces as well.

To determine whether the training conditions altered emotional information processing, spatial cueing data was analyzed with a Group (supraliminal training, masked training, control) X Sex MANCOVA using the difference scores (Day 5 − Day 1) for engagement for trials with angry faces and trials with sad faces, at the exposure durations of 17 ms, 200 ms and 750 ms. Another analysis was performed using the difference scores for disengagement for trials with angry faces and trials with sad faces, at the exposure durations of 17 ms, 200 ms and 750 ms. For the ANT, an attentional control score was calculated by subtracting RTs in the congruent flanker condition from RTs in the incongruent flanker condition. Difference scores were also created for the ANT RTs to examine training-related change in attentional control (Day 5 − Day 1).

To examine whether attentional training influenced cortisol reactivity during the TSST, a Group X Sex X Time (samples 1–6) mixed design ANCOVA was conducted on mean salivary cortisol levels. Additional Group X Sex ANCOVAs were conducted on area under the curve with respect to ground (AUCg: total hormone secretion during the experiment), as well as the area under the curve with respect to increase (AUCi: hormone increase from baseline) (Pruessner, Kirschbaum, Meinlschmid, & Hellhammer, 2003). The same analyses were conducted on sAA levels during the TSST. Planned simple contrasts and Bonferroni corrected pairwise comparisons were used to follow- up significant main effects or interactions.

To examine if attentional training influenced the mood response to stress, change scores were computed by subtracting baseline scores from post-stress scores on the POMS (Mood 3 − Mood 1). These data were subjected to a Group X Sex MANCOVA.

Results

Baseline Measures. One-way ANOVAs revealed that the training groups differed on baseline depression on the Beck Depression Inventory_II, *F*(2, 52) = 4.23, *p* = .02, η_p^2 = .20. Tukey's HSD tests revealed that the supraliminal group had significantly higher scores on the Beck Depression Inventory_II relative to the masked training, *p* = .038, and control conditions, *p* = .038. Therefore, we covaried for Beck Depression Inventory_II scores in all subsequent analyses.

Impact of Attentional Training on Selective Attention. Data for 9 subjects was lost due to computer failure thus the sample was n = 48 for these analyses. A Group X Sex MANCOVA was conducted on the six engagement difference scores (Day 5 − Day 1) for trials with angry and sad faces presented for 17 ms (masked), 200 ms and 750 ms durations. The multivariate test for group was not significant but the between-subject univariate ANCOVAs revealed group differences for masked stimuli depicting threat presented for 17 ms, *F*(2, 38) = 4.70, *p* = .015, η_p^2 = .20. There were no differences for stimuli depicting threat presented for 200 ms or 750 ms, nor for trials with sad faces. Planned simple contrasts revealed that both the supraliminal (*p* = .011, CI [−.055, −.007]) and the masked training groups (*p* = .024, CI [−.044, −.003]) were slower to shift attention toward masked angry faces following training relative to the control condition. Bonferroni-corrected pairwise comparisons revealed no differences between the supraliminal and masked training groups on trials with angry faces.

A Group X Sex MANCOVA on the six difference scores for disengagement from angry and sad faces presented for 17 ms, 200 ms and 750 ms revealed a Group X Sex interaction for trials with angry faces, $F(2, 38) = 3.16$, $p = .054$, $\eta_p^2 = .14$ presented for 750 ms. These results were followed up by an ANCOVA on trials with stimuli depicting threat presented for 750 ms in male and female participants. Results revealed a significant sex difference only in the supraliminal group, $F(1, 16) = 12.08$, $p = .007$, $\eta_p^2 = .57$. Simple contrasts revealed that females were faster to disengage from angry faces following supraliminal training than males ($p = .007$, CI [−.089, −.019]). In sum, the supraliminal and masked training conditions were successful in reducing attentional engagement toward masked angry faces. Supraliminal attention training also elicited more efficient disengagement from angry faces, presented with full conscious awareness (750 ms), in females compared to male participants. There were no training related effects or interactions on trials with sad faces.

Attentional Training and the Salivary Cortisol Response to Stress. A Group X Sex X Time mixed design ANCOVA on cortisol levels revealed a main effect of time, $F(2, 86) = 24.45$, $p = .000$, $\eta_p^2 = .36$, and a Group X Time interaction, $F(4, 86) = 4.07$, $p = .005$, $\eta_p^2 = .16$, (Figure 2). The interaction was followed up with a Group X Sex ANCOVA for AUCi cortisol, which revealed a significant main effect of group, $F(2, 44) = 5.07$, $p = .010$, $\eta_p^2 = .19$. Cortisol AUCi (mean ± *SD*) was 11.74 ± 8.33, 11.04 ± 9.78, and 5.55 ± 4.53, for the supraliminal, masked and control training groups, respectively. Planned simple contrasts showed that both the supraliminal ($p = .008$, CI [2.07, 12.81]) and the masked training groups ($p = .015$, CI [1.33, 11.42]) had higher AUCi cortisol than participants who were in the control condition. Bonferroni-corrected pairwise

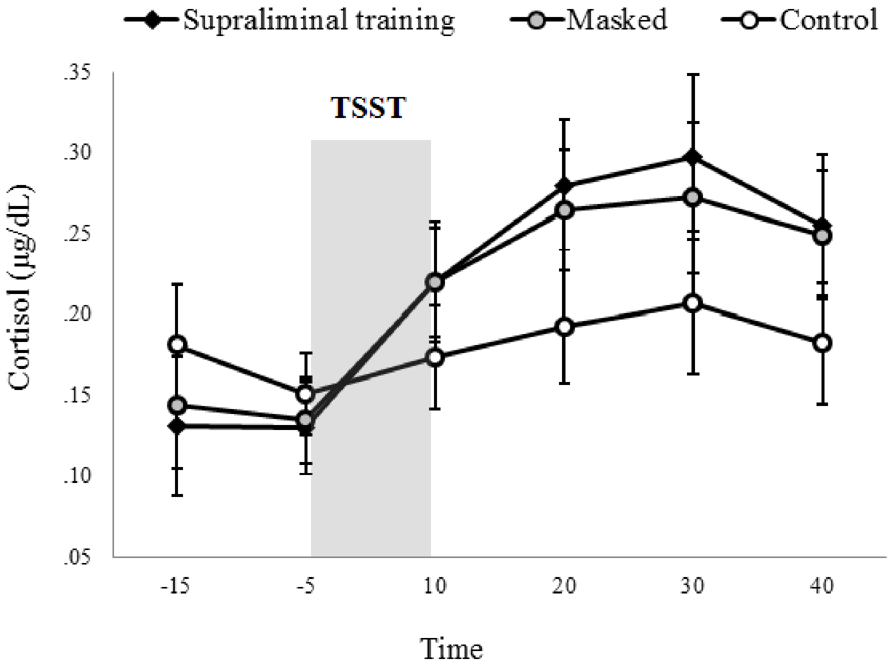

Figure 2. Salivary cortisol reactivity to the TSST across the three groups (i.e., supraliminal training, masked training and control). Bars represent standard error of the mean. Depicts values obtained before co-varying for scores on the Beck Depression Inventory_II.

comparisons revealed no additional differences between supraliminal versus masked training. Analyses were conducted on AUCg, but no group differences were found (data not shown). Cortisol AUCg (mean ± *SD*) was 20.62 ± 8.95, 21.15 ± 14.91, and 18.08 ± 16.55, for the supraliminal, masked and control training groups, respectively. Additional analyses were conducted to examine whether oral contraceptive use may have altered the findings reported above. The Group X Sex X Time analyses on cortisol levels were repeated co-varying for oral contraceptive use: both the main effect, $F(2, 94) = 34.66$, $p = .000$, $\eta_p^2 = .42$ and Group × Time interaction, $F(4, 94) = 4.09$, $p = .004$, $\eta_p^2 = .15$, were retained. In summary, the TSST elicited a significant increase in cortisol from baseline. Attentional training in both experimental groups increased the magnitude of the cortisol response to the TSST relative to participants in the control condition.

Attentional Training and the Salivary Alpha Amylase Response to Stress. The Group X Sex X Time mixed-design ANCOVA on sAA levels revealed a main effect of time, $F(4, 161) = 8.08$, $p = .000$, $\eta_p^2 = .16$, and group, $F(2, 44) = 3.98$, $p = .026$, $\eta_p^2 = .15$ (Figure 3) but no significant interactions were found. The main effect of group was followed up with a Group X Sex ANCOVA for AUCi sAA, which revealed a significant main effect of training group, $F(2, 44) = 13.90$, $p = .000$, $\eta_p^2 = .38$. sAA AUCi (mean ± *SD*) was 10527 ± 5898, 5378 ± 4060, and 4253 ± 3818, for the supraliminal, masked and control training groups, respectively. Planned simple comparisons revealed that the supraliminal training group had higher levels of sAA than the control group ($p = .000$, CI [4974, 11,254]), but there were no differences between the masked training group and controls. Bonferroni-corrected pairwise comparisons revealed that the supraliminal group also displayed higher AUCi sAA than the masked training group ($p = .002$).

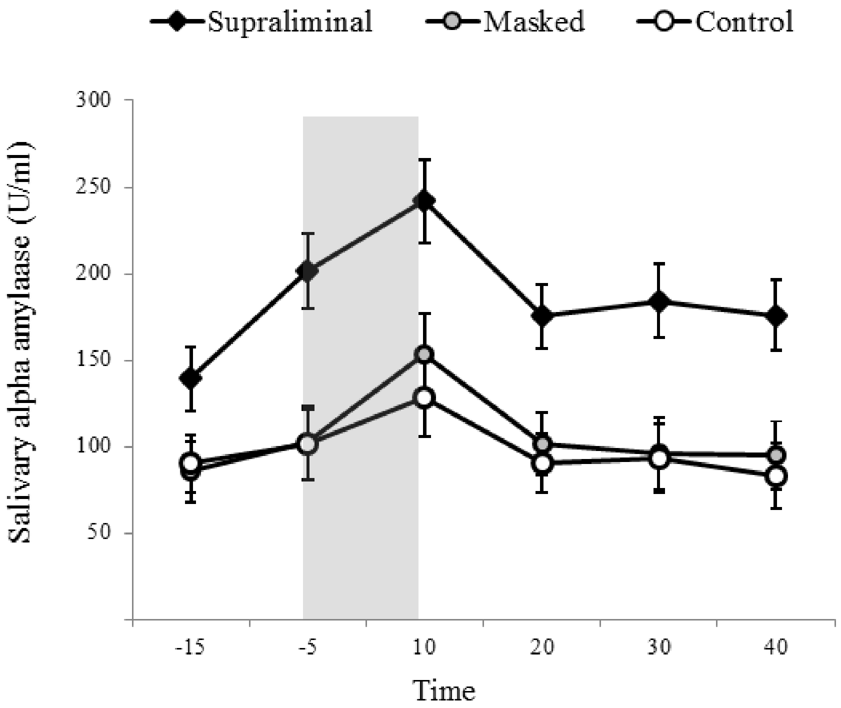

Figure 3. Salivary alpha amylase to the TSST across the three groups (i.e., supraliminal training, masked training, and control). Bars represent standard error of the mean. Depicts values obtained before co-varying for scores on the Beck Depression Inventory_II.

A Group X Sex ANCOVA on AUCg sAA also revealed a significant main effect of group, $F(2, 44) = 7.81$, $p = .001$, $\eta_p^2 = .26$. sAA AUCg (mean ± *SD*) was 20,261 ± 10,244, 11,373 ± 7767, and 10,560 ± 6122, for the supraliminal, masked and control training groups, respectively. Planned simple comparisons revealed that the supraliminal training group had higher AUCg sAA than the control group ($p = .000$, CI [5516, 17,675]), but there were no differences between the masked training and control groups. Bonferroni-corrected pairwise comparisons revealed that the supraliminal condition had elevated AUCg sAA relative to the masked group ($p = .013$). There were no significant sex differences. In summary, attentional training with supraliminal stimuli, but not with masked stimuli, elicited an increased sAA response to the TSST relative to the control condition.

Attentional Training and Mood Response to Stress. The Group X Sex MANCOVA on POMS difference scores, did not reveal a significant main effect of group, but univariate tests showed a marginally significant group difference for hostility, $F(2, 45) = 2.89$, $p = .07$, $\eta_p^2 = .11$. Planned simple contrasts showed elevated hostility post-TSST in the supraliminal training group relative to the control group ($p = .021$, CI [−8.26, −.722]). There were no significant sex differences. In sum, participants who underwent attention training exhibited marginally more hostility in response to the TSST than control participants.

Regression: Baseline Attentional Control and Stress Reactivity. In order to examine whether baseline attentional control moderates the observed association between attentional training and cortisol reactivity, a hierarchical multiple regression was performed using cortisol AUCi as the outcome. To reduce the number of predictor variables in the equation, the training groups were collapsed into a single group (coded as follows: any training = 1; control = 0). In the first step, centered baseline mean attentional control scores, Beck Depression Inventory_II scores, and training group were entered. In the second step, the training group by baseline attentional control score interaction was added. Lastly, in the third step the training group by Beck Depression Inventory_II Score interaction was added. The regression equation was significant [n = 44; R = .599, $F(5, 44) = 4.91$, $p = .001$], accounting for 28% (adjusted R^2) of the variance. Both attentional training group ($\beta = 7.44$; $t = 3.45$, $p = .01$) and the interaction between baseline attentional control and attentional training group ($\beta = -0.134$; $t = -2.24$, $p = .03$) were significant predictors of the AUCi. Thus, baseline attentional control moderated the relationship between attention training and cortisol change in response to stress (Table 2).

Simple slope analyses (Aiken & West, 1991) were performed to follow-up the significant attentional control × attention training interaction. The slope for participants with high attentional control (one standard deviation below the mean) was significantly different than zero, $t(48) = 4.21$, $p = .000$ ($-1SD$; $\beta = .77$), indicating that attention training increased cortisol reactivity in those with stronger attentional control relative to the control group (Figure 4). The slope for participants with low attentional control scores (one standard deviation above the mean), in contrast, did not differ significantly from zero ($+1SD$; $\beta = .16$), indicating that those with low attentional control did not exhibit any training-related changes in cortisol. No moderation effects were found for sAA (data not shown).

Table 2.
Standardized regression coefficients (*B*) for baseline attentional control and the interaction between group and baseline attentional control in the prediction of cortisol area under the curve with respect to increase (controlling for baseline Beck Depression Inventory_II Score).

	B	SE *B*	*β*
Step 1			
Constant	4.615	1.651	
Attentional control	−.065	.03	−.299*
Beck Depression Inventory_II	−.164	.152	−0.146
Attentional training versus control	7.852	2.134	.473*
Step 2			
Constant	5.68	1.67	
Attentional control	.005	.045	.024
Beck Depression Inventory_II	−.103	.15	−.092
Attentional training versus control	7.038	2.096	.424
Attentional training × Baseline Attentional Control	−.119	.057	−.423*
Step 3			
Constant	5.312	1.733	
Attentional control	.013	.046	.06
Beck Depression Inventory_II	−.366	.348	−.327
Attentional training versus control	7.436	2.156	.448
Attentional training × Baseline Attentional Control	−.134	.06	−.474*
Attentional training × Beck Depression Inventory_II	.324	.386	.263

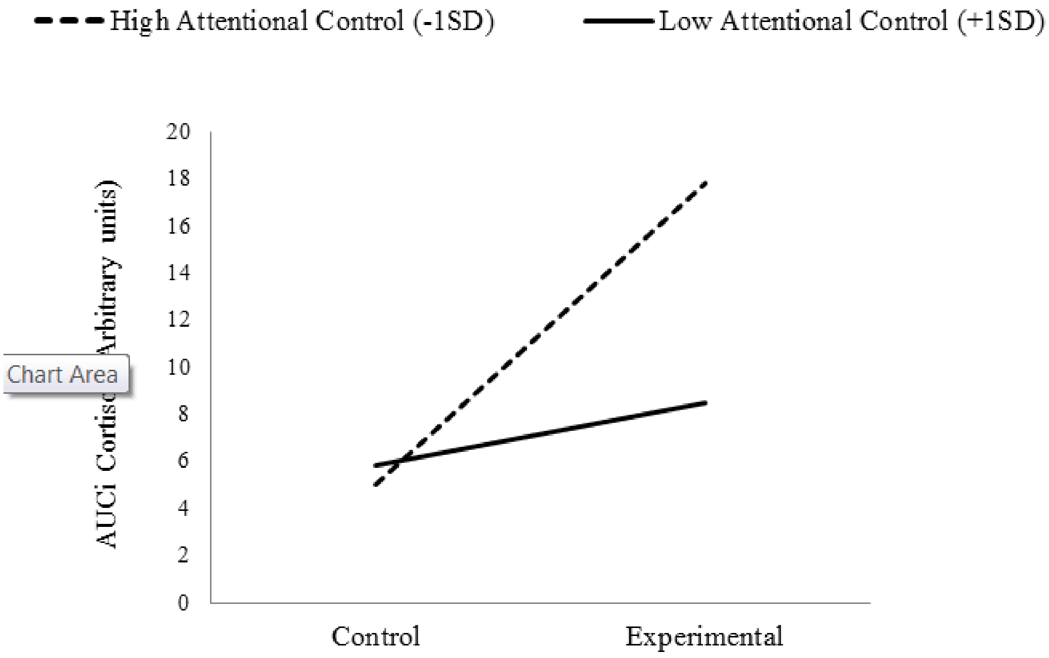

Figure 4. Simple slopes predicting the cortisol area under the curve (AUCi) response to the TSST post-training (i.e., training groups combined) versus control for 1 *SD* below the mean for attentional control and 1 *SD* above the mean for attentional control.

Discussion

The key findings of the study can be summarized as follows. First, three consecutive days of training participants to disengage attention away from threat and to shift attention toward positive stimuli altered attentional bias. Following both the supraliminal and masked training, participants were slower to shift attention toward angry faces relative to a control group, particularly for pictures presented with limited conscious awareness. Female participants were also faster to disengage away from threat post-training, but only after supraliminal training.

Second, attention training aimed at attenuating biased processing of emotional information paradoxically increased the cortisol, sAA and, to a smaller extent, the negative mood response to the TSST compared to a control training protocol that did not include attentional shifting. Although both types of training influenced stress reactivity, attention training with supraliminal stimuli had more robust effects, particularly for sAA, than training with masked stimuli. Third, the hypothesis that attentional control would moderate the relationship between attention training and reactivity to stress was partially supported. The effects of attention training on the cortisol, but not the sAA response to stress, were more robust in those with high attentional control than those with low attentional control.

To the best of our knowledge, this is the first study to demonstrate that attention training can heighten the emotional and physiological response to stress in healthy young adults, and that this effect is particularly robust among those with high attentional control. The training effect reported in this study showed remarkable consistency across systems, as increased stress reactivity was observed across three unrelated indices of stress reactivity: mood, cortisol, and sAA. Despite the robust finding, the training induced increase in stress reactivity is inconsistent with most research in this area. A number of studies have shown that even a short trial of attention training can attenuate the emotional response to stress (Amir et al., 2008; MacLeod et al., 2002), but participants typically included in these investigations have either high levels of trait anxiety (MacLeod et al., 2002) or are diagnosed with an anxiety spectrum disorder (Amir et al., 2008). Thus, attentional training may be successful in reducing stress reactivity among those with clinical symptoms of anxiety but other factors such as baseline attentional control may need to be considered in healthy populations.

Few studies have directly examined the effects of attentional training on physiological responses to stress but preliminary results have shown promise. Both a study using visual search (Dandeneau et al., 2007) or the dot probe (Baert et al., 2012) as a training intervention, showed that attentional training can diminish basal cortisol (Dandeneau et al., 2007) and heart rate variability (Baert et al., 2012). Since different attentional training tasks and physiological markers (i.e., heart–rate variability, cortisol, or sAA) were used, the results are difficult to compare to the present findings. The paucity of studies highlights the need for more research in this area.

Although it is unclear why the attentional training intervention increased stress reactivity, contrary to our prediction, it is possible that the present results are due to the use of the spatial cueing paradigm rather than the dot probe task which is most often used in attentional training research (Bar-Haim, 2010). The spatial cueing task used in this study presented subjects with a single, threatening face and required them to repeatedly disengage attention from threat on some trials and to shift toward a positive stimulus on others. The dot probe task in contrast, presents two facial or word stimuli simultaneously, thus creating competitive processing. Training individuals to allocate attention toward a neutral or positive stimulus in the presence of another threatening stimulus may have different effects than interventions which focus on modifying attentional shifting. Indeed, studies show that tasks which incorporate greater numbers of perceptual stimuli (i.e., high load), reduce external (e.g., visual) and internal (e.g., mind-wandering) distractions, sharpening attentional focus on task-relevant information (Forster & Lavie, 2009). Another potential difference between the dot probe and spatial cueing training is that the former teaches an adaptive allocation of attention while the latter promotes, in part, attentional avoidance of threat (Ellenbogen et al., 2002) which in some cases may lead to negative outcomes (Bar-Haim et al., 2010; Ellenbogen & Schwartzman, 2009; Koster et al., 2006). Finally, there is evidence that attentional training with stimuli presented in a top-bottom orientation (typical of the dot probe methodology) may be more effective in reducing anxiety than training with stimuli presented in a left-right orientation (typical of the spatial cueing methodology) (Hakamata et al., 2010).

Alternatively, the control condition in this study may have inadvertently decreased stress reactivity, so that the training interventions appeared to have increased stress reactivity but were actually unchanged. The control condition aimed to match the presentation of emotional and neutral faces between conditions without attentional shifting requiring participants to process a benign feature of the stimulus (i.e., sex of the actor). It is possible that attending to a neutral component of the emotional stimulus inadvertently trained people to ignore the emotion, reducing stress reactivity. Although this issue needs to be addressed empirically, the mean AUCi for cortisol in participants exposed to the control attentional task and the TSST in this study, was comparable to the experimental group in a similar setting in which participants did not undergo attentional training but did the TSST (Ellenbogen et al., 2010).

The present finding that attentional control moderated the effectiveness of attention training on stress reactivity is consistent with increasing evidence that training-related changes vary by pre-existing individual differences in personality and cognitive factors. Recent studies indicate that attentional training may have null (Julian, Beard, Schmidt, Powers, & Smits, 2012) or even contradictory effects in certain non-anxious populations (Klumpp & Amir, 2010). Amir et al., (2011) recently reported that attentional biases for social threat at pre-assessment predict decreases in social anxiety symptoms following attention training in those diagnosed with generalized anxiety disorder, suggesting that training interventions may be ineffective in the absence of a pre-existing attentional bias. In terms of personality factors, Higgins & Hughes, (2012) found that those with lower neuroticism had heightened cardiovascular reactivity following a putative positive intervention (i.e., shifting away from negative words). Similarly, Baert et al., (2010) found that attentional training was only beneficial in reducing depressive symptoms for individuals with mild depression and had little or even negative effects, in participants with more severe depressive symptoms.

Attentional control, the ability to pay attention to one stimulus at time without becoming distracted, plays a key role in regulating the emotional and physiological response to stress (Ochsner & Gross, 2008; Rueda, Posner, & Rothbart, 2004). Beneficial effects of high attentional control may occur in part, because they are associated with increased attentional flexibility when processing emotional information (Johnson, 2009). For example, higher attentional control has been associated with increased proficiency at disengaging attention away from threat (Derryberry & Reed, 2002) and an enhanced ability to regulate the attentional focus when presented with emotional stimuli (Kanske & Kotz, 2012). However, since in this study attentional control was paradoxically related to higher, not lower, stress reactivity following attention training it is possible that these results may be better understood from a dual systems perspective on information processing (Ouimet, Gawronski, & Dozois, 2009; Strack & Deutsch, 2004).

Ouimet et al., (2009) suggest that threat processing involves both the initial rapid response of an (automatic) associative network and the slower strategic response of a more evaluative or reflective system. Response conflicts occur when there is a mismatch between the information derived from both systems. If the rule-based system is trained over time to negate the detection of early threat, the underlying associations within the associative network, rather than diminishing, may remain intact or become strengthened resulting in a paradoxical increase in fear responses once stress is encountered later (Bar-Haim et al., 2010; Ouimet et al., 2009; Wegner, 1994).

Of particular significance to this study is the finding that individual differences in working memory capacity (i.e., attentional control) moderate the impact of associative and rule-based processes on behavioral responses (Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008). Specifically, those with high attentional control were shown to prioritize rule-based processes in governing responses to threat more than those with lower attentional control, who tended to use the associative network to guide subsequent behavioral responses to threat. In this study, among those with high attentional control, attentional training to negate biased processing of threat may have been related to changes within the associative system, but not the rule-based system. These changes in associative processes could have elicited enhanced compensatory stress reactivity by strengthening danger-related rule-based relationships and in turn, subsequent stress responses. Although low attentional control was not directly associated with cortisol attenuation, it is possible that training which modified underlying threat networks prevented the increase in stress reactivity observed in those with high attentional control.

There are several limitations to the current investigation. First, it is possible that three days of training was insufficient to elicit changes in stress reactivity. However, other studies have documented significant anxiety reduction using shorter training protocols (Amir et al., 2008). Second, the spatial cueing task used to assess the efficacy of the training protocol did not include positive stimuli, a factor that may be important to consider (Taylor et al., 2011). Therefore, it is not known whether training influenced the processing of positive information, despite the fact that the protocol promoted attentional shifts to happy faces.

Third, the attentional training task in this study aimed to facilitate disengagement away from angry faces while the stress-inducing facial stimuli used during the TSST were neutral, not angry, facial expressions of the committee members. It is possible, therefore, that the training did not induce a dampening effect on the stress response due to this mismatch. Previous research (Ellenbogen et al., 2006, 2010) showed that disengagement from threat was associated with lower cortisol, therefore we sought to investigate whether attentional training that sharpens this ability would result in similar benefits. It may be interesting to repeat attentional training using neutral faces or with other stimuli that better reflect specific features of the TSST context, e.g., negative evaluation. Alternatively, it is possible that the training in the present study could have stress-dampening effects in a more relevant context, during a hostile exchange or a stressor involving stimuli which depict threat.

Fourth, the present study did not test the validity of the masking procedure and therefore cannot ensure that stimuli were not consciously recognized. However, these masking procedures have been employed with success previously (Ellenbogen et al., 2006, 2010). Fifth, the present study assessed the efficacy of the training program on attentional bias using a single spatial cueing task with emotional stimuli. Given that cueing tasks have been criticized (Mogg, Holmes, Garner, & Bradley, 2008), future research should assess effects of training on attentional biases using multiple measures.

Sixth, the study was conducted in a university population and may not generalize to other populations. Finally, it is also possible that attenuating attentional engagement to threatening pictures is maladaptive in the absence of an attentional bias at baseline (Amir et al., 2011). This issue was addressed by conducting moderation analyses (i.e. examining a training X attentional bias interaction; data not shown). Although there was no evidence of an interaction between attentional biases prior to training and training-related outcomes, the sample size lacked power to adequately address the issue. Future work in this area should target vulnerable samples that exhibit biased processing of negative emotional information.

In conclusion, this study is among the first attention training manipulations to report robust paradoxical effects: three days of training attenuated attentional shifting to angry faces but increased stress reactivity on different indices of the stress response, particularly among those with high attentional control. These data raise concerns over the use of training protocols in healthy populations, suggesting that cueing-based training programs can elicit potentially negative effects on stress reactivity. In particular, persons with higher attentional control may be poor candidates for this type of intervention. Further research in this area is necessary to shed light on the potential mechanisms underlying these findings.

CHAPTER 3. TRANSITION TO STUDY 2

Study 1 examined the effects of three consecutive days of ABM training using a spatial cueing paradigm on attentional biases and on the acute stress response to psychosocial stress. A secondary aim was to assess the moderating role of baseline attentional control on these outcomes. Instead of the expected attenuation of physiological reactivity, ABM training increased the cortisol and sAA response to stress, primarily in those with higher attentional control. Participants with low attentional control, in contrast, seemed to benefit more from the intervention.

It is not known why ABM training failed to attenuate stress reactivity. One possibility is that these paradoxical findings were related to the task used. Although studies have used spatial cueing as an ABM training paradigm (Baert et al., 2010; Bar-Haim et al., 2011), most investigations have used the dot probe task (Mogoaşe et al., 2014). Thus, the goal of the present study was to compare the spatial cueing and the dot probe ABM training programs in the same study. Similar to the dot probe task, spatial cueing ABM has been shown to attenuate symptoms of mild depression in adults (Baert et al., 2010) and to reduce state anxiety in children (Bar-Haim et al., 2011). However, each type of ABM training may achieve these outcomes via a different mechanism of action. That is, although similar in their goal to reduce attentional biases for negative or threatening information, each task may achieve this by tapping into a different attentional framework.

The dot probe presents two stimuli simultaneously, side by side or above and below a fixation point. Thus, this task activates a competitive form of processing which is thought to be a critical feature of attentional biases particularly in anxious populations (Mathews & MacLeod, 2002). The modified spatial cueing ABM task in contrast, is designed to modify how efficiently individuals shift attention toward and away from specific emotional information (Posner et al., 1980). Therefore within the spatial cueing task only one stimulus type is presented at a time which presumably allows for the measurement of attentional disengagement away from threat and engagement toward adaptive information more distinctly (Koster et al., 2004). Since each paradigm targets different attentional processes, selective attention in the dot probe paradigm versus attentional shifting in the spatial cueing task, it is possible that each ABM task can exert a unique influence on either the attentional bias and/or subsequent stress reactivity.

Study 1 did not assess long-terms effects of ABM training. Several studies have demonstrated stable effects of ABM training over a period of 4 months in anxious patients (Amir et al., 2009; Amir & Taylor, 2012; Cowart & Ollendick, 2011; Eldar et al., 2012; Schmidt et al., 2009). To our knowledge there are no studies examining physiological reactivity at least two months following the termination of ABM training. Thus, another important aim of study 2 was to assess whether the effects of study 1 would remain stable over time. Since the effects of ABM training were comparable for salivary cortisol and alpha amylase in the first study, only the former was measured.

To summarize, the objectives of study 2 were, a) to examine whether as in study 1, three days of ABM using the spatial cueing task would lead to elevated salivary cortisol, b) to assess differences between the dot probe and spatial cueing ABM paradigms, c) to examine follow-up effects in response to a second identical stressor presented two months post-training, and d) to determine the moderating role of baseline attentional control on stress reactivity at both time points.

CHAPTER 4. STUDY 2:

Impact of Attention Bias Modification Training and Baseline Attentional Control on the Salivary Cortisol Response to Stress: A Comparison of Training Tasks

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Abstract

Introduction: Attention bias modification (ABM) training can reduce emotional reactivity and anxious symptoms, but less is known about its impact on neuroendocrine stress reactivity. In a previous study, ABM training using an attentional shifting (spatial cueing) paradigm paradoxically increased acute cortisol reactivity compared to a control intervention. To follow-up these findings, the present study compared the cortisol response to the Trier Social Stress Test (TSST I) following the spatial cueing intervention used in the previous study to the more commonly used dot probe ABM training. We also examined the effects of ABM training at two months post-intervention (TSST II) and whether they were moderated by attentional control.

Method: Sixty-nine participants (42 women) were randomly assigned to one of four groups: (1) dot probe ABM, (2) spatial cueing ABM, (3) a gender identification control training with no manipulation of attention, and (4) a no-training group.

Results: The cortisol response to TSST I was more pronounced in the spatial cueing training group, $F(1, 65) = 2.396$, $p = .02$, and the gender identification control group, $F(1, 65) = 2.009$, $p = .05$, than the no-training group. In contrast, ABM training with both the dot probe, $F(1, 42) = 4.72$, $p = .035$, CI [-5.198, -.193] and spatial cueing tasks, $F(1, 42) = 4.71$, $p =.036$, CI [-5.193, -.188] lead to lower cortisol reactivity during TSST II compared to TSST I, and this was pronounced in those with low attentional control at baseline, b = -3.482, t(46) = -2.54, $p = .01$.

Conclusion: These results suggest a potential delayed benefit of ABM training on neuroendocrine stress reactivity, particularly among those who have difficulty selectively attending to specific information when it is presented in the context of conflicting distractors.

KEYWORDS:
Attentional Training, Attention Bias Modification, Cortisol, Stress, Attentional Control

Introduction

Anxiety and affective disorders are characterized by attentional biases for negative stimuli (Bar-Haim et al., 2007; Mathews & MacLeod, 2005; Peckham et al., 2010). Experimental studies have used computerized attention bias modification (ABM) interventions to implicitly train attention to shift away from negative material (i.e., improving disengagement) and/or towards neutral or positive information (i.e. facilitating engagement; Bar-Haim, 2010). Subsequent changes in anxiety, mood or physiological responses post-training are theorized to occur through the change in attentional bias (Clarke et al., 2014). The most commonly used ABM paradigm is based on a selective attention task, the dot probe (MacLeod et al., 1986), which requires participants to identify a neutral stimulus (target), such as a letter or symbol, which can appear in one of two spatial locations above/below (or on the left/right of) a central fixation point. Immediately before the target presentation, an emotional (typically a threatening word or picture) and neutral stimulus appear simultaneously in the two spatial locations. For ABM training the target stimulus is always presented in the spatial location opposite the negative emotional stimulus so participants learn to allocate their attention toward neutral or positive information and away from threat.

The modified spatial cueing paradigm (Posner et al., 1980) has also been used for ABM training (Baert et al., 2010; Bar-Haim et al., 2011; Pilgrim et al., 2014). This task assesses the latency to respond to a neutral target following either a valid or invalid cue which can be emotional or neutral stimuli (e.g., a threatening word or facial image). Cues are valid when presented in the same hemifield as the target and invalid when presented to the contralateral hemifield of the target. In ABM training that aims to focus attention away from threat the target will always appear in the hemifield contralateral to the threat cue (invalid). For ABM training to facilitate processing of neutral or positive information the target will always appear in the same hemifield as the previously presented cue (valid). That is, participants learn to shift attention away (disengage) from negative stimuli but maintain or engage attention toward positive or neutral stimuli. Although both training paradigms are similar, the dot probe training relies on attentional allocation in the context of competing stimuli while spatial cueing training fosters attentional shifting with no competition. In the present study both training tasks will be compared.

A large body of research has shown that dot probe ABM training reduces anxious symptoms in clinically anxious and high trait anxiety populations (Amir et al., 2009; Amir et al., 2011; Eldar et al., 2012; Hakamata et al., 2010; Li et al., 2008; Schmidt et al., 2009; Waters et al., 2013). Several studies have also shown that ABM using the dot probe task can diminish mood reactivity in response to an acute stressor following training (Amir et al., 2008; MacLeod et al., 2002; See et al., 2009). Relative to the dot probe training, studies using the spatial cueing paradigm have been sparse. Still, this type of training can attenuate symptoms of mild depression in adults (Baert et al., 2010) and state anxiety in children (Bar-Haim et al., 2011).

In contrast to studies of behavioral outcomes few studies have examined whether ABM training alters psychophysiological and hormonal markers of stress and anxiety. Dot probe ABM training relative to a control task, attenuated the skin conductance response to a speech stressor in participants with social phobia (Heeren et al., 2012). Five days of ABM training using a visual search task was associated with lower daytime cortisol levels over the work day in young adults working in a stressful environment (Dandeneau et al., 2007). Only one investigation, to the best of our knowledge, has investigated the effects of ABM on the acute cortisol response to stress (Pilgrim et al., 2014). Participants underwent a three day spatial cueing ABM program which used either masked (with limited conscious awareness) or supraliminal (with full conscious awareness) stimuli or a control training task. The intervention successfully decreased the speed at which subjects shifted attention toward masked threatening pictures but paradoxically increased salivary cortisol and alpha amylase, as well as the emotional response to the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). Interestingly, the cortisol response to the TSST was more pronounced following ABM training in those with *high* baseline attentional control than those with *low* attentional control who tended to show the expected reduction in cortisol reactivity following the training. These findings suggest that those with efficient attentional control, which is the ability to flexibly adjust one's focus of attention toward relevant information and away from irrelevant information (Posner & Rothbart, 2007), were particularly susceptible to training-related *increases* in stress reactivity following spatial cueing ABM training which aimed to *decrease* this response.

There were two main goals of the present study. Given that ABM training using the cueing protocol paradoxically augmented stress reactivity in our previous research, the present study was designed to determine whether this effect was due to the specific type of ABM training paradigm or the choice of control task. That is, we compared ABM using the modified spatial cueing paradigm (Baert et al., 2010; Pilgrim et al., 2014) to the more commonly used dot probe ABM training (Amir et al., 2008; MacLeod et al., 2002). In addition, one hypothesis as to why the ABM training increased stress reactivity in the previous study was that the control task, where participants were presented with pictures of facial expressions of emotion and had to identify the sex of the person in the picture (“gender identification task”), could have inadvertently decreased stress reactivity. Therefore, we included a second control group which did not perform any computerized task. The second goal of the present study was to assess post-training follow-up effects of ABM training. Since the effects of ABM on symptoms of anxiety can persist for up to 4 months (Amir et al., 2009; Schmidt et al., 2009), we examined the impact of ABM training on study outcomes post-training as well as at a two month follow-up.

To summarize, healthy participants were randomly assigned to one of two active ABM groups, a dot probe or spatial cueing training intervention, or one of two control groups, the gender identification task or no training. We hypothesized that the (1) spatial cueing ABM training would reduce attentional engagement and/or disengagement biases for threat at early stages of processing and *increase* cortisol reactivity to the TSST similar to the previous study, (2) the dot probe ABM training would also reduce attentional biases for threat at early stages of processing and *decrease* cortisol reactivity to the TSST, (3) lower attentional control would be associated with reductions in cortisol reactivity following ABM while higher attentional control would lead to increased cortisol responses as in our previous study, (4) the two control tasks would not diminish the attentional bias or acute cortisol response, and (5) the effects of ABM on the cortisol response would persist or improve over time.

Method

Participants

A total of 219 participants between the ages of 18 and 30 were recruited via advertisements posted online and on the campuses of McGill and Concordia universities (Montréal, Canada). All potential participants were screened using an in-house questionnaire that was completed online. Individuals were excluded from the study for the presence of past or current psychopathology, any severe medical condition, for use of glucocorticoid medication, cigarette use (i.e., more than 10/week), recreational drugs (i.e., cannabis use more than once a month, any use of stimulants, cocaine, or narcotics), pregnancy, poor English language proficiency and/or previous exposure to the psychosocial stressor used in the present study. Based on the above criteria, 106 participants were deemed eligible to participate in the study. Of these participants, sixty-nine (42 female, 27 male) agreed to take part in the investigation with 16 (8 female) randomly assigned to the spatial cueing training group, 15 (9 female) to the dot probe group, 19 (13 female) to the gender identification control group, and 19 (11 female) to the no training control group. Of the 69 participants who completed the study up until the first TSST session, 50 completed the follow-up TSST session approximately 2 months later (Mean number of days and *SD*: 69.6 ± 31.1).

Materials

***Beck Depression Inventory – II* (BDI - II; Beck et al., 1996; Steer et al., 1999).** Individual differences in depression at baseline were assessed using the BDI - II. The BDI - II is composed of 21 items which measure depressive symptom severity. Chronbach’s alpha in this sample was .906.

***Liebowitz Social Anxiety Scale* (LSAS; Liebowitz, 1987).** Levels of social anxiety at baseline were examined using the LSAS. This questionnaire is a well-validated 24-item measure which provides an assessment of fear and avoidance in social (e.g., attending a party) and performance situations (e.g., doing a presentation) over the previous week. The total social anxiety score, which is obtained by summing the subscales for fear and avoidance, was used in this study. Chronbach's alpha in this sample was .941.

Assessment of attentional bias and attentional control

***Modified spatial cueing paradigm* (Posner et al., 1980).** In order to examine baseline attentional biases as well as changes in the attentional bias, an adapted stimulus detection task used in previous research (Ellenbogen et al., 2002; Stormark et al. , 1995) was administered prior to attentional training (Baseline; Pre– training) and following attentional training on Day 5 (Post– training).

Participants fixated on a grey "+" sign which appeared in the center of a black background and was flanked on both sides by a grey rectangle (3.7 cm X 3.2 cm). Participants pressed a single key as quickly and as accurately as possible when the target (a black dot) appeared in one of the rectangles. Preceding all target presentations, an emotionally valenced stimulus (i.e., a picture of a sad, angry, or neutral facial expression) appeared in one of the rectangles signaling the probable region of the target on the majority of trials. Following Posner et al., (1980), valid or engagement trials (i.e., cue and target are in the same hemifield), and invalid or disengagement trials (i.e., cue and target are in opposite hemifields) represented 75% and 25% of all trials respectively. There were a total of 380 trials divided into 15 blocks of 24 trials (5 blocks for each picture category), and an additional 72 “catch” trials (48 valid, 24 invalid). Catch trials were added in order to discourage automaticity of responses and were excluded from statistical analyses. Stimulus onset asynchrony (the interval between the onset of the cue and onset of the target) for valid and invalid trials was 833 or 283 ms and the interval between trials (from the offset of the target to next cue onset) was 1.85 to 2.5 seconds. Cues (pictures) were presented for 750 ms, 200 ms, or 17 ms followed by a masking stimulus for 183 ms. At 83 ms following the offset of the cue or mask targets were presented for 600 ms.

Subjects performed the task using a chin rest 57 cm away from the monitor. The center of each rectangle was 2.2° of visual angle from the fixation point. Pre-target cues were pictures from the MacArthur Network Face Stimuli Set (http://www.macbrain.org/resources.htm; Tottenham et al., 2009). Masks were made by cutting pictures into small pieces and randomly reassembling them. The backward masking procedure with pictures has been effectively used in other studies of automatic or pre-attentive processing (Öhman & Soares, 1994). The modified spatial cueing task was performed on a PC computer with a 17-in. NEC color monitor. The task was programmed using the STIM Stimulus Presentation System software (version 7.584) developed by the James Long Company (Caroga Lake, NY).

Attention network task **(ANT; Fan et al., 2002).** The ANT examines the functioning of three distinct attentional networks: alerting, executive attention (i.e., attentional control), and orienting. The task is comprised of a flanker paradigm that uses arrows (Eriksen & Eriksen, 1974) and a cued RT task similar to the stimulus detection task used in this study (Posner et al., 1980). In the present study only attentional control was assessed. Participants rapidly indicate the direction of a centrally placed arrow that is flanked by four arrows (two on each side) pointing in the same direction as the central arrow (congruent trial) or in the opposite direction (incongruent trial). In the neutral condition straight lines flank the central arrow. An overall measure of attentional control was calculated using an established RT formula (Fan et al., 2002)

Salivary cortisol. To assess salivary cortisol levels subjects expressed saliva directly into 6 mm polypropylene vials. Saliva samples were frozen at −20 °C until cortisol concentration determination. Cortisol levels, in μg/dl, were determined using an enzyme immunoassay (EIA) kit from Salimetrics LLC (State College, Pennsylvania). The sensitivity of the cortisol assay was 0.012 μg/dl. The inter- and intra-assay coefficient of variation for the cortisol assays were 6.5% and 4.6% (on a range 0.01-10 μg/dl dose), respectively. All assays were conducted at the Douglas Mental Health university Institute, Montréal, Canada.

Attention bias modification training tasks. All attentional training tasks were performed on laptop computers that participants brought home with them. Each laptop contained a link on the desktop to one of the four possible groups: dot probe ABM, spatial cueing ABM, or one of two control groups (gender identification control task or no training control). Participants were asked to open only the shortcut file on the desktop and to carefully read the instructions that detailed how to perform the task. For all participants except those in the "no training control" group, there were a total of 672 trials in each computer task, consisting of pictures of faces presented for 750 ms. The interstimulus interval (i.e., time between the offset of the picture cue and the onset of the target) varied randomly between either 100 ms or 500 ms. Additionally, in order to ensure that participants attended to the facial expressions presented, all tasks incorporated "catch trials" (24), in which an object or a color word was presented and participants were required to write down the letter "o" for an object or "c" for a color on a sheet of paper next to their laptop. These trials served the sole purpose of fostering attention to the task and were used to ensure compliance with the protocol. In order to maintain the double-blind design of the study, links to the tasks were labelled either A, B, C or D. All tasks took approximately 30 min to complete.

The spatial cueing ABM training was based on a stimulus detection task similar to those used in previous research to modify attention (Baert et al., 2010; Pilgrim et al., 2014). The training program was designed to facilitate attentional disengagement or shifts of attention away from threatening faces and to promote shifts of attention toward positive faces. To accomplish this, on all valid trials (336), the pre-target cue was a happy facial expression. For all invalid trials (336), the pre-target cue was an angry facial expression. Facial expressions were presented for 750 ms and participants were instructed to respond with a button press as quickly as possible when they detected the target stimulus.

The dot probe training program was designed to facilitate the allocation of attention to positive stimuli over threatening ones. Although the two types of training are similar, the dot probe task requires that the two faces are presented simultaneously side by side, while spatial cueing presents one picture (cue) per trial. In the dot probe task, positive and negative facial expressions are presented to the right or left of fixation for 750 ms which is followed by a dot that appears in one of the spatial locations of the pictures. For the training, participants were instructed to press a key when the target (black dot) appeared on the screen. The target always appeared in the spatial location of the positive facial cue.

In the gender identification control task, participants viewed the same emotional facial stimuli as shown in the spatial cueing and dot probe tasks but no attentional shifting was required and there was no contingency between the type of emotional face presented and the response. That is, participants were presented with a single happy or angry facial expression on either the right or left side of a fixation point, and were asked to identify the sex of the model by pressing an *M* or *F* key.

Participants in the no training control group were provided with a laptop. Upon opening the link on the desktop participants were instructed to continue their daily routine as usual. Thus, these participants did not engage in the repeated practice of any computer related task.

The Trier Social Stress Test **(TSST; Kirschbaum et al., 1993)**. The TSST is a well-validated psychosocial stressor that required participants to perform a speech and mental arithmetic in front of two "expert" evaluators (one male and one female who were actually trained confederates) while being recorded by audio-visual recording equipment (Kirschbaum et al., 1993). Participants performed a 5 min speech discussing why they felt they were the best candidate for a job position of their choosing and were allotted 10 min to prepare. They were additionally told that they would be asked to complete a second task by the committee after their speech but that they would not be given any further details until after their speech. The second task consisted of serially subtracting 17 from 2023 as fast and as accurately as possible in a 5 min mental arithmetic challenge.

Procedure

This study was run across five consecutive days followed by a second stress session approximately two months later (Figure 5).

Day 1. Participants were randomly assigned to one of the four training groups, as described above. After providing written informed consent, they completed the BDI - II and LSAS, followed by the baseline (Pre-training) modified spatial cueing task and the ANT. Next, each participant received a laptop to take home and was given detailed instructions on how to run and perform all four of the tasks they would potentially be completing.

Days 2 to 4. Participants performed ABM tasks. They were instructed to do them at approximately the same time each day in a quiet area with minimal distractions.

Day 5. Participants returned to the laboratory to undergo the first TSST which, to control for natural fluctuations in daily cortisol rhythms, occurred between 12:30 pm and 5:30 pm. Participants refrained from eating and drinking caffeinated or acidic beverages one hour prior to arrival at the laboratory as well as during the experimental procedures. In order to obtain a post-training assessment of attention, participants first completed the modified spatial cueing paradigm. Next, they rested on a comfortable chair in a dimly lit room listening to soft music or reading for 30 min. Following the relaxation phase participants underwent the TSST. A total of six saliva samples were collected during the session: 15 min prior to the onset of the TSST, (Time -15; S1), 5 min before the start of the TSST following a period of anticipation of the public speech (Time - 5; S2), immediately after the full TSST was completed (Time + 10; S3), and at 10 min intervals after the end of the TSST (Time +20, S4; Time +30, S5; and Time + 40, S6).

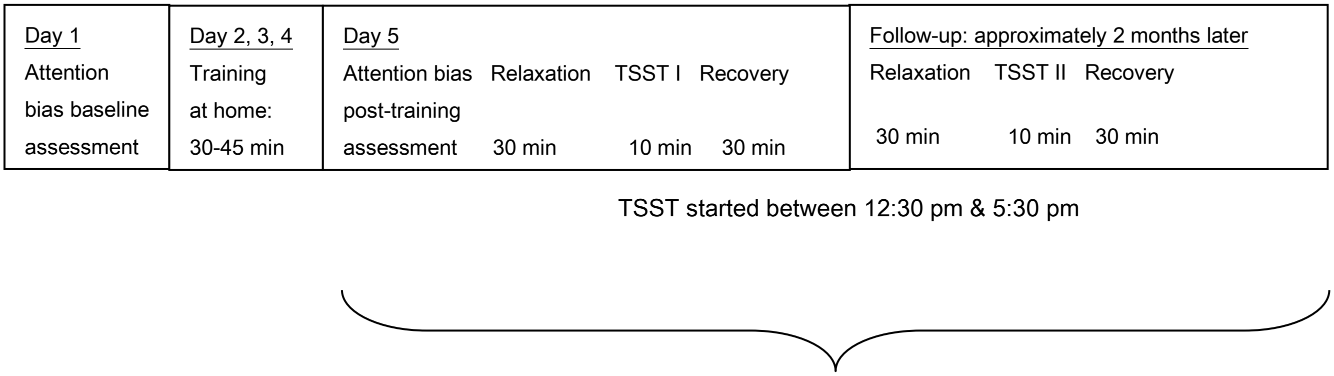


Figure 5. Sequence and duration of tasks. TSST: Trier Social Stress Test.

Three assessments of current mood state were also administered during the procedure (data not shown). At the end of this first phase of the study, participants were compensated 30$.

Follow– up: Approximately two months later, participants returned to take part in the second phase of the study which involved completing the same sequence of tasks done on Day 5. Following completion, participants were given an additional 50$ for a total of 80$. Procedures for this study were approved by the Concordia university Human Research Ethics Committee (Montréal, Canada).

Statistical Analyses

We computed a mean substitution for variables that were missing less than 5% of cases, and transformed statistical outliers above and below the mean to +/- 3 standard deviations from the mean (Tabachnick & Fidell, 2008). In cases where missing values exceeded 5%, missing cases were omitted from analyses. Distributional skew and kurtosis were within an acceptable range for all reported variables.

To examine attentional biases, RTs less than 150 ms or greater than 850 ms were excluded from analyses. An index score of the speed of disengagement from angry faces was computed by subtracting RTs for invalid trials with neutral faces from RTs for invalid trials with angry faces, hereafter referred to as *disengagement index scores*. An index score of the speed of attentional shifting toward angry faces was computed by subtracting RTs for valid trials with angry faces from RTs for valid trials with neutral faces, hereafter referred to as *engagement index scores*. These attentional index scores were computed for Day 1 (Baseline) and Day 5 (post-training). Positive scores on both indices indicate greater selective attention to angry faces relative to neutral faces. To examine the change in attentional bias following training, a difference score for attentional engagement (disengagement) for threatening and sad stimuli was computed (Table 3) by subtracting the index score for engagement (disengagement) at baseline (Pre-training) from the index score post-training on Day 5, multiplied by the beta weight reflecting the strength of the relationship between the two variables (Post-training index score – Pre-training index score * beta weight (b)). This latter computation represents the *change* in attentional bias across the two sessions. Next, these change scores were subjected to a Group (dot probe, spatial cueing, gender identification control task, no training control) X Sex MANOVA, with the engagement difference scores for angry and sad faces at the exposure durations of 17 ms, 200 ms and 750 ms as dependent variables. The MANOVA was repeated using difference scores for disengagement trials. For the ANT, an attentional control score was calculated by subtracting RTs in the congruent flanker group from RTs in the incongruent flanker group obtained on Day 1 (Baseline).

To investigate the effect of training group on cortisol reactivity, we conducted a series of Group X Sex X Time mixed-design ANOVAs using salivary cortisol levels (6 samples) as dependent variables. Within subject effects were Greenhouse-Geisser corrected for possible violations of sphericity. Statistically significant omnibus effects were followed up with simple contrasts assessing cortisol reactivity using the area under the curve with respect to increase (AuCi; Pruessner et al., 2003). To investigate *changes* in cortisol reactivity between TSST I and TSST II, we conducted a series of training Group X Sex X Phase (AuCi TSST I and TSST II) ANOVAs.

To assess attentional control as a moderator of the effect of ABM training on the attentional bias and the cortisol response to stress, we conducted a series of hierarchical multiple regressions predicting disengagement away from threat and cortisol (AuCi) during TSST I, TSST II, as well as the difference score reflecting the change from TSST I to TSST II. In these analyses the dot probe and spatial cueing were collapsed into an active training group, and the gender identification and no training control groups were combined into one control group. We collapsed across groups to improve statistical power to detect interactions using multiple regression.

Results

Baseline Measures. One-way ANOVAs comparing groups at baseline revealed no significant differences in depression (BDI – II), *F*(3, 65) = 1.42, *p* = .245, attentional control (ANT), *F*(3,65) = 1.24, *p* = .302, or anxiety (LSAS), *F*(3, 65) = .118, *p* = .949, between groups. Mean scores (±*SD)* on baseline measures for the dot probe, spatial cueing, gender identification control and no training control groups respectively, are as follows: BDI – II: 5.6 ± 9.1, 9.4 ± 9.1, 8.0 ± 6.6, and 4.8 ± 4.6; ANT: 96 ± 32, 98 ± 36, 80 ± 32, and 85 ± 30; LSAS: 38.2 ± 23.77, 35.37 ± 19.39, 36.10 ± 22.31, and 39 ± 17.49. Neither baseline LSAS scores, r = -.075, n = 69, *p* = .54 or BDI – II scores r = -.026, n = 69, *p* = .83 correlated with baseline attentional control as assessed on the ANT.

Impact of ABM on Attentional Bias. Data for 11 subjects was lost due to computer failure leaving a total sample of 58 for these attentional analyses.

Disengagement Trials. A Group X Sex MANOVA on difference scores for disengagement away from threatening faces presented at 17 ms (masked), 200 ms and 750 ms exposure durations (Table 3) found no significant main effect of Training Group, *F*(9, 117) = .718, Wilk's Λ = .877, *p* = .691, η_p^2 =.043, or Group X Sex interaction, *F*(9, 117) = .998, Wilk's Λ = .835, *p* = .446, η_p^2 =.058. Similarly, a Group X Sex MANOVA on difference scores for disengagement from sad faces found no significant multivariate main effect of Group, $F(9, 117) = 1.47$, Wilk's $\Lambda = .771$, $p = .168$, $\eta_p^2 =.083$, but did reveal a significant Group X Sex interaction, $F(9, 117) = 2.34$, Wilk's $\Lambda = .668$, $p = .018$, $\eta_p^2 =.126$. Univariate Group X Sex ANOVAs of the three exposure duration trials revealed a significant main effect of group, $F(3, 50) = 3.69$, $p = .018$, $\eta_p^2 =.181$ for disengagement trials with masked sad stimuli and a Group X Sex interaction for disengagement away from sad stimuli presented for 200 ms, $F(3, 50) = 3.66$, $p = .018$, $\eta_p^2 =.180$. A simple contrast analysis indicated that the dot probe group was slower to disengage away from masked sad stimuli compared to the no-training control group, $F(1, 54) = 4.72$, $p =.035$, CI [.002, .051] and males in the control group were faster to disengage away from sad stimuli presented for 200 ms than females in the control group, $F(1, 15) = 15.10$, $p =.001$, CI [-.092, -.027].

Engagement Trials. A Group X Sex MANOVA on difference scores for engagement towards angry faces presented at 17 ms (masked), 200 ms and 750 ms exposure durations (Table 3) found a marginally significant multivariate main effect of Group, $F(9, 117) = 1.78$, Wilk's $\Lambda = .732$, p . 08, $\eta_p^2 =.099$, and no Group X Sex interaction, $F(9, 117) = 1.26$, Wilk's $\Lambda = .798$, $p = .265$, $\eta_p^2 =.072$. Univariate analyses found a significant main effect of Group for engagement trials using threatening faces presented for 750 ms, $F(3, 50) = 3.65$, $p = .019$, $\eta_p^2 =.180$. Simple contrasts revealed that the dot probe training group was slower to engage towards threat presented for 750 ms relative to the no training control group, $F(1, 54) = 10.92$, $p =.002$, CI [-.040, -.010].

Table 3.
Attention bias (AB) regressed scores.

Variable	Dot Probe	Spatial Cueing	Gender Identification	No Training
Engagement toward threat				
750 ms threat	-.014 (.015)	.001 (.026)	.001 (.020)	.009 (.022)
200 ms threat	-.004 (.014)	.003 (.019)	-.001 (.018)	-.007 (.017)
Masked threat	-.003 (.019)	-.001 (.021)	.008 (.014)	-.006 (.024)
Disengagement away from threat				
750 ms threat	.004 (.029)	.020 (.047)	-.005 (.037)	-.000 (.036)
200 ms threat	.086 (.032)	-.008 (.023)	.007 (.034)	-.003 (.031)
Masked threat	.009 (.032)	-.007 (.023)	.007 (.034)	.003 (.031)
Engagement toward sad				
750 ms sad	-.011 (.025)	.006 (.012)	-.003 (.019)	.005 (.023)
200 ms sad	-.004 (.019)	.002 (.025)	-.014 (.017)	-.006 (.019)
Masked sad	.003 (.019)	.005 (.019)	.006 (.017)	-.012 (.025)
Disengagement away from sad				
750 ms sad	.009 (.023)	.016 (.035)	.001 (.040)	.004 (.033)
200 ms sad	-.001 (.024)	.004 (.031)	.007 (.034)	.010 (.042)
Masked sad	.019 (.018)	-.008 (.041)	-.028 (.039)	-.009 (.031)

A Group X Sex MANOVA on difference scores for engagement towards sad faces presented at 17 ms (masked), 200 ms and 750 ms exposure durations did not reveal a significant multivariate main effect of Group, *F*(9, 117) = 1.66, Wilk's Λ = .747, *p* =.107, η_p^2 =.093, or a Group X Sex interaction, *F*(9, 117) = 1.09, Wilk's Λ = .822, *p* = .375, η_p^2 =.063. Univariate ANOVAs of the three exposure duration trials did not reveal any other significant effects of Group, Sex, or Group X Sex interactions. In sum, the dot probe training resulted in slower engagement toward angry faces presented for 750 ms post-training, which was consistent with our prediction that ABM would reduce processing of threat. There were no significant effects found for supraliminal stimuli for any other condition. Training effects for masked stimuli presented with limited conscious awareness were in the opposite direction. Dot probe training resulted in slower disengagement away from masked sad stimuli as compared to participants receiving no training. No other training-related effects were observed. There were no differences between the gender identification and the no training control groups, as expected.

Effect of ABM Cortisol Reactivity during TSST I (Post-training)

A Group X Sex X Time mixed design ANOVA revealed a statistically significant main effect of time on the cortisol levels during the TSST I, *F*(1, 85) = 13.08, *p* = .000, η_p^2 =.177. An analysis of polynomial trends revealed significant linear, *F*(1, 61) = 10.09, *p* = .002, η_p^2 = .142, and quadratic effects, *F*(1, 61) = 13.25, *p* =.001, η_p^2 = .178, indicating that there was a significant increase and subsequent decrease in cortisol levels during the TSST I across all groups (Figure 6A). More importantly, this analysis also revealed a significant Group X Time interaction, *F*(4, 85) = 2.44, *p* = .05, η_p^2 =.107). A follow-up simple contrast analysis of cortisol reactivity using the AuCi for TSST I revealed that, relative to the no training control group, participants in the spatial cueing training group showed elevated cortisol reactivity, *F*(1, 65) = 5.74, *p* = .02, CI [.530, 5.84] as did participants in the gender identification control group, *F*(1, 65) = 4.034, *p* = .05, CI [.014, 5.09]. No statistically significant difference in cortisol reactivity was observed between the dot probe training and the no training control groups, *F*(1, 65) = .184, *p* = .67, CI [-2.12, 3.28]. In sum, cortisol levels increased in response to the TSST I. Cortisol reactivity was significantly higher in the spatial cueing ABM training and gender identification control groups than the no training control group.

Effect of ABM on Cortisol Reactivity during the TSST II (Follow-up)

A Group X Sex X Time mixed ANOVA revealed a statistically significant main effect of time on the cortisol response to the TSST II, *F*(2, 99) = 8.050, *p* = .000, η_p^2 =.161. An analysis of the polynomial trends again revealed both linear, *F*(1, 42) = 7.650, *p* = .008, η_p^2 = .154 and quadratic effects, *F*(1, 42) = 5.89, *p* =.02, η_p^2 = .123 suggesting that cortisol levels increased significantly in response to the TSST II followed by a subsequent decrease in cortisol (Figure 6B). The analyses also revealed a significant Group X Time interaction, *F*(7, 99) = 2.305, *p* = .032, η_p^2 =.141, and Sex by Time interaction, *F*(2, 99) = 3.74, *p* = .021, η_p^2 =.082. To follow-up these interactions, a Group X Sex Univariate ANOVA was conducted on the cortisol AUCi during TSST II. No significant group differences were observed for cortisol AUCi, *F*(3, 42) = .979, *p* = =.421, η_p^2 = .065, but a marginally significant effect of sex was found, *F*(1, 42) = 3.52, *p* = .068, η_p^2 =.077. Simple contrasts revealed higher cortisol AUCi in male participants compared to female participants, *F*(1, 48) = 3.52, *p* = .068, CI [-.162, 4.46].

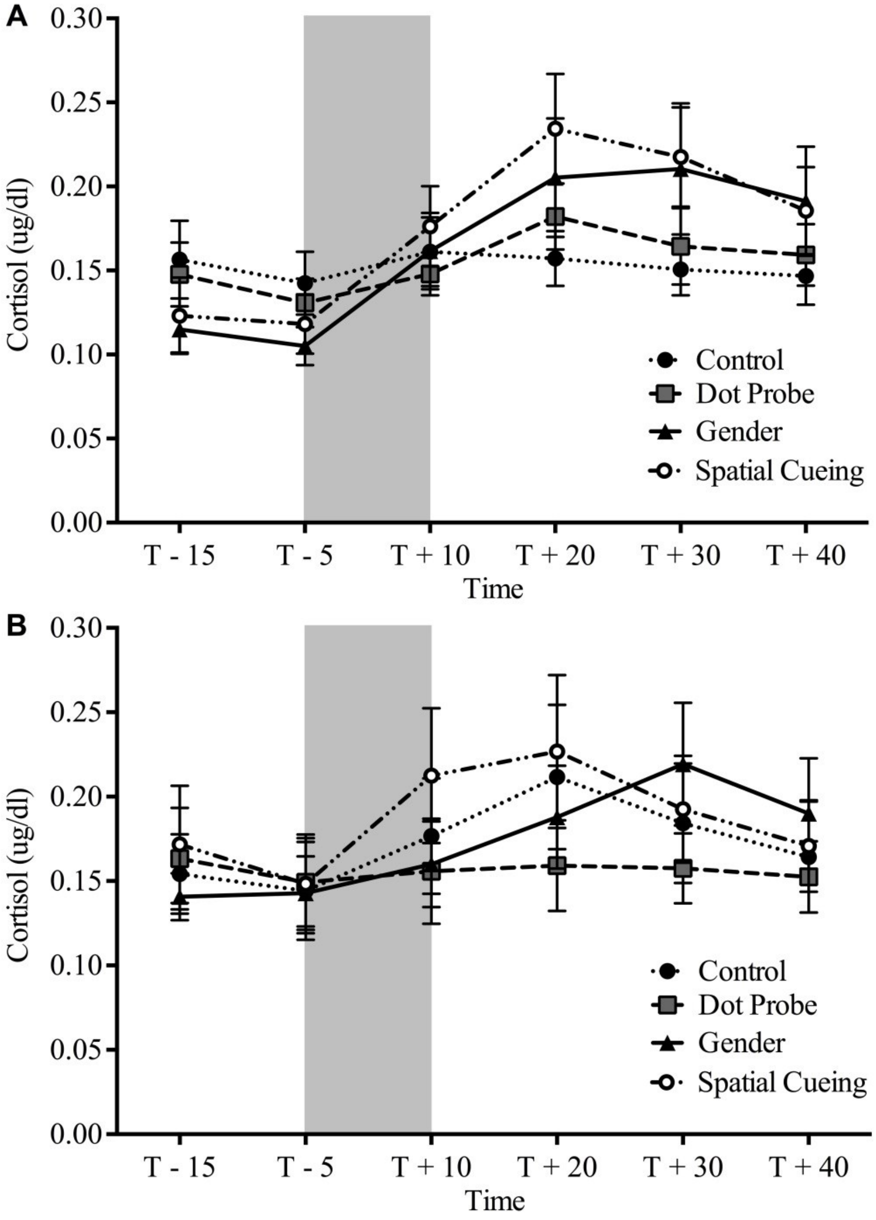


Figure 6A., B. Salivary cortisol levels during the post-training Trier Social Stress Test (TSST I; A) and follow-up (+ 2 months) (TSST II; B) in participants assigned to attention bias modification training (spatial cueing or dot probe) or a control intervention (gender identification task or no training). Bars represent standard error of the mean. The shaded area represents time spent during or in anticipation of the TSST.

Next, we computed a series of Group X Sex X Phase (AUCi TSST I and AUCi TSST II) ANOVAs to determine whether participants showed a change in cortisol reactivity from post-training to follow-up. For AUCi cortisol, these analyses did not reveal a significant main effect of Phase, $F(1, 42) = 0.172, p = .401, \eta_p^2 =.017$, but there was a significant Group by Phase interaction, $F(3, 42) = 2.97, p =.042, \eta_p^2 =.175$ and a marginally significant Sex by Phase interaction, $F(1, 42) = 3.87, p =.056, \eta_p^2 =.084$.To follow-up these interactions, a Group X Sex Univariate ANOVA was conducted on the difference score for the cortisol AUCi obtained at follow-up versus post-training (i.e., AUCi Follow-up – AUCi Post-training * b). Simple contrasts revealed significantly lower cortisol reactivity at the TSST II compared to the TSST I in both the dot probe, $F(1, 42) = 4.72, p = .035$, CI [-5.198, -.193] and spatial cueing training groups, $F(1, 42) = 4.71, p =.036$, CI [-5.193, -.188] relative to the no training control group. There was no difference between the gender identification control and the no training control groups from TSST I to TSST II, $F(1, 46) = 1.62, p = .210$, CI [-4.131, .933] (Figure 7). In sum, both ABM training protocols reduced the cortisol response to a psychosocial stressor at the two month follow-up, but not at the post-training assessment.

Does Baseline Attentional Control Moderate the Change in Attentional Bias?

Disengagement trials. To further explore the finding that ABM training reduced cortisol reactivity from post-training to follow-up, we examined whether attentional control might also moderate the relationship between training and the change in attentional bias on engagement and disengagement trials. Sex of the participant was excluded from these regression analyses because it did not have a robust influence on the effects of training on attentional biases.

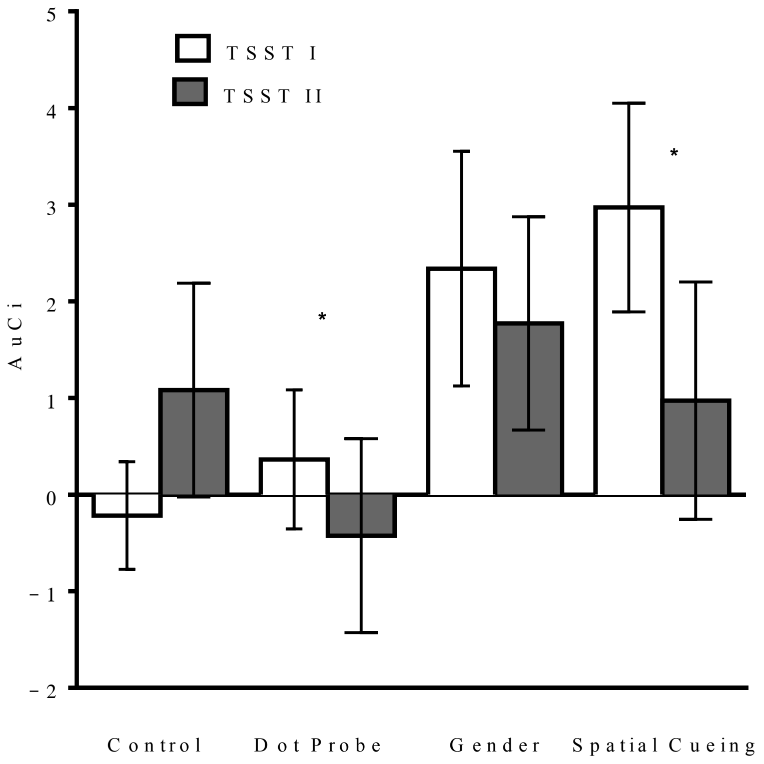


Figure 7. Salivary cortisol area under the curve with respect to increase (AUCi) during the post-training Trier Social Stress Test (TSST I) and follow-up (TSST II) across experimental groups. Bars represent standard error of the mean.

We conducted a series of hierarchical regression models using baseline attentional control and active ABM training (both cueing and dot probe training) as predictor variables in Step 1, and their interaction as a predictor in Step 2. Difference scores (Follow-up – Post-training * b) for attentional bias on disengagement and engagement trials were used as the dependent variable in these analyses. For disengagement away from masked threatening faces, the first step of the model was not statistically significant, R^2 = .05, *F*(2, 56) = 1.561, *p* = .22. However, the second step of the model was statistically significant, R^2 = .08, *F*(1, 55) = 4.972, *p* = .03, demonstrating that the training group by attentional control interaction predicted change in disengagement away from masked threat, b = -0.001, *t*(55) = -2.230, *p* = .03. To further explore this interaction, we conducted a simple slope analysis which revealed that participants with low attentional control at baseline (+*SD*) showed less attentional bias for, or faster disengagement away from, masked stimuli depicting threat in the active training groups relative to the control groups, albeit as a statistical trend, b = -0.0178, *t*(55) = -1.662, *p* = .10, whereas those with high attentional control (-*SD*) did not show this differential effect across training groups, b = 0.172, *t*(55) = 1.546, *p* = .13; Figure 8A. Similar findings were found on disengagement trials where angry faces were presented for 200 ms (Attentional Control X Group interaction, b = -0.001, *t*(54) = -2.204, *p* = .03).

For disengagement trials using angry faces presented for 750s ms, low attentional control had the opposite effect on the relationship between ABM training and attentional bias as those reported for masked and 200 ms stimuli. The analyses above were repeated and the Attentional Control X Group interaction predicted change in disengagement away from angry faces presented for 750 ms, b = 0.01, *t*(54) = 1.933, *p* = .06.

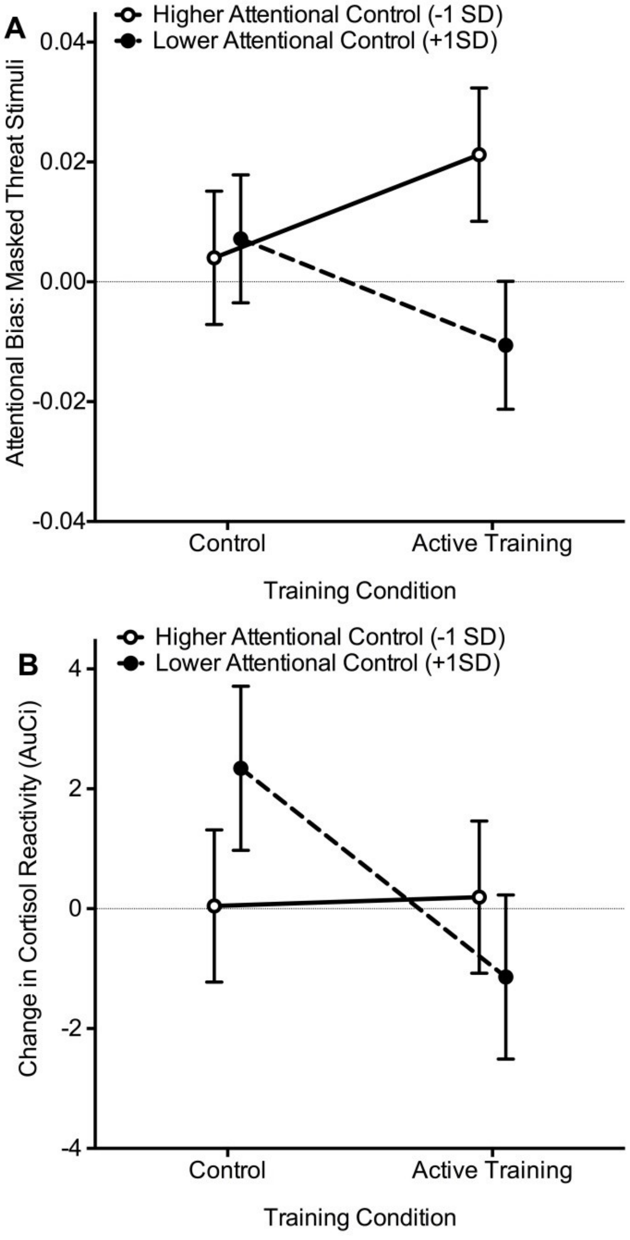


Figure 8A., B. The figure reflects the simple slope analyses which aimed to clarify the interactions between baseline attentional control and post-training disengagement away from masked stimuli depicting threat (A), and baseline attentional control and cortisol area under the curve with respect to increase from post-training to follow-up (B). The active training group refers to participants assigned to either dot probe or spatial cueing attentional bias modification training. The control group refers to participants assigned to either the gender identification control task or the no-training control condition. Attentional control is plotted as one standard deviation above and below the mean on the executive attention conflict trials of the Attention Network Task.

The simple slope analysis, however, revealed that participants with low attentional control at baseline (+*SD*) became slower to disengage away from angry faces presented for 750 ms following active training, b = 0.038, *t*(54) = 3.899, *p* = .000, whereas those with higher attentional control (-*SD*) at baseline did not show this differential effect across training groups, b = 0.000, *t*(54) = 0.041, *p* = .10.

Engagement trials. The regression models reported above were repeated using engagement difference scores. Significant results were found only for trials using angry faces presented for 750 ms. In this analysis, the group by attentional control interaction predicted change in engagement toward angry faces presented for 750 ms, b = 0.00, *t*(54) = 2.419, *p* = .02. The simple slope analysis revealed that participants with low attentional control at baseline (+*SD*) were faster to engage attention toward stimuli depicting threat presented for 750 ms following active training, b = -0.0271, *t*(54) = -2.760, *p* = .008, whereas those with high attentional control (-*SD*) at baseline did not show this differential effect across training groups, b = 0.001, *t*(54) = 0.016, *p* = .10.

In sum, in those with lower attentional control, ABM training was related to reduced attentional bias towards threat for stimuli presented at early stages of attentional processing (i.e., masked or presented for 200 ms), but with greater attentional bias at later stages of processing (i.e., when presented for 750 ms).

Does Baseline Attentional Control Moderate The Impact Of Training On Cortisol Reactivity?

To investigate whether attentional control moderated training related changes in cortisol reactivity during TSST I and TSST II, we conducted a series of hierarchical regression models using baseline attentional control and training group (collapsed across the two training programs) as predictor variables in Step 1 and their interaction as a predictor variable in Step 2. Sex of the participant was also excluded from these regression analyses because it did not have a robust influence on the effects of training on cortisol reactivity. Attentional control did not moderate the relationship between ABM training and cortisol reactivity (AUCi) during the TSST I and TSST II, but it did moderate the *change in cortisol reactivity* across the two TSST sessions, defined as the AUCi for cortisol during TSST II minus the AUCi for cortisol during the TSST1 multiplied by the beta weight. The first step of the model was not statistically significant, $R^2 = .06$, $F(2, 47) = 1.505$, $p = .23$. The second step of the model revealed a statistical trend, $R^2 = .06$, $F(1, 46) = 3.631$, $p = .06$, demonstrating an interaction between training group and attentional control in predicting cortisol reactivity at follow-up, b = -0.056, $t(46) = -1.905$, $p = .06$. To further explore this interaction, we conducted a simple slope analysis which revealed that participants with low attentional control at baseline (+ 1*SD*) showed decreased cortisol reactivity at follow-up in the active training groups relative to the control groups, b = -3.482, $t(46) = -2.54$, $p = .01$, whereas those with high attentional control (- 1*SD*) did not show this differential effect across training groups, b = 0.147, $t(46) = 0.115$, $p = .91$; Figure 8B. In summary, participants in the active training group who also had low baseline attentional control showed a decrease in cortisol reactivity from TSST I to TSST II relative to those in the control groups and those with high attentional control.

To ensure that this moderating effect was unique to baseline attentional control and not to a training induced improvement in attentional control, these analyses were repeated entering active training group and the difference score for attentional control

(Follow-up – Post-training attentional control * b). No evidence of moderation by change in attentional control was found (data not shown).

Does Baseline Attentional Control Moderate the Relationship between Attentional Bias and Cortisol Reactivity?

Since ABM training reduces attentional bias particularly at early stages of processing as well as cortisol reactivity to the TSST in participants low in attentional control, we examined whether attentional bias was associated with cortisol reactivity in participants low in attentional control. That is, we assessed whether attentional control moderated the relationship between post-training disengagement away from masked threat and the change in cortisol reactivity from post-training to follow-up. A hierarchical regression was used to predict change in stress reactivity from post-training to follow-up, with the following predictors: (1) training group (as previously described), (2) post-training disengagement away from masked threat and baseline attention control, and (3) the interaction between baseline attentional control and disengagement away from masked threat.

The first step of the model revealed a significant effect of training group on cortisol reactivity, $R^2 = .09$, $F(1, 43) = 4.26$, $p = .045$, replicating the ANOVA findings reported earlier. While the second step of the model was not significant, $R^2 = .02$, $F(2, 41) = .482$, $p = .621$, the Attention Bias X Attentional Control interaction term predicted cortisol reactivity, b = 0.387, $t(43) = 2.230$, $p = .032$. To further explore this interaction, we conducted a simple slope analysis which revealed that participants with low attentional control (+1*SD*) who had reduced attentional bias at the follow-up (+1*SD*) exhibited attenuated cortisol reactivity relative to those with high attentional control who showed increased attentional bias (-1*SD*; b = 0.703, *t*(45) = 2.82 , *p* = .007). Among participants with high attentional control, attentional bias was unrelated to cortisol reactivity, b = 0.02, *t*(45) = 0.288, *p* = .77. In sum, faster disengagement away from masked threat (i.e., reduced attentional bias) predicted diminished cortisol reactivity among participants with low attentional control, whereas disengagement away from masked threat was unrelated to cortisol reactivity in those with higher attentional control. Therefore, reduced attentional bias may represent a putative mechanism by which ABM training attenuates cortisol reactivity to the TSST over time in persons with low attentional control. This relationship was not observed among those with high attentional control.

Discussion

The goals of this investigation were to examine the impact of two different forms of ABM, spatial cueing and the dot probe task, on the cortisol response to stress and to assess whether attentional control moderates this association as observed in a previous study (Pilgrim et al., 2014). A second aim was to assess whether ABM related changes in cortisol reactivity at post-training would be maintained or improved at a follow-up two months later. The results of the study can be summarized as follows. First, the dot probe ABM reduced attentional biases for threatening faces in line with the expected effects of training. In contrast, the spatial cueing ABM training did not show any evidence of decreasing attentional bias. Second, both ABM training protocols reduced the cortisol response to a psychosocial stressor at the two month follow-up compared to post-training but not immediately post-training. Third, as predicted, attention control was a robust moderator of the effects of ABM training (combining the two training groups) on the cortisol response to stress observed at the two month follow-up but not right after the training. Relative to participants with high attentional control, participants with low attentional control exhibited greater training-related reductions of attentional bias specifically at early stages of processing immediately following the ABM intervention, as well as lower cortisol reactivity to the TSST at the follow-up assessment but not immediately after training. Moreover, supplementary analyses demonstrated that a decrease in attentional bias particularly at early stages of processing (i.e., faster disengagement away from masked threat) predicted reduced cortisol reactivity in response to the follow-up TSST, but only among those with low attentional control. Thus, these data indicated for the first time that ABM training can induce a delayed attenuation of the cortisol response to challenge and that these effects are particularly robust among participants with low attentional control.

In response to the first TSST completed the day after the last ABM session, the present study found elevated cortisol reactivity in those who underwent the spatial cueing ABM training, compared to the no training control which, in part, replicated the paradoxical findings reported in our previous study (Pilgrim et al., 2014). That is, spatial cueing ABM training to shift away from angry faces towards happy faces *increased* both negative mood ratings and the acute salivary cortisol and alpha amylase responses to the TSST (Pilgrim et al., 2014). Together, these studies suggest that the spatial cueing ABM training may increase both the subjective and physiological stress response in healthy volunteers at least in the short term.

One possible explanation of this effect is that the spatial cueing task induced attentional avoidance of threatening information, a maladaptive pattern of prolonged disengagement of attention away from negative stimuli (Cisler & Koster, 2010) sometimes observed in individuals with high anxiety (Ellenbogen & Schwartzman, 2009). ABM training studies using spatial cueing procedures have been less consistent than those using the dot probe in reducing symptoms of depression and anxiety (Baert et al., 2010; Bar-Haim et al., 2011).Thus, the present study further highlights the potential for negative outcomes following spatial cueing ABM at least in non-clinical samples. However, since there are only very few studies using this task as a training tool relative to the dot probe (Mogoaşe et al., 2014), more research is necessary to shed light on the reliability of this effect.

Unexpectedly, the dot probe ABM intervention had no influence on the cortisol response to the first TSST challenge. This null finding was inconsistent with dot probe ABM training studies of heart rate variability and skin conductance (Baert et al., 2012; Heeren et al., 2012), and one study of naturalistic cortisol levels in persons working in a stressful environment using a visual search ABM procedure (Dandeneau et al., 2007).The different post-training outcomes observed across studies might be due to the type of physiological measure under investigation in these studies, the investigation of different aspects of the stress response (naturalistic daytime levels, acute stress reactivity, or recovery following acute stress), or to the type of stressor encountered (acute laboratory stressor versus work stress). More research investigating the same outcome measures and using comparable stressors and similar ABM methods is necessary to further shed light on the effects of ABM specifically on physiological responses to acute stress.

The present investigation is the first ABM study to show reduced cortisol reactivity to a psychosocial challenge, presented for a second time approximately two months following ABM training. This highlights the importance of measuring the long-term effects of ABM training programs on physiological outcomes. A significant feature of the HPA axis is its' ability to habituate to, or dampen the body's response to repeated stress exposures to the same stimulus (Levine, 1978). Wear and tear on the mind and body (i.e., allostatic load) may ensue when responses to previously encountered stressors remain high (McEwen, 2008). One way of interpreting the present findings is that ABM training improved habituation of the stress response over time. Interestingly, healthy individuals exhibit strong habituation of the cortisol response following repeated exposures to a stressor, and this is impaired in those exhibiting a low self-concept (Kirschbaum et al., 1995; Pruessner et al., 1997), burn-out (Kudielka et al., 2006), and in those who tend to ruminate excessively following acute stress (Gianferante et al., 2014). Therefore, an initial increase in cortisol reactivity followed by subsequently lower responses to the same stressor may represent a healthy, beneficial effect of ABM training. It may be important for future ABM studies to investigate the impact of training on the stress response at several time points.

Although attentional control was unrelated to participants' cortisol response to the first stressor, it was associated with an attenuated cortisol response during the follow-up TSST, completed approximately two months post-training. It is unclear why the effect at time one which was observed in our previous study (Pilgrim et al., 2014) was not replicated in this investigation although it could be that the greater number of groups in this study (4 in this one versus 3 in the previous one) and the small sample size, lacked the power to detect the effect at both time points. Low attentional control was also associated in the current study with a training-related reduction in attentional bias for angry stimuli presented at early stages of emotional information processing and this was associated with an attenuated cortisol response to the TSST. Taken together, the present findings demonstrate that the reduction in attentional bias appears to be driving changes in cortisol reactivity over time in persons low in attentional control but not in those with high attentional control. More generally, persons with low attentional control appear to be more receptive to ABM training than participants with high attentional control.

Low attentional control as assessed on the ANT refer to difficulties focusing on relevant information which is presented in the context of conflicting distractors (Fan et al., 2002).One way of interpreting the present findings is that ABM is more effective in persons who exhibit this attentional profile at baseline. This would be consistent with the ABM literature showing a more robust, beneficial effect of ABM training in persons diagnosed with an anxiety disorder (Hakamata et al., 2010). In further support of this view, Derryberry and Reed, (2002) have shown that those with higher trait anxiety and lower self-reported attentional control evidence greater attentional biases for negative information compared to those with comparable levels of anxiety but higher reported attentional control. Therefore, it is possible that ABM training is particularly relevant to persons with poor control of voluntary attention but not among those who have strong control over attention. The implications of these findings, if replicated, suggest that screening for attentional control could lead to a better selection of persons who might benefit from an ABM intervention. Of course, the present findings require replication in clinical samples.

Another possibility to consider in the present study was whether a training-related increase in attentional control among those with low attentional control explained decreases in cortisol reactivity. No support for this hypothesis was found in a regression analysis examining *change in attentional control* as a predictor of cortisol reactivity (data not shown). This suggests that ABM in those with lower attentional control worked mainly by reducing attentional biases for negative information at early stages of processing. This would be consistent with the valence specific model which hypothesizes that ABM can modify biases for affective stimuli which tend to impact subsequent behavior and physiological responses outside of higher order attentional control (Heeren et al., 2013; Todd et al., 2012). This also suggests that those with lower attentional control may govern their behavior based more on underlying affective associations, making them more receptive to ABM interventions which target this level of processing through incidental, implicit learning (i.e., learning that occurs without an a priori intention to acquire the information and without any awareness that learning is taking place (Grafton et al., 2014; Reber, 1989). Consistent with this view, Hofmann et al., (2008) showed that automatic values about appetitive stimuli predicted how those with lower attentional control responded when confronted with this type of information, whereas controlled/explicit attitudes governed responses in those with high attentional control (Barrett et al., 2004; Strack & Deutsch, 2004). In line with the current study, this implies that fostering faster disengagement of attention away from threat at early stages of processing, targets the automatic levels of processing which tend to govern behavioral and physiological responses to stress in those with lower attentional control. This also suggests that this type of intervention would have a smaller or negligible effect in those with higher attentional control.

One reason for this may be that explicit tasks activate deliberative, controlled processes rather than the automatic processes which tend to underlie behavioral and physiological responses to acute stress (Ellenbogen et al., 2006; Grafton et al., 2014). Dual processing frameworks (Barrett et al., 2004; Strack & Deutsch, 2004) posit that this occurs because acute stress triggers a switch from a controlled, top down, reflective system of stress regulation to an automatic, bottom up, reflexive one mediated by subcortical pathways (Arnsten, 2009). Support for this comes from studies showing that implicit processes are better predictors of the acute stress response (Ellenbogen et al., 2010; Fox et al., 2010; Quirin et al., 2009) and circadian cortisol rhythms (Quirin et al., 2009) than explicit ones.

There is preliminary evidence that making ABM training tasks explicit rather than implicit has a negative influence on outcomes in some cases (Grafton et al., 2014). In those with higher trait anxiety, Grafton et al., (2014) reported no attenuating effect of training on anxiety responses to acute stress following an explicit ABM intervention compared to an implicit training procedure. Interestingly, elevated mindfulness, a heightened level of attentional awareness analogous to high attentional control (Kabat-Zinn, 2006; Teasdale et al., 1995) has also been associated with impaired incidental learning of implicit contingencies (Stillman et al., 2014; Whitmarsh et al., 2013).

There are several limitations to this study. The investigation only included university students, and therefore cannot be generalized to other populations. It is possible that ABM training would have different effects in clinical populations who have strong attentional biases. Another limitation of the current investigation is the use of the modified spatial cueing paradigm as the sole pre and post-training assessment of attentional bias. There are no studies assessing the test-retest reliability of the modified spatial cueing task, but the dot probe task, one of the most widely used assessments of attentional bias, has been criticized for poor reliability (Cisler et al., 2009). Another limitation of the spatial cueing task was the absence of trials with positive faces. We did not examine baseline or post-training responses to positive faces, which may have been important to consider (Taylor et al., 2011). Similarly, the use of only angry faces in the ABM training limits the understanding of the impact of ABM on the processing of other social facial expressions. Given that there were four conditions, the study may have also lacked sufficient power to detect interactions between specific ABM training protocols and other factors. Clearly, future studies assessing statistical moderation and mediation require larger sample sizes.

In conclusion, the study replicated the finding that ABM training using an attentional shifting task can lead to a paradoxical increase in cortisol reactivity. ABM training however, attenuated the cortisol response to acute stress at a follow-up session, approximately two months after the training was complete. Both types of training lead to lower cortisol reactivity at the follow-up assessment in participants with poor attentional control, suggesting a potential delayed benefit of ABM training in these participants. Thus, ABM training may be more effective in persons with poor attentional flexibility which has important clinical implications in terms of increasing clinical efficacy of this intervention. Further research investigating these hypotheses is warranted.

CHAPTER 5. GENERAL DISCUSSION

This dissertation aimed to address some important questions arising from the ABM training literature. There were no studies examining the impact of ABM training on the acute cortisol and sAA response to a psychosocial stressor and since studies have shown that attentional biases are associated with cortisol levels (Ellenbogen et al., 2006; Fox et al., 2010; Putman, Hermans, Koppeschaar, van Schijndel, & van Honk, 2007; Putman, Hermans, & van Honk, 2010; Putman & Roelofs, 2011), it was important to determine whether ABM training could modify cortisol reactivity in response to a psychosocial challenge.

A number of important findings arose from the two studies. First, no support for the hypothesis that ABM training would attenuate the stress response immediately post-training was found. Instead, a paradoxical effect was observed: ABM training using a spatial cueing task increased stress reactivity immediately post-training. However, study two demonstrated a delayed effect of ABM at follow-up, where participants who underwent a dot probe or spatial cueing training procedure had lower cortisol in response to the second TSST relative to a no training control. Thus, it appears that ABM training may initially sensitize the physiological response to stress, but then attenuate reactivity over time after repeated exposure to a similar psychosocial challenge. Finally, across both studies those with lower attentional control demonstrated reduced cortisol following ABM training suggesting that this intervention may be better suited to individuals with this attentional profile.

Despite the consistencies across the two studies, there were also important divergent findings. Although in study 1, attention control moderated the impact of ABM training on cortisol reactivity in response to the TSST done immediately after the ABM training, attentional control did not show this relationship in study 2. That is, in study 2 attentional control only moderated the impact of ABM training on cortisol reactivity to the second TSST done two months after the training (TSST II). It is unclear why this occurred however, since the addition of a control group in study 2 resulted in four groups compared to the three group design in study 1, combined with the relatively small sample size, study 2 may have lacked sufficient power to detect the effect of ABM following the first TSST. Another possible explanation might stem from the use of different ABM training settings. To increase accessibility and to reduce subject attrition, participants in study 2 performed the ABM training interventions at home on a laptop whereas in study 1, participants completed all three training sessions at the laboratory. Due to this change several measures were taken to ensure compliance with the task in study 2, such as, providing detailed verbal and written instructions which described when and how to perform the ABM training sessions, encouraging participants to conduct the sessions in a quiet area at the same time each day, and inserting “catch trials”, which required subjects to name whether words appearing randomly within training trials, were colors or objects. Despite these measures, it remains possible that there was still more variability in the ABM training setting in study 2 compared to study 1 which in turn impacted outcomes. Indeed, a recent meta-analysis conducted after these two studies were completed showed that ABM interventions conducted outside of the laboratory typically yield a smaller effect size than those conducted in this research setting (Mogoaşe et al., 2014). A similar set of studies should thus be replicated in the laboratory.

Discrepancies between the Present Findings and the ABM Training Literature

The present results are in contrast to two important studies which examined the impact of ABM on the neuroendocrine and cardiovascular response in a similar population of self-reported, healthy participants (Baert et al., 2012; Dandeneau et al., 2007). Using a dot probe ABM intervention, Baert et al., (2012) reported enhanced heart rate variability specifically during the recovery phase of a simulated job interview post-training. In a study which examined the circadian rhythm of cortisol in a healthy sample, Dandeneau et al., (2007) found that a five day visual search ABM training, which consisted of finding a positive face within a matrix of rejecting expressions lead to lower daytime cortisol levels during the work day, higher self-reported self-esteem and enhanced behavior as rated by blind employers.

Within clinical studies that examined the impact of ABM training on a physiological marker of acute stress reactivity, results have been mixed. In participants with social anxiety, McNally et al., (2013) reported the same degree of improvement in heart rate responses to a speech task following an ABM training intervention and a control task. Since the control intervention did not incorporate any contingency between the location of the emotional cue and the target and still yielded the same outcomes as the ABM paradigm, these findings suggested that ABM does not necessarily change outcomes via the modification of attentional bias. In contrast, in subjects with social anxiety, Heeren et al., (2012) found a superior effect of ABM on emotional, behavioral and skin conductance responses compared to a control task.

Incongruences across these investigations might be due to the use of different ABM training interventions. Most investigations used the dot probe task (Baert et al., 2012; Heeren et al., 2012; McNally et al., 2013) and some have used the visual search paradigm (Dandeneau et al., 2007) as a means to conduct ABM training. These training interventions may capitalize on a competitive form of processing as the primary means of modifying the attentional bias. The spatial cueing task used in the current dissertation, although similar, is posited to target the shifting subtype of the attentional network (Raz, 2004). Despite the inherent similarities between the dot probe and the spatial cueing task, the latter ABM training yielded a higher stress response compared to the no training condition, indicating that spatial cueing training had an augmenting effect on stress reactivity, at least in the short term. Although this is in contrast to some ABM interventions which also used the spatial cueing task to reduce anxiety (Bar-Haim et al., 2011) and mild depression (Baert et al., 2010), very few studies have used this method of training and the effect size obtained from those that have used it were recently shown to be smaller relative to studies using the dot probe (Mogoaşe et al., 2014).

Since the spatial cueing task requires participants to repeatedly disengage away from negative information which is presented on its own rather than in the context of competing stimuli, as in the dot probe, it is possible that it fosters attentional avoidance of negative affect (Ellenbogen et al., 2002). In contrast to adaptive disengagement which occurs at an early stage of attentional processing and is characterized by a rapid refocusing of attention away from irrelevant information, an avoidant attentional style develops when there is a prolonged evasion of negative stimuli (Cisler & Koster, 2010). This avoidance pattern has been associated with greater symptoms of PTSD (Bar-Haim et al., 2010; Wald, Lubin, et al., 2011; Wald, Shechner, et al., 2011) and with symptoms of clinical anxiety (Ellenbogen & Schwartzman, 2009). To shed light on whether the spatial cueing task facilitates avoidance, future ABM research should compare this training method with the visual search and dot probe interventions in a larger sample of individuals.

Previous studies examining the impact of ABM on physiological biomarkers also differed in other fundamental ways. For example, the present investigation was the first to examine the influence of ABM on the acute cortisol response while prior research in healthy samples assessed the influence of training on daytime cortisol levels (Dandeneau et al., 2007). These are distinct processes; the acute cortisol response reflects the body's immediate response to a specific challenge and daytime cortisol levels measure the circadian release of the hormone across the day. Thus, studies of the different measures of HPA activity cannot be easily compared. Previous investigations also examined different SNS biomarkers. In the present studies sAA was measured. This digestive enzyme is a correlate of norephinephrine reactivity in response to acute stress (Nater & Rohleder, 2009). Other investigations assessed skin conductance responses (Heeren et al., 2012) and cardiovascular reactivity (Baert et al., 2012; McNally et al., 2013) each of which may reflect similar but distinct measures of SNS activity. Finally, only two of the ABM studies which measured physiological responses to stress recruited healthy subjects (Baert et al., 2012; Dandeneau et al., 2007); other investigations employed participants diagnosed with social anxiety (Heeren et al., 2012; McNally et al., 2013). The use of these different methodologies may have limited the extent to which the present findings can be compared to previous studies.

Despite these differences, the findings lend to a growing body of literature examining the influence of ABM on physiological markers of acute stress reactivity. In addition, the results of this dissertation may shed some light on the mechanisms underlying the change in attentional bias following ABM interventions. Specifically, across two studies, the current findings suggest that ABM may be better suited to individuals with lower attentional control and this in turn may provide preliminary support for the valence specific model of ABM.

Theoretical Interpretations

The ABM literature highlights two different avenues through which ABM training can modify attentional biases for negative information, as well as stress reactivity (Heeren et al., 2013). One possible mechanism involves directly altering the functioning of a bottom up/valence specific system and another involves a top down/attentional control pathway. The valence specific theory postulates that in order to benefit from ABM training one must either have an attentional bias for emotional content which predisposes an individual to react in a certain manner, depending on the situation or context, or that one primarily uses this type of bottom up, affect-based system to guide and regulate behavior (Todd et al., 2012). The attentional control model in contrast suggests that ABM training works simply by sharpening higher order control over the processing of negative emotional content (Compton, 2003; Derryberry & Reed, 2002; Eysenck et al., 2007).

Support for the valence specific model comes from studies that show that the change in attentional bias following ABM can occur at very early stages of processing (O'Toole & Dennis, 2012) and also from investigations showing that the change in the attentional bias over time plays a critical role in ABM outcomes (Amir et al., 2009; Kuckertz, Gildebrant, et al., 2014). Recent findings in participants with elevated trait anxiety have lent further support to the valence specific model (Heeren et al., 2014). Heeren et al., (2014) showed that the within-subject variability, which reflected the variance that was *unique* to two baseline measures of attentional bias, was a stronger predictor of performance gains on an ABM task than the variance that was *shared* across time. These findings suggest changes in the attentional bias which occur *within sessions* predict performance improvements in response to an ABM training task (Heeren et al., 2014). The factors that predict this within-subject susceptibility to change are less well understood. According to the authors an important avenue for future ABM research will be to identify the variables that reliably predict within-subject variability of the attentional bias and to develop interventions that maximize changes (Heeren et al., 2014).

The findings of this dissertation suggest that those with poorer attentional control at baseline may be more likely to exhibit these dynamic changes in attentional bias relative to those who begin the intervention with higher attentional control. Attentional control as assessed on the ANT is a measure of conflict resolution where RTs to detect targets on congruent trials (i.e., where the person must detect the direction of a central arrow flanked on either side by arrows pointing in the *same* direction) are subtracted from those obtained on incongruent ones (i.e., where the participant must identify the direction of a central arrow flanked on either side by arrows pointing in the *opposite* direction (Fan et al., 2002). Thus, in order to perform the task quickly and accurately the individual must efficiently ignore any arrows that point in the direction opposite to the central target arrow. Poor attentional control, as reflected by larger RTs on incongruent trials, suggests that it takes participants *longer* to detect the direction of the central arrow when it is flanked by arrows pointing in the *opposite* direction compared to when the central arrow matches the direction of the other arrows. Since participants with high attentional control on the ANT may be better at ignoring certain information, it is possible that on the ABM task they filtered out the emotional content in favor of detecting the target dot as quickly and accurately as possible. If so, they may have failed to fully process the nature of the emotional associations made in the task (disengagement away from angry faces and engagement toward happy faces) compared to those with poorer attentional control. Thus, those with poor attentional control on the ANT may be better suited to benefit from tasks like ABM because they more openly process all of the affect-based associations made in an ABM paradigm without ignoring or filtering them out.

The current dissertation lacked the power to formally test for moderated mediation: i.e., to examine whether the change in the attentional bias following ABM training mediated the association between ABM training and the reduction in stress reactivity specifically in those with poor attentional control. However, the results obtained still provide some preliminary support for this hypothesis. First, compared to a control condition, ABM training led to reduced cortisol reactivity only in those with poor attentional control. Second, individuals with poor attentional control at the start of the experiment were also faster to disengage attention away from masked angry faces following ABM training. Third, low attentional control in those who were faster to disengage away from masked angry faces had lower stress reactivity. Last, the reduction in cortisol responses was not moderated by the increase in attentional control (data not shown). That is, those with low attentional control who underwent an improvement in attentional control did not necessarily have a reduced cortisol response. This suggests that

ABM outcomes were specifically moderated by baseline levels of attentional control and not by training induced improvements in attentional control.

An alternative explanation to the role of baseline attentional control in these studies may have also been that the pre-existing attentional bias moderated the impact of ABM on cortisol reactivity. The presence of an initial attentional bias has been shown to predict positive outcomes following ABM (Amir et al., 2011; Heeren et al., 2014; Kuckertz, Gildebrant, et al., 2014; O'Toole & Dennis, 2012). Across both of our investigations, follow-up regression analyses (data not shown) failed to show that the attentional bias at baseline predicted reduced cortisol responses following active ABM training. This suggests that attentional control at baseline uniquely moderated the impact of training over and above the existence of an initial attentional bias. In line with the valence specific model, these findings together provide some evidence that ABM can elicit lower cortisol reactivity through the change in attentional bias in those with poor attentional control at the start of the experiment. These findings also suggest that among participants with higher levels of attentional control at baseline ABM may be less effective.

Low Attentional Control as a Risk Factor for Maladaptive Stress Reactivity

One plausible reason for these findings might be that those with higher attentional control are better at controlling emotions in stressful contexts (Schmeichel & Demaree, 2010; Schmeichel, Volokhov, & Demaree, 2008) and thus do not require ABM interventions. That is, poor levels of attentional control may have moderated the impact of ABM training on cortisol in these studies because it is a risk factor for the development of maladaptive patterns of stress reactivity. Support for this view comes from studies showing that low self-reported attentional control is related to higher trait anxiety (Tortella-Feliu et al., 2014) and symptoms of depression (Tully, Lincoln, & Hooker, 2012). In a seminal study, Derryberry & Reed, (2002) showed that those with high levels of trait anxiety and low attentional control had an attentional bias for threatening information at both an early (stimuli shown for 250 ms) and a later stage of processing, (stimuli shown for 500 ms) while those with high trait anxiety and high attentional control only showed the bias for the former. Several studies have also shown however, that low attentional control alone is not sufficient to increase the risk of psychopathology (Susa, Pitică, Benga, & Miclea, 2012). Higher self-reported levels of fear combined with low attentional control predicted the type of attentional biases for threat typical of those with elevated symptoms of posttraumatic stress, while low attentional control in those with reduced fear did not (Susa et al., 2012). Similarly, the relationship between low attention control and attentional biases for threat was eliminated when the influence of high neuroticism was partialled out (Muris, Meesters, & Rompelberg, 2007). These findings, taken together, suggest that low attentional control may not be a risk factor for anxiety or for the types of attentional biases characteristic of clinical populations unless it is combined with other vulnerabilities.

Another possibility is that ABM training is better suited to individuals with lower attentional control because of underlying differences in the way emotional information is acquired and processed. The valence specific model posits that ABM changes the bottom up pathway while the attentional control theory postulates that ABM targets top down control. The former overlaps with an implicit mode of information processing while the attentional control model, in contrast, highlights the role of an explicit level of processing on ABM outcomes.

Implicit versus Explicit Learning

In the standard format used in the two studies comprising this dissertation, the ABM interventions were designed to change attentional biases and subsequent physiological, emotional and behavioral markers of interest by sharpening implicit information processing, but not necessarily top down, explicit modes of learning (Bar-Haim, 2010). Automatic, or implicit tasks foster learning which occurs automatically and outside of conscious awareness (Mauss, Bunge, & Gross, 2007). Implicit associations are made through repeated experience with recurrent patterns or experience (Mauss et al., 2007). Thus, if an individual has happy or sad experiences several times within a specific context, each time that person enters a similar situation the feeling and experience will be elicited automatically (Williams, Bargh, Nocera, & Gray, 2009).

In contrast, explicit learning requires that the individual has an intellectual understanding of the knowledge or the procedures that are to be learned (Mauss et al., 2007). In this context, individuals must make a conscious effort to learn and store information in memory (Mauss et al., 2007). Therefore, implicit learning capitalizes on helping individuals to learn without the use of top down effortful control. One reason that those with poorer attentional flexibility tended to respond in the intended direction of ABM training could be due to these underlying individual differences in their susceptibility to implicit learning.

Role of Attentional Control in Implicit Learning

There is accumulating evidence that attentional control moderates the extent to which the implicit versus the explicit mode of learning is used to guide emotional, physiological and behavioral responses (Hofmann et al., 2008; O'Connor, Fite, Nowlin, & Colder, 2007; Payne, 2005; Thush et al., 2008). For example, in adolescents at risk for alcohol abuse, positive *implicit* attitudes about alcohol strongly predicted how much alcohol was used in the following month in students with low levels of attentional control. Among students with high attentional control, having an *explicit* positive-attitude regarding alcohol predicted alcohol use in the following month (Thush et al., 2008). Given these findings, some researchers suggest that the effectiveness of intervention methods may be augmented by targeting the intervention to either an implicit or explicit mode of information processing for different subgroups of at-risk youth (O'Connor et al., 2007). The current research proposes a similar hypothesis in that implicit ABM training interventions may work best for those with poor attentional control while explicit forms of training may be better for those with higher attentional control.

Implicit information processing has been shown to predict emotional reactivity to stress as well. In one study, greater implicit preferences for controlling anger were associated with enhanced control over this emotion in response to a subsequent laboratory provocation (Mauss, Evers, Wilhelm, & Gross, 2006). Implicitly priming participants to better control their emotions has also reduced the level of anger expressed in response to a provocation task (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trotschel, 2001). During priming, participants have also been shown to be unaware of having been primed to pursue a specific goal or of the fact that their behavior has changed in pursuit of an underlying objective (Bargh et al., 2001; Moore, Ferguson, & Chartrand, 2011; Williams et al., 2009) Importantly, this lack of awareness *enhanced* rather than impaired execution of the desired behavior (Williams et al., 2009).

In the ABM training literature, there is also preliminary evidence suggesting that explicit instructions regarding the contingency between emotional and neutral pairings may under some circumstances, hinder rather than enhance training outcomes (Grafton et al., 2014). Grafton et al., (2014) randomly assigned healthy undergraduate students with moderate levels of trait anxiety to either an "*attend threat*" or "*avoid threat"* condition. After giving explicit instructions about the ABM training procedure, the attenuating effect of training on anxiety responses to the stressor anagram task was eliminated. The authors suggested that the ABM training intervention may have failed to modify stress reactivity because the ABM training procedures activated controlled processes rather than the implicit incidental processes which tend to drive the stress response (Grafton et al., 2014). Support for this assertion comes from studies showing that implicit processes are better predictors of the acute cortisol response (Ellenbogen et al., 2006, 2010; Fox et al., 2010; Quirin et al., 2009) and daytime cortisol levels (Quirin et al., 2009) than explicit measures. Taken together, these findings implicate the role of implicit processes specifically in determining the magnitude of cortisol reactivity following ABM. In addition, making the task explicit by increasing awareness of the task goal, particularly in those with low attentional control, may impair performance in some cases.

Recent research on mindfulness also supports this hypothesis. The "mindful" state is described as a heightened level of conscious awareness of all that is occurring in the present moment, rather than an automatic mode of consciousness with limited momentary awareness (Teasdale et al., 1995; Williams & Kuyken, 2012). Thus, high mindfulness is viewed as analogous to high attentional control (Brown & Ryan, 2003; Kabat-Zinn, 2006). High ratings of mindfulness, indicative of high attentional control, were associated with less efficient processing and learning of implicit automatic contingencies (Stillman et al., 2014), suggesting that the heightened awareness that occurs in the mindful state may not only impede the development of negative habits (e.g., maladaptive attentional biases), but the development of neutral or even positive associations as well (Stillman et al., 2014).

Rather than viewing implicit processes in a negative light, researchers assert that the capacity for implicit learning can be positive (Eagleman, 2011; Kaufman et al., 2010; Mauss et al., 2007). Recent research has associated implicit learning with high levels of verbal analogical reasoning, academic performance and aspects of personality such as openness, intuition, and reduced indecision (Kaufman et al., 2010). There is also accumulating evidence that implicit automatic processes can improve decision making while explicit, controlled processes at times impair it (Eagleman, 2011).

In the context of self-regulation, using an implicit, automatic strategy such as disengaging away from threatening content at an early stage of processing can be adaptive or maladaptive depending on the situation (Sheppes & Gross, 2011). Blocking affective information early, before it has the chance to build in intensity, has been shown to be more effective than reappraisal in the handling of higher intensity emotional information (Sheppes, Brady, & Samson, 2014; Sheppes & Meiran, 2007). With lower intensity emotions, recent research has demonstrated that both implicit (e.g., attentional disengagement) and explicit (e.g., cognitive reappraisal) processes can be equally effective (Sheppes et al., 2014). Thus, healthy emotion regulation involves knowing when to use an automatic or a controlled, effortful strategy, as neither is always superior to the other. There are also likely to be individual differences in terms of the ease with which each strategy is applied.

Overall, these findings raise the possibility that implicit processes can underlie healthy self-regulatory responses and that ABM training may target this level of learning, particularly among those with poor attentional control.

ABM Training and Habituation

The current research program showed that ABM training, particularly using the spatial cueing task, led to higher cortisol reactivity in response to the first TSST, but at follow-up, it was associated with a reduced cortisol response to the stressor. This effect occurred in both ABM training groups relative to the no training control condition, which seemed to undergo an increase in cortisol reactivity at follow-up. These findings raise the possibility that the beneficial effects of ABM for physiological processes may be most discernable following repeated exposure to a psychosocial challenge. No studies to date, have examined the effects of ABM on physiological reactivity across multiple stress exposures. Although this investigation was not a strict habituation study per se, consistent with these findings, the cortisol response to the TSST does tend to gradually decrease chiefly during the second TSST encounter in healthy individuals (Pruessner et al., 1997). This suggests that lower cortisol responses to a second stressor are an adaptive response.

Evidence suggests that failure to habituate in response to repeated stress is an indicator of both maladaptive cortisol (Deinzer, Kirschbaum, Gresele, & Hellhammer, 1997; Epel, McEwen, & Ickovics, 2010; Gunnar, Connors, & Isensee, 1989; Kirschbaum et al., 1995; Kudielka et al., 2006; Levine, 1978) and SNS reactivity (Jönsson et al., 2010; Kelsey, Soderlund, & Arthur, 2004), linked to the development of negative health outcomes (McEwen, 2008). Specific facets of personality such as trait rumination (Gianferantea et al., 2014; Johnson, Lavoie, Bacon, Carlson, & Campbell, 2012), dominance (Lee & Hughes, 2014), chronic exhaustion due to job-related stress (Kudielka et al., 2006) and low self-worth (Elfering & Grebner, 2012; Kirschbaum et al., 1995; Pruessner et al., 1997) prevent this process and are linked to less (cardiovascular and cortisol) attenuation in response to repeated stress. There are nonetheless substantial individual differences in habitation patterns (Wüst et al., 2005). Wüst et al., (2005) demonstrated that the salivary cortisol response habituated in 52% of participants exposed to the TSST, while 16% showed response sensitization across three test sessions.

Mason (1968) suggests that higher order explicit cognitive factors, such as appraisal of predictability and sense of control, explain these individual differences in the cortisol response following repeated exposure. It is possible that contextual features observed across stressful encounters dampen the response as a result of changes in the way contextual features are appraised over time. In support of this, introducing a novel element into a familiar stressor, such as increasing task difficulty, does not eliminate cardiac adaptation (Kelsey et al., 1999; Kelsey et al., 2004), but adding a social evaluative component does (Kelsey et al., 2000). In this way, when a stressful event is later appraised as only mildly threatening and controllable rather than insurmountable, it produces an adaptive neuroendocrine response characterized by short-term increases and efficient cortisol habituation in response to subsequent stressors (Epel et al., 2010).

In contrast, there is also evidence that habituation of the physiological response does not always involve complex cognitive functions (Gunnar et al., 1989; Gunnar, Hertsgaard, Larson, & Rigatuso, 1991). Forty-nine healthy newborns were subjected to two stressful physical examinations which involved undressing the infant, eliciting reflexes and rubbing the abdomen (Gunnar et al., 1989). Saliva for cortisol determination was obtained immediately before and 25 min after each exam however, the results indicated an increase in cortisol only following the first but not the second exam (Gunnar et al., 1989). Together, these findings suggest that individual differences in information processing on both an implicit and explicit level of processing can be crucial in determining physiological habituation in response to repeated stress (Blascovich, Mendes, Hunter, & Salomon, 1999; Kelsey et al., 2004).

Limitations and Future Directions

There are several limitations of the present investigations which should be addressed in future studies. The change in attentional bias was weaker in study 2 compared to study 1. One reason for this smaller effect might be due to the poor test-retest reliability of attention bias assessment tasks. In fact, the psychometric properties of these paradigms have received little to no scientific inquiry in the literature (Cisler et al., 2009; Schmukle, 2005). In addition, research also tends to demonstrate inadequate convergent validity with certain attentional bias tasks such as the modified Stroop, an RT paradigm which requires individuals to name the color of the ink an emotional or neutral word is written in, and the dot probe (Mogg et al., 2000; Van Bockstaele, Koster, Verschuere, Crombez, & De Houwer, 2012). These findings suggest that the effects of ABM training do not necessarily correlate with other tasks or generalize to other facets of emotional processing. These findings highlight the need to better understand the mechanisms through which ABM training exerts its positive effects.

The development of different ABM tasks capable of efficiently and reliably distinguishing between different components of attention such as disengagement and engagement may also provide some insight (Grafton & MacLeod, 2014). Grafton & MacLeod, (2014) argue that existing attention bias paradigms such as the dot probe and spatial cueing task do not adequately examine engagement versus disengagement by failing to properly anchor baseline attention onto a specific region of the display on every trial. The authors suggest that attentional tasks which present emotional stimuli (negative or neutral) next to the original region of attentional focus assess engagement, while presenting the information further from the prior region of attentional focus more distinctly, measures disengagement. To better isolate these attentional components, Grafton & MacLeod, (2014) have developed the Attentional Response to Distal vs. Proximal Emotional Information (ARDPEI), a variant of the dot probe and spatial cueing tasks. Based on results obtained using this task, the authors suggest that anxiety is actually characterized by deficits both in initial engagement of attention toward threat followed by impaired disengagement at later stages.

Another limitation of these studies might be the lack of a baseline exposure to the TSST prior to the ABM intervention. However, since these studies used a randomized design it is unlikely that the reported effects were influenced by baseline individual differences in stress reactivity to the TSST. Moreover, given that there is evidence of habituation following repeated exposures to the TSST, it was important to limit the number of TSSTs encountered in the study protocol.

In addition, both of these studies conducted the training interventions in different settings. In study 1, all of the ABM training sessions occurred in a quiet room in the laboratory whereas in study 2 the intervention was completed at home. Although, participants in study 2 were given detailed instructions explaining where and when to complete the training it is possible that the relatively weaker effects of study 2 were due to this difference in training settings. A recent meta-analysis has shown significantly smaller effects in studies that used home versus laboratory training (Mogoaşe et al., 2014). Thus, future research should replicate these findings when ABM training is performed in a controlled, laboratory setting.

Given these factors several methodological considerations should be put in place in future studies. First, these findings underscore the importance of accounting for attentional control in future ABM training studies as well as investigating the influence of ABM training across multiple acute stressors. Administering several measures of implicit attentional processes versus higher order attentional control, both prior to and post-ABM training may also yield critical insight into the types of individuals who may benefit from ABM training. Relevant tests for implicit learning might include the alternating serial RT task (Nissen & Bullemer, 1987; Willingham, Nissen, & Bullemer, 1989) and the artificial grammer learning test (Reber, 1989; Reber, 1967) for implicit learning. Since working memory capacity is seen as analogous to attentional control (Kane & Engle, 2002; Kane, Poole, Tuholski, & Engle, 2006) reliable and valid working memory tests (Conway et al., 2005) such as complex span tests (i.e., automated operation span; Turner & Engle, 1989) and reading span tasks (Daneman & Carpenter, 1980), in addition to the ANT used here, might be useful to employ in future studies.

Second, subsequent investigations would also benefit from employing different tests of attentional bias (e.g., the ARDPEI; Grafton & MacLeod, 2014) pre and post-training in order to ensure that changes are detected and generalizable across assessment tools. Third, based on recent studies (Abend et al., 2013; Heeren et al., 2014), it is important to examine within-subject variability in the attentional bias overtime.

Fourth, stress reactivity should be assessed at multiple time points, in a larger sample of healthy individuals. Fifth, ABM training studies using bigger sample sizes would provide sufficient power to test moderated mediation hypotheses related to attentional control. Finally, it will be important for future research to replicate these findings in individuals with elevated or clinical levels of anxiety or in those who show an attentional bias for negative information at baseline.

Conclusion

The present research suggests a complex relationship between ABM training and stress reactivity. ABM training elicited a paradoxical increase in stress reactivity which was followed by later reductions during a post-treatment follow-up. The findings highlight the need for caution when conducting ABM training in healthy participants. This research also showed that low attentional control was associated with cortisol attenuation in response to acute stress following ABM training. Thus, the findings suggest that the assessment of individual differences may be fundamental in deciding who benefits from an ABM training intervention.

REFERENCES

Abend, R., Karni, A., Sadeh, A., Fox, N. A., Pine, D. S., & Bar-Haim, Y. (2013). Learning to attend to threat accelerates and enhances memory consolidation. *PloS One, 8*(4), e62501. http://doi.org/10.1371/journal.pone.0062501

Aiken, L. S., & West, S. G. (1991). Multiple regression: Testing and interpreting interactions. Newbury Park: Sage.

Akerstedt, T., & Levi, L. (1978). Circadian rhythms in the secretion of cortisol, adrenaline and noradrenaline. *European Journal of Clinical Investigation, 8*(2), 57–58.

Amir, N., Beard, C., Burns, M., & Bomyea, J. (2009). Attention modification program in individuals with generalized anxiety disorder. *Journal of Abnormal Psychology, 118*(1), 28–33. http://doi.org/10.1037/a0012589

Amir, N., Beard, C., Taylor, C. T., Klumpp, H., Elias, J., Burns, M., & Chen, X. (2009). Attention training in individuals with generalized social phobia: A randomized controlled trial. *Journal of Consulting and Clinical Psychology, 77*(5), 961–973. http://doi.org/10.1037/a0016685

Amir, N., Taylor, C. T., & Donohue, M. C. (2011). Predictors of response to an attention modification program in generalized social phobia. *Journal of Consulting and Clinical Psychology, 79*(4), 533–541. http://doi.org/10.1037/a0023808

Amir, N., Weber, G., Beard, C., Bomyea, J., & Taylor, C. T. (2008). The effect of a single-session attention modification program on response to a public-speaking challenge in socially anxious individuals. *Journal of Abnormal Psychology, 117*(4), 860–868. http://doi.org/10.1037/a0013445

Andrews, J., Wadiwalla, M., Juster, R. P., Lord, C., Lupien, S. J., & Pruessner, J. C. (2007). Effects of manipulating the amount of social-evaluative threat on the cortisol stress response in young healthy men. *Behavioral Neuroscience, 121*(5), 871–876. http://doi.org/10.1037/0735-7044.121.5.871

Applehans, B. M., & Luecken, L. J. (2006). Attentional processes, anxiety, and the regulation of cortisol reactivity. *Anxiety, Stress & Coping, 19*(1), 81–92. http://doi.org/10.1080/10615800600565724

Arnsten, A. F. (2000). Through the looking glass: Differential noradenergic modulation of prefrontal cortical function. *Neural Plasticity, 7*(1-2), 133–146. http://doi.org/10.1155/NP.2000.133

Arnsten, A. F. T. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nature Reviews. Neuroscience, 10*(6), 410–422. http://doi.org/10.1038/nrn2648

Baert, S., Casier, A., & De Raedt, R. (2012). The effects of attentional training on physiological stress recovery after induced social threat. *Anxiety, Stress, and Coping, 25*(4), 365–379. http://doi.org/10.1080/10615806.2011.605122

Baert, S., De Raedt, R., Schacht, R., & Koster, E. H. W. (2010). Attentional bias training in depression: Therapeutic effects depend on depression severity. *Journal of Behavior Therapy and Experimental Psychiatry, 41*(3), 265–274. http://doi.org/10.1016/j.jbtep.2010.02.004

Bargh, J. A., Gollwitzer, P. M., Lee-Chai, A., Barndollar, K., & Trötschel, R. (2001). The automated will: Nonconscious activation and pursuit of behavioral goals. *Journal of Personality and Social Psychology, 81*(6), 1014–1027.

Bargh, J. A., & Pietromonaco, P. (1982). Automatic information processing and social perception: The influence of trait information presented outside of conscious awareness on impression formation. *Journal of Personality and Social Psychology, 43*(3), 437–449.

Bar-Haim, Y. (2010). Research review: Attention bias modification (ABM): A novel treatment for anxiety disorders. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 51*(8), 859–870. http://doi.org/10.1111/j.14697610.2010.02251.x

Bar-Haim, Y., Holoshitz, Y., Eldar, S., Frenkel, T. I., Muller, D., Charney, D. S., … Wald, I. (2010). Life-threatening danger and suppression of attention bias to threat. *The American Journal of Psychiatry, 167*(6), 694–698. http://doi.org/10.1176/appi.ajp.2009.09070956

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin, 133*(1), 1–24. http://doi.org/10.1037/0033-2909.133.1.1

Bar-Haim, Y., Morag, I., & Glickman, S. (2011). Training anxious children to disengage attention from threat: A randomized controlled trial. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 52*(8), 861–869. http://doi.org/10.1111/j.1469-7610.2011.02368.x

Barrett, L. F., Tugade, M. M., & Engle, R. W. (2004). Individual differences in working memory capacity and dual-process theories of the mind. *Psychological Bulletin, 130*(4), 553–573. http://doi.org/10.1037/0033-2909.130.4.553

Beard, C., Sawyer, A. T., & Hofmann, S. G. (2012). Efficacy of attention bias modification using threat and appetitive stimuli: A meta-analytic review. *Behavior Therapy, 43*(4), 724–740. http://doi.org/10.1016/j.beth.2012.01.002

Bechor, M., Pettit, J. W., Silverman, W. K., Bar-Haim, Y., Abend, R., Pine, D. S., … Jaccard, J. (2014). Attention Bias Modification Treatment for children with anxiety disorders who do not respond to cognitive behavioral therapy: A case series. *Journal of Anxiety Disorders, 28*(2), 154–159. http://doi.org/10.1016/j.janxdis.2013.09.001

Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behaviour Research and Therapy, 35*(1), 49–58.

Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. (1996). Comparison of Beck Depression Inventories -IA and -II in psychiatric outpatients. *Journal of Personality Assessment, 67*(3), 588–597. http://doi.org/10.1207/s15327752jpa6703_13

Bishop, S., Duncan, J., Brett, M., & Lawrence, A. D. (2004). Prefrontal cortical function and anxiety: Controlling attention to threat-related stimuli. *Nature Neuroscience, 7*(2), 184–188. http://doi.org/10.1038/nn1173

Bishop, S. J. (2008). Neural mechanisms underlying selective attention to threat. *Annals of the New York Academy of Sciences, 1129*, 141–152. http://doi.org/10.1196/annals.1417.016

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience, 12*(1), 92–98. http://doi.org/10.1038/nn.2242

Blascovich, J., Mendes, W. B., Hunter, S. B., & Salomon, K. (1999). Social "facilitation" as challenge and threat. *Journal of Personality and Social Psychology, 77*(1), 68–77.

Boettcher, J., Berger, T., & Renneberg, B. (2012). Internet-based attention training for social anxiety: A randomized controlled trial. *Cognitive Therapy and Research, 36*(5), 522–536. http://doi.org/10.1007/s10608-011-9374-y

Bosch, J. A., Veerman, E. C. I., de Geus, E. J., & Proctor, G. B. (2011). α-Amylase as a reliable and convenient measure of sympathetic activity: Don't start salivating just yet! *Psychoneuroendocrinology, 36*(4), 449–453. http://doi.org/10.1016/j.psyneuen.2010.12.019

Bradley, B. P., Mogg, K., & Millar, N. H. (2010). Covert and overt orienting of attention to emotional faces in anxiety. *Cognition and Emotion, 14*(6), 789–808. http://doi.org/10.1080/02699930050156636

Brand, S., Holsboer-Trachsler, E., Naranjo, J. R., & Schmidt, S. (2012). Influence of mindfulness practice on cortisol and sleep in long-term and short-term meditators. *Neuropsychobiology, 65*(3), 109–118. http://doi.org/10.1159/000330362

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84*(4), 822–848.

Brown, R. E. (2000). An introduction to neuroendocrinology. Cambridge: Cambridge University Press.

Browning, M., Holmes, E. A., Charles, M., Cowen, P. J., & Harmer, C. J. (2012). Using attentional bias modification as a cognitive vaccine against depression. *Biological Psychiatry, 72*(7), 572–579. http://doi.org/10.1016/j.biopsych.2012.04.014

Browning, M., Holmes, E. A., Murphy, S. E., Goodwin, G. M., & Harmer, C. J. (2010). Lateral prefrontal cortex mediates the cognitive modification of attentional bias. *Biological Psychiatry, 67*(10), 919–925. http://doi.org/10.1016/j.biopsych.2009.10.031

Bush, G., Luu, P., & Posner, M. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences, 4*(6), 215–222.

Carlbring, P., Apelstrand, M., Sehlin, H., Amir, N., Rousseau, A., Hofmann, S. G., & Andersson, G. (2012). Internet-delivered attention bias modification training in individuals with social anxiety disorder-a double blind randomized controlled trial. *BMC Psychiatry, 12*, 66. http://doi.org/10.1186/1471-244X-12-66

Chamberlain, S. R., & Robbins, T. W. (2013). Noradrenergic modulation of cognition: Therapeutic implications. *Journal of Psychopharmacology, 27*(8), 694–718. http://doi.org/10.1177/0269881113480988

Chatterton, R. T., Vogelsong, K. M., Lu, Y. C., Ellman, A. B., & Hudgens, G. A. (1996). Salivary alpha-amylase as a measure of endogenous adrenergic activity. *Clinical Physiology, 16*(4), 433–448.

Chrousos, G. P. (2009). Stress and disorders of the stress system. *Nature Reviews. Endocrinology, 5*(7), 374–381. http://doi.org/10.1038/nrendo.2009.106

Cisler, J. M., Bacon, A. K., & Williams, N. L. (2009). Phenomenological characteristics of attentional biases towards threat: A critical review. *Cognitive Therapy and Research, 33*(2), 221–234. http://doi.org/10.1007/s10608-007-9161-y

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30*(2), 203–216. http://doi.org/10.1016/j.cpr.2009.11.003

Clarke, P. J. F., Browning, M., Hammond, G., Notebaert, L., & MacLeod, C. (2014). The causal role of the dorsolateral prefrontal cortex in the modification of attentional bias: Evidence from transcranial direct current stimulation. *Biological Psychiatry, 76*(12), 946–952. http://doi.org/10.1016/j.biopsych.2014.03.003

Clarke, P., Notebaert, L., & MacLeod, C. (2014). Absence of evidence or evidence of absence: Reflecting on therapeutic implementations of attentional bias modification. B*MC Psychiatry, 14*, 1–6. http://doi.org/10.1186/1471-244X-14-8

Compton, R. J. (2003). The interface between emotion and attention: A review of evidence from psychology and neuroscience. *Behavioral and Cognitive Neuroscience Reviews, 2*(2), 115–129. http://doi.org/10.1177/1534582303002002003

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review, 12*(5), 769–786.

Cowart, M. J. W., & Ollendick, T. H. (2011). Attention training in socially anxious children: A multiple baseline design analysis. *Journal of Anxiety Disorders, 25*(7), 972–977. http://doi.org/10.1016/j.janxdis.2011.06.005

Dandeneau, S. D., & Baldwin, M. W. (2004). The inhibition of socially rejecting information among people with high versus low self-esteem: The role of attentional bias and the effects of bias reduction training. *Journal of Social and Clinical Psychology, 23*(4), 584–602.

Dandeneau, S. D., & Baldwin, M. W. (2009). The buffering effects of rejection-inhibiting attentional training on social and performance threat among adult students. *Contemporary Educational Psychology, 34*(1), 42–50.

Dandeneau, S. D., Baldwin, M. W., Baccus, J. R., Sakellaropoulo, M., & Pruessner, J. C. (2007). Cutting stress off at the pass: Reducing vigilance and responsiveness to social threat by manipulating attention. *Journal of Personality and Social Psychology, 93*(4), 651–666. http://doi.org/10.1037/0022-3514.93.4.651

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*(4), 450–466. http://doi.org/10.1016/S0022-5371(80)90312-6

De Kloet, E. R. (2004). Hormones and the stressed brain. *Annals of the New York Academy of Sciences, 1018*, 1–15. http://doi.org/10.1196/annals.1296.001

De Voogd, E. L., Wiers, R. W., Prins, P. J. M., & Salemink, E. (2014). Visual search attentional bias modification reduced social phobia in adolescents. *Journal of Behavior Therapy and Experimental Psychiatry, 45*(2), 252–259. http://doi.org/10.1016/j.jbtep.2013.11.006

Deinzer, R., Kirschbaum, C., Gresele, C., & Hellhammer, D. H. (1997). Adrenocortical responses to repeated parachute jumping and subsequent h-CRH challenge in inexperienced healthy subjects. *Physiology & Behavior, 61*(4), 507–511.

Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology, 111*(2), 225–236.

Derryberry, D., & Rothbart, M. K. (1997). Reactive and effortful processes in the organization of temperament. *Development and Psychopathology, 9*(4), 633–652.

Dickerson, S. S., Gruenewald, T. L., & Kemeny, M. E. (2004). When the social self is threatened: Shame, physiology, and health. *Journal of Personality, 72*(6), 1191–1216. http://doi.org/10.1111/j.1467-6494.2004.00295.x

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130*(3), 355–391. http://doi.org/10.1037/0033-2909.130.3.355

Eagleman, D. (2011). *Incognito: The Secret Lives of the Brain*. New York, NY: Pantheon Books.

Eldar, S., Apter, A., Lotan, D., Edgar, K. P., Naim, R., Fox, N. A., … Bar-Haim, Y. (2012). Attention bias modification treatment for pediatric anxiety disorders: A randomized controlled trial. *The American Journal of Psychiatry, 169*(2), 213–220.

Eldar, S., & Bar-Haim, Y. (2010). Neural plasticity in response to attention training in anxiety. *Psychological Medicine, 40*(4), 667–677. http://doi.org/10.1017/S0033291709990766

Eldar, S., Ricon, T., & Bar-Haim, Y. (2008). Plasticity in attention: Implications for stress response in children. *Behaviour Research and Therapy, 46*(4), 450–461. http://doi.org/10.1016/j.brat.2008.01.012

Elfering, A., & Grebner, S. (2012). Getting used to academic public speaking: Global self-esteem predicts habituation in blood pressure response to repeated thesis presentations. *Applied Psychophysiology and Biofeedback, 37*(2), 109–120. http://doi.org/10.1007/s10484-012-9184-3

Ellenbogen, M. A., Carson, R. J., & Pishva, R. (2010). Automatic emotional information processing and the cortisol response to acute psychosocial stress. *Cognitive, Affective & Behavioral Neuroscience, 10*(1), 71–82. http://doi.org/10.3758/CABN.10.1.71

Ellenbogen, M. A., & Schwartzman, A. E. (2009). Selective attention and avoidance on a pictorial cueing task during stress in clinically anxious and depressed participants. *Behaviour Research and Therapy, 47*(2), 128–138. http://doi.org/10.1016/j.brat.2008.10.021

Ellenbogen, M. A., Schwartzman, A. E., Stewart, J., & Walker, C.-D. (2002). Stress and selective attention: The interplay of mood, cortisol levels, and emotional information processing. *Psychophysiology, 39*(6), 723–732. http://doi.org/10.1111/1469-8986.396072

Ellenbogen, M. A., Schwartzman, A., Stewart, J., & Walker, C. D. (2006). Automatic and effortful emotional information processing regulates different aspects of the stress response. *Psychoneuroendocrinology, 31*(3), 373–387. http://doi.org/10.1016/j.psyneuen.2005.09.001

Engert, V., Vogel, S., Efanov, S. I., Duchesne, A., Corbo, V., Ali, N., & Pruessner, J. C. (2011). Investigation into the cross-correlation of salivary cortisol and alpha-amylase responses to psychological stress. *Psychoneuroendocrinology, 36*(9), 1294–1302. http://doi.org/10.1016/j.psyneuen.2011.02.018

Epel, E. S., McEwen, B. S., & Ickovics, J. R. (2010). Embodying psychological thriving: Physical thriving in response to stress. *Journal of Social Issues, 54*(2), 301–322. http://doi.org/10.1111/j.1540-4560.1998.tb01220.x

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*(1), 143–149. http://doi.org/10.3758/BF03203267

Eysenck, M. W., & Derakhshan, N. (2011). New perspectives in attentional control theory. *Personality and Individual Differences, 50*(7), 955–960.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336–353. http://doi.org/10.1037/1528-3542.7.2.336

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience, 14*(3), 340–347. http://doi.org/10.1162/089892902317361886

Fan, Y., Tang, Y.-Y., & Posner, M. I. (2014). Cortisol level modulated by integrative meditation in a dose-dependent fashion. *Stress and Health : Journal of the International Society for the Investigation of Stress, 30*(1), 65–70. http://doi.org/10.1002/smi.2497

Ferguson, M. J., & Bargh, J. A. (2004). Liking is for doing: The effects of goal pursuit on automatic evaluation. *Journal of Personality and Social Psychology, 87*(5), 557–572. http://doi.org/10.1037/0022-3514.87.5.557

Foley, P., & Kirschbaum, C. (2010). Human hypothalamus-pituitary-adrenal axis responses to acute psychosocial stress in laboratory settings. *Neuroscience and Biobehavioral Reviews, 35*(1), 91–96. http://doi.org/10.1016/j.neubiorev.2010.01.010

Forster, S., & Lavie, N. (2009). Harnessing the wandering mind: The role of perceptual load. *Cognition, 111*(3), 345–355. http://doi.org/10.1016/j.cognition.2009.02.006

Fox, E., Cahill, S., & Zougkou, K. (2010). Preconscious processing biases predict emotional reactivity to stress. *Biological Psychiatry, 67*(4), 371–377. http://doi.org/10.1016/j.biopsych.2009.11.018

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology. General, 130*(4), 681–700.

Gaab, J., Blättler, N., Menzi, T., Pabst, B., Stoyer, S., & Ehlert, U. (2003). Randomized controlled evaluation of the effects of cognitive-behavioral stress management on cortisol responses to acute stress in healthy subjects. *Psychoneuroendocrinology, 28*(6), 767–779.

Gaab, J., Sonderegger, L., Scherrer, S., & Ehlert, U. (2006). Psychoneuroendocrine effects of cognitive-behavioral stress management in a naturalistic setting-a randomized controlled trial. *Psychoneuroendocrinology, 31*(4), 428–438. http://doi.org/10.1016/j.psyneuen.2005.10.005

Gianferante, D., Thoma, M. V, Hanlin, L., Chen, X., Breines, J. G., Zoccola, P. M., & Rohleder, N. (2014). Post-stress rumination predicts HPA axis responses to repeated acute stress. *Psychoneuroendocrinology, 49*, 244–252. http://doi.org/10.1016/j.psyneuen.2014.07.021

Gilbert, P. (1998). The evolved basis and adaptive functions of cognitive distortions. *The British Journal of Medical Psychology, 71*(4), 447–463.

Grafton, B., Mackintosh, B., Vujic, T., & MacLeod, C. (2014). When ignorance is bliss: Explicit instruction and the efficacy of CBM-A for anxiety. *Cognitive Therapy and Research, 38*(2), 172–188. http://doi.org/10.1007/s10608-013-9579-3

Grafton, B., & MacLeod, C. (2014). Enhanced probing of attentional bias: The independence of anxiety-linked selectivity in attentional engagement with and disengagement from negative information. *Cognition & Emotion, 28*(7), 1287–1302. http://doi.org/10.1080/02699931.2014.881326

Grafton, B., Watkins, E., & MacLeod, C. (2012). The ups and downs of cognitive bias: Dissociating the attentional characteristics of positive and negative affectivity. *Journal of Cognitive Psychology, 24*(1), 33–53. http://doi.org/10.1080/20445911.2011.578066

Granger, D. A. (2006). Integrating the measurement of salivary α-amylase into studies of child health, development, and social relationships. *Journal of Social and Personal Relationships, 23*(2), 267–290. http://doi.org/10.1177/0265407506062479

Grissom, N., & Bhatnagar, S. (2009). Habituation to repeated stress: Get used to it. *Neurobiology of Learning and Memory, 92*(2), 215–224. http://doi.org/10.1016/j.nlm.2008.07.001

Gross, J. J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology, 39*(3), 281–291. http://doi.org/10.1017.S0048577201393198

Gruenewald, T. L., Kemeny, M. E., Aziz, N., & Fahey, J. L. (2004). Acute threat to the social self: Shame, social self-esteem, and cortisol activity. *Psychosomatic Medicine, 66*(6), 915–924. http://doi.org/10.1097/01.psy.0000143639.61693.ef

Gunnar, M. R., Connors, J., & Isensee, J. (1989). Lack of stability in neonatal adrenocortical reactivity because of rapid habituation of the adrenocortical response. *Developmental Psychobiology, 22*(3), 221–233. http://doi.org/10.1002/dev.420220304

Gunnar, M. R., Hertsgaard, L., Larson, M., & Rigatuso, J. (1991). Cortisol and behavioral responses to repeated stressors in the human newborn. *Developmental Psychobiology, 24*(7), 487–505. http://doi.org/10.1002/dev.420240704

Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., … Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry, 68*(11), 982–990. http://doi.org/10.1016/j.biopsych.2010.07.021

Hallion, L. S., & Ruscio, A. M. (2011). A meta-analysis of the effect of cognitive bias modification on anxiety and depression. *Psychological Bulletin, 137*(6), 940–958. http://doi.org/10.1037/a0024355

Hazen, R. A., Vasey, M. W., & Schmidt, N. B. (2009). Attentional retraining: A randomized clinical trial for pathological worry. *Journal of Psychiatric Research, 43*(6), 627–633. http://doi.org/10.1016/j.jpsychires.2008.07.004

Heeren, A., De Raedt, R., Koster, E. H. W., & Philippot, P. (2013). The (neuro)cognitive mechanisms behind attention bias modification in anxiety: Proposals based on theoretical accounts of attentional bias. *Frontiers in Human Neuroscience, 7*, 119. http://doi.org/10.3389/fnhum.2013.00119

Heeren, A., Mogoaşe, C., McNally, R. J., Schmitz, A., & Philippot, P. (2015). Does attention bias modification improve attentional control? A double-blind randomized experiment with individuals with social anxiety disorder. *Journal of Anxiety Disorders, 29*, 35–42. http://doi.org/10.1016/j.janxdis.2014.10.007

Heeren, A., Philippot, P., & Koster, E. H. W. (2014). Impact of the temporal stability of preexistent attentional bias for threat on its alteration through attention bias modification. *Journal of Behavior Therapy and Experimental Psychiatry.* http://doi.org/10.1016/j.jbtep.2014.10.012

Heeren, A., Reese, H. E., McNally, R. J., & Philippot, P. (2012). Attention training toward and away from threat in social phobia: Effects on subjective, behavioral, and physiological measures of anxiety. *Behaviour Research and Therapy, 50*(1), 30–39. http://doi.org/10.1016/j.brat.2011.10.005

Heimberg, R. G., Horner, K. J., Juster, H. R., Safren, S. A., Brown, E. J., Schneier, F. R., & Liebowitz, M. R. (1999). Psychometric properties of the Liebowitz Social Anxiety Scale. *Psychological Medicine, 29*(1), 199–212.

Herman, J. P., & Cullinan, W. E. (1997). Neurocircuitry of stress: Central control of the hypothalamo-pituitary-adrenocortical axis. *Trends in Neurosciences, 20*(2), 78–84.

Higgins, N. M., & Hughes, B. M. (2012). Individual differences in the impact of attentional bias training on cardiovascular responses to stress in women. *Anxiety, Stress, and Coping, 25*(4), 381–395. http://doi.org/10.1080/10615806.2011.616956

Hofmann, W., Gschwendner, T., Friese, M., Wiers, R. W., & Schmitt, M. (2008). Working memory capacity and self-regulatory behavior: Toward an individual differences perspective on behavior determination by automatic versus controlled processes. *Journal of Personality and Social Psychology, 95*(4), 962–977. http://doi.org/10.1037/a0012705

Howard, S., & Hughes, B. M. (2012). Benefit of social support for resilience-building is contingent on social context: Examining cardiovascular adaptation to recurrent stress in women. *Anxiety, Stress, and Coping, 25*(4), 411–423. http://doi.org/10.1080/10615806.2011.640933

Hsu, D. T., Kirouac, G. J., Zubieta, J.-K., & Bhatnagar, S. (2014). Contributions of the paraventricular thalamic nucleus in the regulation of stress, motivation, and mood. *Frontiers in Behavioral Neuroscience, 8*(73), 1-11. http://doi.org/10.3389/fnbeh.2014.00073

Johnson, D. R. (2009). Emotional attention set-shifting and its relationship to anxiety and emotion regulation. *Emotion, 9*(5), 681–690. http://doi.org/10.1037/a0017095

Johnson, J. A., Lavoie, K. L., Bacon, S. L., Carlson, L. E., & Campbell, T. S. (2012). The effect of trait rumination on adaptation to repeated stress. *Psychosomatic Medicine, 74*(3), 258–262. http://doi.org/10.1097/PSY.0b013e31824c3ef2

Jönsson, P., Wallergård, M., Osterberg, K., Hansen, A. M., Johansson, G., & Karlson, B. (2010). Cardiovascular and cortisol reactivity and habituation to a virtual reality version of the Trier Social Stress Test: A pilot study. *Psychoneuroendocrinology, 35*(9), 1397–1403. http://doi.org/10.1016/j.psyneuen.2010.04.003

Julian, K., Beard, C., Schmidt, N. B., Powers, M. B., & Smits, J. A. J. (2012). Attention training to reduce attention bias and social stressor reactivity: An attempt to replicate and extend previous findings. *Behaviour Research and Therapy, 50*(5), 350–358. http://doi.org/10.1016/j.brat.2012.02.015

Juster, R.-P., Perna, A., Marin, M.-F., Sindi, S., & Lupien, S. J. (2012). Timing is everything: Anticipatory stress dynamics among cortisol and blood pressure reactivity and recovery in healthy adults. *Stress, 15*(6), 569–577. http://doi.org/10.3109/10253890.2012.661494

Kabat-Zinn, J. (2006). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice, 10*(2), 144–156. http://doi.org/10.1093/clipsy.bpg016

Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin & Review, 9*(4), 637–671.

Kane, M. J., Poole, B. J., Tuholski, S. W., & Engle, R. W. (2006). Working memory capacity and the top down control of visual search: Exploring the boundaries of "executive attention". *Journal of Experimental Psychology. Learning, Memory, and Cognition, 32*(4), 749–777. http://doi.org/10.1037/0278-7393.32.4.749

Kanske, P., & Kotz, S. A. (2012). Effortful control, depression, and anxiety correlate with the influence of emotion on executive attentional control. *Biological Psychology, 91*(1), 88–95. http://doi.org/10.1016/j.biopsycho.2012.04.007

Kaufman, S. B., Deyoung, C. G., Gray, J. R., Jiménez, L., Brown, J., & Mackintosh, N. (2010). Implicit learning as an ability. *Cognition, 116*(3), 321–340. http://doi.org/10.1016/j.cognition.2010.05.011

Kelsey, R. M., Blascovich, J., Leitten, C. L., Schneider, T. R., Tomaka, J., & Wiens, S. (2000). Cardiovascular reactivity and adaptation to recurrent psychological stress: The moderating effects of evaluative observation. *Psychophysiology, 37*(6), 748–756.

Kelsey, R. M., Blascovich, J., Tomaka, J., Leitten, C. L., Schneider, T. R., & Wiens, S. (1999). Cardiovascular reactivity and adaptation to recurrent psychological stress: Effects of prior task exposure. *Psychophysiology, 36*(6), 818–831.

Kelsey, R. M., Soderlund, K., & Arthur, C. M. (2004). Cardiovascular reactivity and adaptation to recurrent psychological stress: Replication and extension. *Psychophysiology, 41*(6), 924–394. http://doi.org/10.1111/j.1469-8986.2004.00245.x

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The "Trier Social Stress Test"-a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*(1-2), 76–81. http://doi.org/119004

Kirschbaum, C., Prüssner, J. C., Stone, A. A., Federenko, I., Gaab, J., Lintz, D., … Hellhammer, D. H. (1995). Persistent high cortisol responses to repeated psychological stress in a subpopulation of healthy men. *Psychosomatic Medicine, 57*(5), 468–474.

Klumpp, H., & Amir, N. (2010). Preliminary study of attention training to threat and neutral faces on anxious reactivity to a social stressor in social anxiety. *Cognitive Therapy and Research, 34*(3), 263–271. http://doi.org/10.1007/s10608-009-9251-0

Koster, E. H. W., Crombez, G., Verschuere, B., & De Houwer, J. (2004). Selective attention to threat in the dot probe paradigm: Differentiating vigilance and difficulty to disengage. *Behaviour Research and Therapy, 42*(10), 1183–1192. http://doi.org/10.1016/j.brat.2003.08.001

Koster, E. H. W., Crombez, G., Verschuere, B., & De Houwer, J. (2006). Attention to threat in anxiety-prone individuals: Mechanisms underlying attentional bias. *Cognitive Therapy and Research, 30*(5), 635–643. http://doi.org/10.1007/s10608-006-9042-9

Kreher, D. A., Powers, S. I., & Granger, D. A. (2012). The relationship between cortisol, salivary alpha-amylase, and cognitive bias in young women. *Behavioral Neuroscience, 126*(1), 157–166. http://doi.org/10.1037/a0026654

Kuckertz, J. M., Amir, N., Boffa, J. W., Warren, C. K., Rindt, S. E. M., Norman, S., … McLay, R. (2014). The effectiveness of an attention bias modification program as an adjunctive treatment for Post-Traumatic Stress Disorder. *Behaviour Research and Therapy, 63*, 25–35. http://doi.org/10.1016/j.brat.2014.09.002

Kuckertz, J. M., Gildebrant, E., Liliequist, B., Karlström, P., Väppling, C., Bodlund, O., … Carlbring, P. (2014). Moderation and mediation of the effect of attention training in social anxiety disorder. *Behaviour Research and Therapy, 53*, 30–40. http://doi.org/10.1016/j.brat.2013.12.003

Kudielka, B. M., Schommer, N. C., Hellhammer, D. H., & Kirschbaum, C. (2004). Acute HPA axis responses, heart rate, and mood changes to psychosocial stress (TSST) in humans at different times of day. *Psychoneuroendocrinology, 29*(8), 983–992. http://doi.org/10.1016/j.psyneuen.2003.08.009

Kudielka, B. M., von Känel, R., Preckel, D., Zgraggen, L., Mischler, K., & Fischer, J. E. (2006). Exhaustion is associated with reduced habituation of free cortisol responses to repeated acute psychosocial stress. *Biological Psychology, 72*(2), 147–153. http://doi.org/10.1016/j.biopsycho.2005.09.001

Kvetnansky, R., Lu, X., & Ziegler, M. G. (2013). Stress-triggered changes in peripheral catecholaminergic systems. *Advances in Pharmacology, 68*, 359–397. http://doi.org/10.1016/B978-0-12-411512-5.00017-8

Lazarus, R. S., & Folkman, S. F. (1984). *Stress, Appraisal, and Coping*. New York, NY: Springer.

LeDoux, J. E. (1995). Emotion: Clues from the brain. *Annual Review of Psychology, 46*, 209–235. http://doi.org/10.1146/annurev.ps.46.020195.001233

Lee, E. M., & Hughes, B. M. (2014). Trait dominance is associated with vascular cardiovascular responses and attenuated habituation to social stress. *International Journal of Psychophysiology, 92*(2), 79–84. http://doi.org/10.1016/j.ijpsycho.2014.03.001

Levine, S. (1978). Cortisol changes following repeated experiences with parachute training. In H. Ursin, E. Baade, & S. Levine (Eds.), *Psychobiology of Stress—A Study of Coping Men* (pp. 51-56). New York, NY: Academic Press.

Li, S., Tan, J., Qian, M., & Liu, X. (2008). Continual training of attentional bias in social anxiety. *Behaviour Research and Therapy, 46*(8), 905–912. http://doi.org/10.1016/j.brat.2008.04.005

Liebowitz, M. R. (1987). Social phobia. *Modern Problems of Pharmacopsychiatry, 22*, 141–173.

Linden, W., Earle, T. L., Gerin, W., & Christenfeld, N. (1997). Physiological stress reactivity and recovery: Conceptual siblings separated at birth? *Journal of Psychosomatic Research, 42*(2), 117–135.

Lorr, M., & McNair, D. M. (1988). *Manual for the Profile of Mood States, Bipolar Form (POMS-BI).* San Diego, CA: Educational and Industrial Testing Service.

Lowther, H., & Newman, E. (2014). Attention bias modification (ABM) as a treatment for child and adolescent anxiety: A systematic review. *Journal of Affective Disorders, 168*, 125–135. http://doi.org/10.1016/j.jad.2014.06.051

Lupien, S. J., Maheu, F., Tu, M., Fiocco, A., & Schramek, T. E. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. *Brain and Cognition, 65*(3), 209–237. http://doi.org/10.1016/j.bandc.2007.02.007

Lupien, S. J., & McEwen, B. S. (1997). The acute effects of corticosteroids on cognition: Integration of animal and human model studies. *Brain Research. Brain Research Reviews, 24*(1), 1–27.

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews. Neuroscience, 10*(6), 434–445. http://doi.org/10.1038/nrn2639

Lupien, S. J., Wilkinson, C. W., Brière, S., Ménard, C., Ng Ying Kin, N. M. K., & Nair, N. P. V. (2002). The modulatory effects of corticosteroids on cognition: Studies in young human populations. *Psychoneuroendocrinology, 27*(3), 401–416.

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences, 12*(4), 163–169. http://doi.org/10.1016/j.tics.2008.01.005

MacLeod, C., & Hagan, R. (1992). Individual differences in the selective processing of threatening information and emotional responses to a stressful life event. *Behaviour Research and Therapy, 30*(2), 151–161.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95*(1), 15–20.

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology, 111*(1), 107–123.

Mason, J. W. (1968). A review of psychoendocrine research on the sympathetic-adrenal medullary system. *Psychosomatic Medicine, 30*(5), 631–653.

Mathews, A., & MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cognition & Emotion, 16*(3), 331–354. http://doi.org/10.1080/02699930143000518

Mathews, A., & MacLeod, C. (2005). Cognitive vulnerability to emotional disorders. *Annual Review of Clinical Psychology, 1*, 167–195. http://doi.org/10.1146/annurev.clinpsy.1.102803.143916

Mauss, I. B., Bunge, S. A., & Gross, J. J. (2007). Automatic emotion regulation. *Social and Personality Psychology Compass, 1*(1), 146–167. http://doi.org/10.1111/j.1751-9004.2007.00005.x

Mauss, I. B., Evers, C., Wilhelm, F. H., & Gross, J. J. (2006). How to bite your tongue without blowing your top: Implicit evaluation of emotion regulation predicts affective responding to anger provocation. *Personality & Social Psychology Bulletin, 32*(5), 589–602. http://doi.org/10.1177/0146167205283841

McEwen, B. S. (1998). Protective and damaging effects of stress mediators. *The New England Journal of Medecine, 338*(3), 171-179.

McEwen, B. S. (2001). From molecules to mind: Stress, individual differences, and the social environment. *Annals of the New York Academy of Sciences, 935*, 42–49.

McEwen, B. S. (2005). Glucocorticoids, depression, and mood disorders: Structural remodeling in the brain. *Metabolism: Clinical and Experimental, 54*(Suppl. 1), 20–23. http://doi.org/10.1016/j.metabol.2005.01.008

McEwen, B. S. (2008). Central effects of stress hormones in health and disease: Understanding the protective and damaging effects of stress and stress mediators. *European Journal of Pharmacology, 583*(2-3), 174–185. http://doi.org/10.1016/j.ejphar.2007.11.071

McEwen, B. S., & Lasley, E. N. (2003). Allostatic load: when protection gives way to damage. *Advances in Mind-Body Medecine, 19*(1), 28-33.

McEwen, B. S., & Sapolsky, R. M. (1995). Stress and cognitive function. *Current Opinion in Neurobiology, 5*(2), 205–216.

McNally, R. J., Enock, P. M., Tsai, C., & Tousian, M. (2013). Attention bias modification for reducing speech anxiety. *Behaviour Research and Therapy, 51*(12), 882–888. http://doi.org/10.1016/j.brat.2013.10.001

Mineka, S., & Öhman, A. (2002). Phobias and preparedness: The selective, automatic, and encapsulated nature of fear. *Biological Psychiatry, 52*(10), 927–937. http://doi.org/10.1016/S0006-3223(02)01669-4

Minkley, N., Schröder, T. P., Wolf, O. T., & Kirchner, W. H. (2014). The socially evaluated cold-pressor test (SECPT) for groups: Effects of repeated administration of a combined physiological and psychological stressor. *Psychoneuroendocrinology, 45*, 119–127. http://doi.org/10.1016/j.psyneuen.2014.03.022

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy, 36*(9), 809–848.

Mogg, K., & Bradley, B. P. (2002). Selective orienting of attention to masked threat faces in social anxiety. *Behaviour Research and Therapy, 40*(12), 1403–1414.

Mogg, K., Bradley, B. P., Dixon, C., Fisher, S., Twelftree, H., & McWilliams, A. (2000). Trait anxiety, defensiveness and selective processing of threat: An investigation using two measures of attentional bias. *Personality and Individual Differences, 28*(6), 1063–1077. http://doi.org/10.1016/S0191-8869(99)00157-9

Mogg, K., Holmes, A., Garner, M., & Bradley, B. P. (2008). Effects of threat cues on attentional shifting, disengagement and response slowing in anxious individuals. *Behaviour Research and Therapy, 46*(5), 656–667. http://doi.org/10.1016/j.brat.2008.02.011

Mogoaşe, C., David, D., & Koster, E. H. W. (2014). Clinical efficacy of attentional bias modification procedures: An updated meta-analysis. *Journal of Clinical Psychology, 70*(12), 1133–1157. http://doi.org/10.1002/jclp.22081

Moore, S. G., Ferguson, M. J., & Chartrand, T. L. (2011). Affect in the aftermath: How goal pursuit influences implicit evaluations. *Cognition & Emotion, 25*(3), 453–465. http://doi.org/10.1080/02699931.2010.538598

Morris, M. C., & Rao, U. (2014). Cortisol response to psychosocial stress during a depressive episode and remission. *Stress, 17*(1), 51–58. http://doi.org/10.3109/10253890.2013.857398

Muris, P., Meesters, C., & Rompelberg, L. (2007). Attention control in middle childhood: Relations to psychopathological symptoms and threat perception distortions. *Behaviour Research and Therapy, 45*(5), 997–1010. http://doi.org/10.1016/j.brat.2006.07.010

Najmi, S., & Amir, N. (2010). The effect of attention training on a behavioral test of contamination fears in individuals with subclinical obsessive-compulsive symptoms. *Journal of Abnormal Psychology, 119*(1), 136–142. http://doi.org/10.1037/a0017549

Najström, M., & Jansson, B. (2007). Skin conductance responses as predictor of emotional responses to stressful life events. *Behaviour Research and Therapy, 45*(10), 2456–2463. http://doi.org/10.1016/j.brat.2007.03.001

Nater, U. M., & Rohleder, N. (2009). Salivary alpha-amylase as a non-invasive biomarker for the sympathetic nervous system: Current state of research. *Psychoneuroendocrinology, 34*(4), 486–496. http://doi.org/10.1016/j.psyneuen.2009.01.014

Neubauer, K., von Auer, M., Murray, E., Petermann, F., Helbig-Lang, S., & Gerlach, A. L. (2013). Internet-delivered attention modification training as a treatment for social phobia: A randomized controlled trial. *Behaviour Research and Therapy, 51*(2), 87–97. http://doi.org/10.1016/j.brat.2012.10.006

Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology, 19*(1), 1–32. http://doi.org/10.1016/0010- 0285(87)90002-8

Nyklíček, I., Mommersteeg, P. M. C., Van Beugen, S., Ramakers, C., & Van Boxtel, G. J. (2013). Mindfulness-based stress reduction and physiological activity during acute stress: A randomized controlled trial. *Health Psychology : Official Journal of the Division of Health Psychology, American Psychological Association, 32*(10), 1110–1113. http://doi.org/10.1037/a0032200

O’Connor, R. M., Fite, P. J., Nowlin, P. R., & Colder, C. R. (2007). Children’s beliefs about substance use: An examination of age differences in implicit and explicit cognitive precursors of substance use initiation. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors, 21*(4), 525–533. http://doi.org/10.1037/0893-164X.21.4.525

O’Toole, L., & Dennis, T. A. (2012). Attention training and the threat bias: An ERP study. *Brain and Cognition, 78*(1), 63–73. http://doi.org/10.1016/j.bandc.2011.10.007

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences, 9*(5), 242–249. http://doi.org/10.1016/j.tics.2005.03.010

Ochsner, K. N., & Gross, J. J. (2008). Cognitive emotion regulation: Insights from social cognitive and affective neuroscience. *Current Directions in Psychological Science, 17*(2), 153–158. http://doi.org/10.1111/j.1467-8721.2008.00566.x

Öhman, A. (2005). The role of the amygdala in human fear: Automatic detection of threat. *Psychoneuroendocrinology, 30*(10), 953–958. http://doi.org/10.1016/j.psyneuen.2005.03.019

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology. General, 130*(3), 466–478.

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*(3), 483–522.

Öhman, A., & Soares, J. J. (1998). Emotional conditioning to masked stimuli: Expectancies for aversive outcomes following nonrecognized fear-relevant stimuli. *Journal of Experimental Psychology. General, 127*(1), 69–82.

Öhman, A., & Soares, J. J. (1993). On the automatic nature of phobic fear: Conditioned electrodermal responses to masked fear-relevant stimuli. *Journal of Abnormal Psychology, 102*(1), 121–132.

Öhman, A., & Soares, J. J. F. (1994). “Unconscious anxiety”: Phobic responses to masked stimuli. *Journal of Abnormal Psychology, 103*(2), 231–240.

Osinsky, R., Lösch, A., Hennig, J., Alexander, N., & Macleod, C. (2012). Attentional bias to negative information and 5-HTTLPR genotype interactively predict students’ emotional reactivity to first university semester. *Emotion, 12*(3), 460–469. http://doi.org/10.1037/a0026674

Ouimet, A. J., Gawronski, B., & Dozois, D. J. A. (2009). Cognitive vulnerability to anxiety: A review and an integrative model. *Clinical Psychology Review, 29*(6), 459–470. http://doi.org/10.1016/j.cpr.2009.05.004

Paulewicz, B., Blaut, A., & Kłosowska, J. (2012). Cognitive effects of attentional training depend on attentional control. *Polish Psychological Bulletin, 43*(4), 272–277. http://doi.org/10.2478/v10059-012-0030-5

Payne, B. K. (2005). Conceptualizing control in social cognition: How executive functioning modulates the expression of automatic stereotyping. *Journal of Personality and Social Psychology, 89*(4), 488–503. http://doi.org/10.1037/0022-3514.89.4.488

Peckham, A. D., McHugh, R. K., & Otto, M. W. (2010). A meta-analysis of the magnitude of biased attention in depression. *Depression and Anxiety, 27*(12), 1135–1142. http://doi.org/10.1002/da.20755

Pessoa, L., & Ungerleider, L. G. (2004). Neuroimaging studies of attention and the processing of emotion-laden stimuli. *Progress in Brain Research, 144*, 171-182.

Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. *Neuron, 48*(2), 175–187. http://doi.org/10.1016/j.neuron.2005.09.025

Pilgrim, K., Ellenbogen, M. A., & Paquin, K. (2014). The impact of attentional training on the salivary cortisol and alpha amylase response to psychosocial stress: Importance of attentional control. *Psychoneuroendocrinology, 44*, 88–99. http://doi.org/10.1016/j.psyneuen.2014.01.024

Pilgrim, K., Marin, M.-F., & Lupien, S. J. (2010). Attentional orienting toward social stress stimuli predicts increased cortisol responsivity to psychosocial stress irrespective of the early socioeconomic status. *Psychoneuroendocrinology, 35*(4), 588–595. http://doi.org/10.1016/j.psyneuen.2009.09.015

Posner, M. I., & Rothbart, M. K. (1998). Attention, self-regulation and consciousness. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 353*(1377), 1915–1927. http://doi.org/10.1098/rstb.1998.0344

Posner, M. I., & Rothbart, M. K. (2000). Developing mechanisms of self-regulation. *Development and Psychopathology, 12*(3), 427–441.

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58*, 1–23. http://doi.org/10.1146/annurev.psych.58.110405.085516

Posner, M. I., Snyder, C. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology, 109*(2), 160–174.

Pruessner, J. C., Baldwin, M. W., Dedovic, K., Renwick, R., Mahani, N. K., Lord, C., … Lupien, S. (2005). Self-esteem, locus of control, hippocampal volume, and cortisol regulation in young and old adulthood. *NeuroImage, 28*(4), 815–826. http://doi.org/10.1016/j.neuroimage.2005.06.014

Pruessner, J. C., Dedovic, K., Pruessner, M., Lord, C., Buss, C., Collins, L., … Lupien, S. J. (2010). Stress regulation in the central nervous system: Evidence from structural and functional neuroimaging studies in human populations - 2008 Curt Richter Award Winner. *Psychoneuroendocrinology, 35*(1), 179–191. http://doi.org/10.1016/j.psyneuen.2009.02.016

Pruessner, J. C., Gaab, J., Hellhammer, D. H., Lintz, D., Schommer, N., & Kirschbaum, C. (1997). Increasing correlations between personality traits and cortisol stress responses obtained by data aggregation. *Psychoneuroendocrinology, 22*(8), 615–625.

Pruessner, J. C., Kirschbaum, C., Meinlschmid, G., & Hellhammer, D. H. (2003). Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. *Psychoneuroendocrinology, 28*(7), 916–931.

Pruessner, J. C., Wolf, O. T., Hellhammer, D. H., Buske-Kirschbaum, A., von Auer, K., Jobst, S., … Kirschbaum, C. (1997). Free cortisol levels after awakening: A reliable biological marker for the assessment of adrenocortical activity. *Life Sciences, 61*(26), 2539–2549.

Putman, P., Hermans, E. J., Koppeschaar, H., van Schijndel, A., & van Honk, J. (2007). A single administration of cortisol acutely reduces preconscious attention for fear in anxious young men. *Psychoneuroendocrinology, 32*(7), 793–802. http://doi.org/10.1016/j.psyneuen.2007.05.009

Putman, P., Hermans, E. J., & van Honk, J. (2010). Cortisol administration acutely reduces threat-selective spatial attention in healthy young men. *Physiology & Behavior, 99*(3), 294–300. http://doi.org/10.1016/j.physbeh.2009.11.006

Putman, P., & Roelofs, K. (2011). Effects of single cortisol administrations on human affect reviewed: Coping with stress through adaptive regulation of automatic cognitive processing. *Psychoneuroendocrinology, 36*(4), 439–448. http://doi.org/10.1016/j.psyneuen.2010.12.001

Quirin, M., Kazén, M., Rohrmann, S., & Kuhl, J. (2009). Implicit but not explicit affectivity predicts circadian and reactive cortisol: Using the implicit positive and negative affect test. *Journal of Personality, 77*(2), 401–425. http://doi.org/10.1111/j.1467-6494.2008.00552.x

Raskin, M. (1975). Decreased skin conductance response habituation in chronically anxious patients. *Biological Psychology, 2*(4), 309–319.

Raz, A. (2004). Anatomy of attentional networks. *Anatomical Record. Part B, New Anatomist, 281*(1), 21–36. http://doi.org/10.1002/ar.b.20035

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior, 6*(6), 855–863. http://doi.org/10.1016/S0022-5371(67)80149-X

Reber, A. S. (1989). More thoughts on the unconscious: Reply to Brody and to Lewicki and Hill. *Journal of Experimental Psychology. General, 118*(3), 242–244.

Regehr, C., Glancy, D., & Pitts, A. (2013). Interventions to reduce stress in university students: A review and meta-analysis. *Journal of Affective Disorders, 148*(1), 1–11. http://doi.org/10.1016/j.jad.2012.11.026

Richey, J. A., Keough, M. E., & Schmidt, N. B. (2012). Attentional control moderates fearful responding to a 35% CO(2) challenge. *Behavior Therapy, 43*(2), 285–299. http://doi.org/10.1016/j.beth.2011.06.004

Roelofs, K., Bakvis, P., Hermans, E. J., van Pelt, J., & van Honk, J. (2007). The effects of social stress and cortisol responses on the preconscious selective attention to social threat. *Biological Psychology, 75*(1), 1–7. http://doi.org/10.1016/j.biopsycho.2006.09.002

Rohleder, N., Nater, U. M., Wolf, J. M., Ehlert, U., & Kirschbaum, C. (2004). Psychosocial stress-induced activation of salivary alpha-amylase: An indicator of sympathetic activity? *Annals of the New York Academy of Sciences, 1032*, 258–263. http://doi.org/10.1196/annals.1314.033

Rozenman, M., Weersing, V. R., & Amir, N. (2011). A case series of attention modification in clinically anxious youths. *Behavior Research and Therapy, 49*(5), 324–330. http://doi.org/10.1016/j.brat.2011.02.007

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2004). Attentional control and self regulation. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of Self-Regulation: Research, Theory, and Applications* (pp. 283–300). New York, NY: Guilford Press.

Sapolsky, R. M. (2000). Glucocorticoids and hippocampal atrophy in neuropsychiatric disorders. *Archives of General Psychiatry, 57*(10), 925–935.

Sapolsky, R. M. (2007). Stress, Stress-Related Disease, and Emotional Regulation. In Gross, James J. (Ed.), *Handbook of emotion regulation* (pp. 606–615). New York, NY: Guilford Press.

Schmeichel, B. J., & Demaree, H. A. (2010). Working memory capacity and spontaneous emotion regulation: High capacity predicts self-enhancement in response to negative feedback. *Emotion, 10*(5), 739–744. http://doi.org/10.1037/a0019355

Schmeichel, B. J., Volokhov, R. N., & Demaree, H. A. (2008). Working memory capacity and the self-regulation of emotional expression and experience. *Journal of Personality and Social Psychology, 95*(6), 1526–1540. http://doi.org/10.1037/a0013345

Schmidt, N. B., Richey, J. A., Buckner, J. D., & Timpano, K. R. (2009). Attention training for generalized social anxiety disorder. *Journal of Abnormal Psychology, 118*(1), 5–14. http://doi.org/10.1037/a0013643

Schmukle, S. C. (2005). Unreliability of the dot probe task. *European Journal of Personality, 19*(7), 595–605. http://doi.org/10.1002/per.554

See, J., MacLeod, C., & Bridle, R. (2009). The reduction of anxiety vulnerability through the modification of attentional bias: A real-world study using a home-based cognitive bias modification procedure. *Journal of Abnormal Psychology, 118*(1), 65–75. http://doi.org/10.1037/a0014377

Sheppes, G., Brady, W. J., & Samson, A. C. (2014). In (visual) search for a new distraction: The efficiency of a novel attentional deployment versus semantic meaning regulation strategies. *Frontiers in Psychology, 5*, 346. http://doi.org/10.3389/fpsyg.2014.00346

Sheppes, G., & Gross, J. J. (2011). Is timing everything? Temporal considerations in emotion regulation. *Personality and Social Psychology Review, 15*(4), 319–331. http://doi.org/10.1177/1088868310395778

Sheppes, G., & Meiran, N. (2007). Better late than never? On the dynamics of online regulation of sadness using distraction and cognitive reappraisal. *Personality & Social Psychology Bulletin, 33*(11), 1518–1532. http://doi.org/10.1177/0146167207305537

Sheppes, G., Scheibe, S., Suri, G., & Gross, J. J. (2011). Emotion-regulation choice. *Psychological Science, 22*(11), 1391–1396. http://doi.org/10.1177/0956797611418350

Sheppes, G., Scheibe, S., Suri, G., Radu, P., Blechert, J., & Gross, J. J. (2014). Emotion regulation choice: A conceptual framework and supporting evidence. *Journal of Experimental Psychology. General, 143*(1), 163–181. http://doi.org/10.1037/a0030831

Sluis, R. A., & Boschen, M. J. (2014). Fear of evaluation in social anxiety: Mediation of attentional bias to human faces. *Journal of Behavior Therapy and Experimental Psychiatry, 45*(4), 475–483. http://doi.org/10.1016/j.jbtep.2014.06.007

Sood, A., & Jones, D. T. On mind wandering, attention, brain networks, and meditation. *Explore (NY), 9*(3), 136–141. http://doi.org/10.1016/j.explore.2013.02.005

Steer, R. A., Ball, R., Ranieri, W. F., & Beck, A. T. (1999). Dimensions of the Beck Depression Inventory-II in clinically depressed outpatients. *Journal of Clinical Psychology, 55*(1), 117–128.

Stevens, A., & White, A. (2010). ACTH: Cellular peptide hormone synthesis and secretory pathways. *Results and Problems in Cell Differentiation, 50*, 63–84. http://doi.org/10.1007/400_2009_30

Stillman, C. M., Feldman, H., Wambach, C. G., Howard, J. H., & Howard, D. V. (2014). Dispositional mindfulness is associated with reduced implicit learning. *Consciousness and Cognition, 28*, 141–150. http://doi.org/10.1016/j.concog.2014.07.002

Stormark, K. M., Nordby, H., & Hugdahl, K. (1995). Attentional shifts to emotionally charged cues: Behavioural and ERP data. *Cognition & Emotion, 9*(5), 507–523. http://doi.org/10.1080/02699939508408978

Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8*(3), 220–247. http://doi.org/10.1207/s15327957pspr0803_1

Susa, G., Pitică, I., Benga, O., & Miclea, M. (2012). The self regulatory effect of attentional control in modulating the relationship between attentional biases toward threat and anxiety symptoms in children. *Cognition & Emotion, 26*(6), 1069–1083. http://doi.org/10.1080/02699931.2011.638910

Suway, J. G., White, L. K., Vanderwert, R. E., Bar-Haim, Y., Pine, D. S., & Fox, N. A. (2013). Modification of threat-processing in non-anxious individuals: A preliminary behavioral and ERP study. *Journal of Behavior Therapy and Experimental Psychiatry, 44*(3), 285–292. http://doi.org/10.1016/j.jbtep.2012.11.006

Tabachnick, B.G., & Fidell, L.S. (2008). *Using multivariate statistics* (5th ed.). Boston, MA: Prentice Hall.

Taylor, C. T., Bomyea, J., & Amir, N. (2011). Malleability of attentional bias for positive emotional information and anxiety vulnerability. *Emotion, 11*(1), 127–138. http://doi.org/10.1037/a0021301

Teasdale, J. D., Segal, Z., & Williams, J. M. (1995). How does cognitive therapy prevent depressive relapse and why should attentional control (mindfulness) training help? *Behaviour Research and Therapy, 33*(1), 25–39.

Thoma, M. V, Kirschbaum, C., Wolf, J. M., & Rohleder, N. (2012). Acute stress responses in salivary alpha-amylase predict increases of plasma norepinephrine. *Biological Psychology, 91*(3), 342–348. http://doi.org/10.1016/j.biopsycho.2012.07.008

Thush, C., Wiers, R. W., Ames, S. L., Grenard, J. L., Sussman, S., & Stacy, A. W. (2008). Interactions between implicit and explicit cognition and working memory capacity in the prediction of alcohol use in at-risk adolescents. *Drug and Alcohol Dependence, 94*(1-3), 116–124. http://doi.org/10.1016/j.drugalcdep.2007.10.019

Todd, R. M., Cunningham, W. A., Anderson, A. K., & Thompson, E. (2012). Affect-biased attention as emotion regulation. *Trends in Cognitive Sciences, 16*(7), 365–372. http://doi.org/10.1016/j.tics.2012.06.003

Tortella-Feliu, M., Morillas-Romero, A., Balle, M., Bornas, X., Llabrés, J., & Pacheco-Unguetti, A. P. (2014). Attentional control, attentional network functioning, and emotion regulation styles. *Cognition & Emotion, 28*(5), 769–780. http://doi.org/10.1080/02699931.2013.860889

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research, 168*(3), 242–249. http://doi.org/10.1016/j.psychres.2008.05.006

Tsigos, C., & Chrousos, G. P. (2002). Hypothalamic-pituitary-adrenal axis, neuroendocrine factors and stress. *Journal of Psychosomatic Research, 53*(4), 865–871.

Tully, L. M., Lincoln, S. H., & Hooker, C. I. (2012). Impaired executive control of emotional information in social anhedonia. *Psychiatry Research, 197*(1-2), 29–35. http://doi.org/10.1016/j.psychres.2011.12.023

Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language, 28*(2), 127–154. http://doi.org/10.1016/0749-596X(89)90040-5

Van Bockstaele, B., Koster, E. H. W., Verschuere, B., Crombez, G., & De Houwer, J. (2012). Limited transfer of threat bias following attentional retraining. *Journal of Behavior Therapy and Experimental Psychiatry, 43*(2), 794–800. http://doi.org/10.1016/j.jbtep.2011.11.001

Van Bockstaele, B., Verschuere, B., Tibboel, H., De Houwer, J., Crombez, G., & Koster, E. H. W. (2014). A review of current evidence for the causal impact of attentional bias on fear and anxiety. *Psychological Bulletin, 140*(3), 682–721. http://doi.org/10.1037/a0034834

Van den Hout, M., Tenney, N., Huygens, K., Merckelbach, H., & Kindt, M. (1995). Responding to subliminal threat cues is related to trait anxiety and emotional vulnerability: A successful replication of Macleod and Hagan (1992). *Behaviour Research and Therapy, 33*(4), 451–454.

Van Dillen, L. F., & Koole, S. L. (2007). Clearing the mind: A working memory model of distraction from negative mood. *Emotion, 7*(4), 715–723. http://doi.org/10.1037/1528-3542.7.4.715

Vanderhasselt, M.-A., De Raedt, R., Leyman, L., & Baeken, C. (2009). Acute effects of repetitive transcranial magnetic stimulation on attentional control are related to antidepressant outcomes. *Journal of Psychiatry & Neuroscience, 34*(2), 119–126.

Verhaak, C. M., Smeenk, J. M. ., van Minnen, A., & Kraaimaat, F. W. (2004). Neuroticism, pre-attentive and attentional biases towards threat and anxiety before and after a severe stressor: A prospective study. *Personality and Individual Differences, 36*(4), 767–778. http://doi.org/10.1016/S0191-8869(03)00131-4

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*(12), 585–594. http://doi.org/10.1016/j.tics.2005.10.011

Wadiwalla, M., Andrews, J., Lai, B., Buss, C., Lupien, S. J., & Pruessner, J. C. (2010). Effects of manipulating the amount of social-evaluative threat on the cortisol stress response in young healthy women. *Stress, 13*(3), 214–220. http://doi.org/10.3109/10253890903277561

Wald, I., Lubin, G., Holoshitz, Y., Muller, D., Fruchter, E., Pine, D. S., … Bar-Haim, Y. (2011). Battlefield-like stress following simulated combat and suppression of attention bias to threat. *Psychological Medicine, 41*(4), 699–707. http://doi.org/10.1017/S0033291710002308

Wald, I., Shechner, T., Bitton, S., Holoshitz, Y., Charney, D. S., Muller, D., … Bar-Haim, Y. (2011). Attention bias away from threat during life threatening danger predicts PTSD symptoms at one-year follow-up. *Depression and Anxiety, 28*(5), 406–411. http://doi.org/10.1002/da.20808

Wang, L., Liu, X., Guise, K. G., Knight, R. T., Ghajar, J., & Fan, J. (2010). Effective connectivity of the fronto-parietal network during attentional control. *Journal of Cognitive Neuroscience, 22*(3), 543–553. http://doi.org/10.1162/jocn.2009.21210

Waters, A. M., Pittaway, M., Mogg, K., Bradley, B. P., & Pine, D. S. (2013). Attention training towards positive stimuli in clinically anxious children. *Developmental Cognitive Neuroscience, 4,* 77–84. http://doi.org/10.1016/j.dcn.2012.09.004

Watson, D., & Friend, R. (1969). Measurement of social-evaluative anxiety. *Journal of Consulting and Clinical Psychology, 33*(4), 448–457.

Watson, J. P., Gaind, R., & Marks, I. M. (1972). Physiological habituation to continuous phobic stimulation. *Behaviour Research and Therapy, 10*(3), 269–278.

Waugh, C. E., Muhtadie, L., Thompson, R. J., Joormann, J., & Gotlib, I. H. (2012). Affective and physiological responses to stress in girls at elevated risk for depression. *Development and Psychopathology, 24*(2), 661–675. http://doi.org/10.1017/S0954579412000235

Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review, 101*(1), 34–52.

Wells, T. T., & Beevers, C. G. (2010). Biased attention and dysphoria: Manipulating selective attention reduces subsequent depressive symptoms. *Cognition & Emotion, 24*(4), 719–728. http://doi.org/10.1080/02699930802652388

Whitmarsh, S., Uddén, J., Barendregt, H., & Petersson, K. M. (2013). Mindfulness reduces habitual responding based on implicit knowledge: Evidence from artificial grammar learning. *Consciousness and Cognition, 22*(3), 833–845. http://doi.org/10.1016/j.concog.2013.05.007

Williams, J. M. G., & Kuyken, W. (2012). Mindfulness-based cognitive therapy: A promising new approach to preventing depressive relapse. *The British Journal of Psychiatry, 200*(5), 359–360. http://doi.org/10.1192/bjp.bp.111.104745

Williams, J. M., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120*(1), 3–24.

Williams, L. E., Bargh, J. A., Nocera, C. C., & Gray, J. R. (2009). The unconscious regulation of emotion: Nonconscious reappraisal goals modulate emotional reactivity. *Emotion, 9*(6), 847–854.

Willingham, D. B., Nissen, M. J., & Bullemer, P. (1989). On the development of procedural knowledge. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 15*(6), 1047–1060.

Wüst, S., Federenko, I. S., van Rossum, E. F. C., Koper, J. W., & Hellhammer, D. H. (2005). Habituation of cortisol responses to repeated psychosocial stress-further characterization and impact of genetic factors. *Psychoneuroendocrinology, 30*(2), 199–211. http://doi.org/10.1016/j.psyneuen.2004.07.002

Yang, W., Ding, Z., Dai, T., Peng, F., & Zhang, J. X. (2014). Attention Bias Modification training in individuals with depressive symptoms: A randomized controlled trial. *Journal of Behavior Therapy and Experimental Psychiatry.* http://doi.org/10.1016/j.jbtep.2014.08.005

APPENDIX A

Sample Consent Form Study 1

CONSENT TO PARTICIPATE IN RESEARCH PROJECT
Centre for Research in Human Development
Concordia university

Investigator: Mark Ellenbogen, Ph.D, Associate Professor, Department of Psychology
Co-Investigator: Kamala Pilgrim, Ph.D Candidate, Department of Psychology

I agree to take part in the research being conducted by the above investigators at Concordia university. I have been informed that the purpose of this research is to examine whether three days of repeated practice on simple computerized tests, aimed to enhance mental abilities (particularly attention), can improve public speaking performance and change hormone levels. The hormone of interest is called cortisol, and it can be measured in saliva.

I understand that the duration of the study is approximately 8 hours in total spanning over 6 sessions, across 6 days:

> The session on Day 1 will last approximately 1 hour and 30 min, sessions on Days 2 to 4 will be approximately 30 minutes each, and Day 5 will last about 2 hours and 30 min. These aforementioned sessions will be scheduled consecutively over 5 days. The last session, Day 6, will be scheduled one month following session 5, and will last approximately 2 hours and 30 min. The sessions will take place at the Loyola campus of Concordia university.

I understand that I will be asked questions about my feelings, moods and behaviours.

During the study, I will be asked to complete questionnaires and also to complete computerized tests. The computerized tests will utilize pictures of faces, which will display emotional content. Although unlikely, it is possible that viewing these pictures may disconcert me.

I understand that I will be called upon to perform a public speech in front of two expert judges who will be evaluating my performance, which will also be videotaped. All of this will take place under the supervision of trained staff.

I also agree to provide saliva samples over the course of two (2) sessions of the study. I will provide a total of twelve (12) small samples, six (6) at session 5, i.e., Day 5, and six (6) at session 6, i.e. Day 6. The saliva sampling procedure is totally without pain and is of no risk whatsoever to my health.

Remuneration: I understand that I will receive 3 participation pool credits (for psychology students; Worth 1.5 course credits) **AND/OR** $75 at the end of the study, i.e. I will receive 50$ at the end of the first 5 sessions and 25$ after the 6th session.

I understand that any information I provide will remain **strictly confidential** and that all questionnaires and all samples will be identified by code number only. The part of the experiment that will be taped for research purposes will be identified by code number only.

Furthermore, I understand that my **participation** in this study is totally **voluntary** and that I may withdraw at any point in the study without prejudice of any kind.

**If at any time you have questions about your rights as a research participant, please contact Kyla Wiscombe, Research Ethics and Compliance Officer, Concordia university, at (514) 848-2424 x 7481 or by email at kwiscomb@alcor.concordia.ca

I, ____________________________________ have read this consent form and I understand what my participation in this study entails. By signing I agree to participate in this study.

____ __________________________

Signature Date

<u>Team Member</u>

____ __________________________

Experimenter's signature Date

<u>Contact information</u>

If you have any questions relevant to this study, please do not hesitate to contact, Kamala Pilgrim, or Mark Ellenbogen at:
Centre for Research in Human Development, Department of Psychology, SP-219,
Concordia university, 7141 Sherbrooke, St. West, Montréal, Qc, H4B 1R6
<u>Tel:</u> (514) 848-2424, x 5213

APPENDIX B

Sample Consent Form Study 1

CONSENT TO PARTICIPATE IN RESEARCH PROJECT
Centre for Research in Human Development
Concordia university

Investigator: Mark Ellenbogen, Ph.D., Associate Professor, Department of Psychology
Co-investigator: Kamala Pilgrim, Ph.D. Candidate, Department of Psychology

I agree to take part in the research being conducted by the above investigators at Concordia university. I have been informed that the purpose of this research is to examine whether three, consecutive days of repeated practice on simple computerized tests, aimed to enhance cognitive abilities (e.g., attention), can improve public speaking performance and change hormone levels. The hormone of interest is called cortisol, and it can be measured in saliva.

I understand that the duration of the study is approximately 8 hours in total spanning over 6 days. The first 5 days of the study will be consecutive and the 6th day will occur one month later, as outlined here:

> I will take part in a **laboratory** session during the first day that will last approximately 1 hour and 30 min.
> I will complete a computer task **at home** at a specified time. The computer task takes approximately 30 minutes to complete. I will do this on the 2nd, 3rd, and 4th days. The laptop computer will be provided by the research team.
> I will take part in a **laboratory** session during the fifth day that will last approximately 2 hours.
> This latter session will be repeated one month later.

I understand that I will be asked questions about my feelings, mood and behaviours. During the study I will be asked to complete questionnaires and also to complete computerized tests. The computerized tests will utilize pictures of faces which will display emotional content. Although unlikely, it is possible that viewing these pictures may disconcert me. I understand that I will be called upon to perform a public speech in front of two expert judges who will be evaluating my performance which will also be videotaped. All of this will take place under the supervision of trained staff.
I also agree to provide saliva samples over the course of 2 sessions of the study. I will provide a total of 12 small samples, 6 during the day 5 session, and 6 during the day 6 session (one month later). The saliva sampling procedure is totally without pain and is of no risk whatsoever to my health.

I understand that that the laptops should be **handled with care and returned promptly at the end of the experiment**. However, if any damage occurs to the laptop (e.g., if it is dropped, or if it comes into contact with liquid), I understand that **I am NOT**

<u>financially responsible</u>. Failure to return the laptop, after repeated telephone calls and e-mails, will be considered as theft, and treated as such.

Remuneration: I understand that I will receive 3 participation pool credits (for psychology students; Worth 1.5 course credits) **AND/OR** 80$ at the end of the study, i.e., I will receive 30$ at the end of the first 5 sessions and 50$ after the 6th session occurring one month later. I understand that any information I provide will **remain strictly confidential** and that all questionnaires and all samples will be identified by code number only. The part of the experiment that will be taped for research purposes will be identified by code number only. Furthermore, I understand that my participation in this study is totally **voluntary** and that I may withdraw at any point from the study without prejudice of any kind.

**If at any time you have questions about your rights as a research participant, please contact Kyla Wiscombe , Research Ethics and Compliance Officer, Concordia university, at (514) 848-2424 x 7481 or by email at kwiscomb@alcor.concordia.ca.

I,___________________________ have read this consent form and I understand what my participation in this study entails. By signing I agree to participate in this study.

____ _________________________

Signature Date

<u>Team Member</u>

____ _________________________

Experimenter's signature Date

Contact information

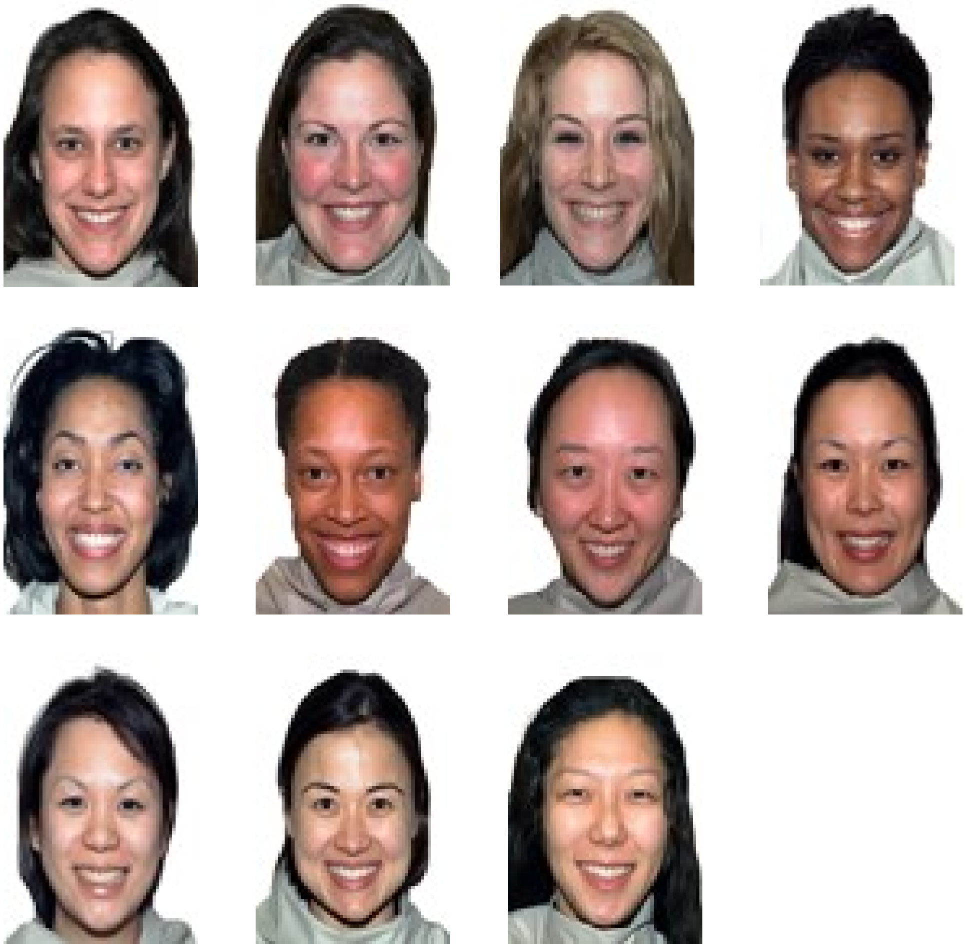
If you have any questions relevant to this study, please do not hesitate to contact,
Kamala Pilgrim, or Mark Ellenbogen at:
Centre for Research in Human Development, Department of Psychology, SP-219,
Concordia university, 7141 Sherbrooke, St. West, Montréal, Qc, H4B 1R6
<u>Tel:</u> (514) 848-2424, x 5213

APPENDIX C

Facial Pictures used in ABM – Females/Angry

APPENDIX D

Facial Pictures used in ABM – Females/Happy



APPENDIX E

Facial Pictures used in ABM – Males/Angry

APPENDIX F

Facial Pictures used in ABM – Males/Happy