THE EFFECTS OF ACUTE EXERCISE ON ATTENTIONAL BIAS, MEMORY, AND MOOD

by

STEPHANIE LYN COOPER

(Under the Direction of Phillip D. Tomporowski)

ABSTRACT

The anxiolytic effects of an acute bout of exercise are well documented; however, little is known about the effects of exercise on attentional bias. Individuals with clinical and non-clinical anxiety exhibit an attentional bias towards unpleasant or threatening stimuli in their environment; therefore, it is of interest to determine if exercise also impacts the way in which individuals allocate their attention to unpleasant or threatening stimuli. In order to determine the impact of exercise on attentional bias, a narrative review was completed, as well as a series of two experiments. The narrative review summarizes the research that has examined exercise-induced changes in attentional bias and reports a lack of uniformity across studies. It is suggested that theory-based research is needed to better understand the relation among exercise, changes in attentional bias, and modification of anxiety symptoms. Following the narrative review, the results of two theory-based studies are reported. The outcomes of the two studies were compared, and it is suggested that the effects of exercise on attentional bias varies based on type of stimuli utilized during the attention task (i.e. word vs. picture). The effect of exercise on word-based attentional bias was small (d = 0.23), while the effect of exercise was small to moderate for picture-based attentional bias (d = 0.45). Changes in mood were also observed pre- to post-exercise for both experiments, which confirms the results of previous research examining the mood-enhancing effects of exercise. Lastly, differences in memory performance between exercise and control conditions observed, but were not uniform across studies; therefore, future research is needed to determine if differences in exercise-induced changes in attentional bias are related to memory performance post-exercise.

INDEX WORDS: *Anxiety, Dot-Probe Task, Bias Modification, Recognition Task, Physical Activity*

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DEDICATION

"Home, I learned, can be anywhere you make it. Home is also the place to which you come back again and again." – Margaret Mead

I would like to dedicate this work to my father, Mark R. Cooper. I sometimes play the "what if" game, and wonder what my passion would be had you not exercised everyday at 5 AM during my childhood years. My desire to be physically active and learn about the benefits of exercise grew from watching you prioritize exercise as a part of your daily routine. I am so thankful to have a father that has pushed me to excel, has had steadfast confidence in my ability to succeed, and has provided emotional and financial support through my undergraduate and graduate careers. Thank you for believing in me.

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"It is not the critic who counts; not the man who points out how the strong man stumbles, or where the doer of deeds could have done them better. The credit belongs to the man who is actually in the arena, whose face is marred by dust and sweat and blood; who strives valiantly; who errs, who comes short again and again, because there is no effort without error and shortcoming; but who does actually strive to do the deeds; who knows great enthusiasms, the great devotions; who spends himself in a worthy cause; who at the best knows in the end the triumph of high achievement, and who at the worst, if he fails, at least fails while daring greatly…" -Theodore Roosevelt, excerpt from "Citizenship in the Republic," April 23, 1910-

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CHAPTER 1

INTRODUCTION

The prevalence of anxiety in the United States is higher than any other mental disorder, with approximately 40.4% of adult females and 26.4% of adult males experiencing an anxiety disorder during their lifetime (Kessler, Petukhova, Sampson, Zaslavsky, & Wittchen, 2012). Many theories have been developed to explain the etiology of anxiety disorders, and treatments have been established to alleviate anxiety symptoms because of the profound effects anxiety can have on day-to-day life. Anxiety is purported to have a detrimental impact on cognitive performance, which impacts one's ability to perform daily tasks efficiently (Eysenck, Derakshan, Santos, & Calvo, 2007). The Attentional Control Theory (ACT) provides hypotheses about the specific executive functions that are hindered by anxiety, which leads to an attentional bias towards threatening information (Eysenck et al., 2007). Attentional bias occurs when an individual disproportionately allocates attention towards threatening stimuli compared to neutral or pleasant stimuli (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Cisler & Koster, 2010). The relationship between attentional bias and anxiety is claimed to be robust and reciprocal (i.e. bidirectional); therefore, it is important to find treatments that not only alleviate anxiety, but also treatments that can alter attentional bias towards threat (Bar-Haim et al., 2007; van Bockstaele et al., 2014).

Computer-based attention bias modification (ABM) programs have been developed to treat attentional bias related to anxiety. There is strong evidence that ABM effectively decreases attentional bias towards threat stimuli and lessens anxiety symptoms (Beard, Sawyer, &

Hofmann, 2012; Hakamata et al., 2010; Hallion & Ruscio, 2011; Mogoase, David, & Koster, 2014). Recent research has explored other treatment modalities to alleviate attentional bias; specifically, exercise-induced changes in attention deployment have been examined (Barnes, Coombes, Armstrong, Higgins, & Janelle, 2010; Tian & Smith, 2011).

The anxiolytic effects of both acute and chronic exercise are well documented; however, there are very few studies that explore the impact of exercise on attentional bias (Herring, Lindheimer, & O'Connor, 2013; Petruzzello, Landers, Hatfield, Kuitz, & Salazar, 1991). Tian and Smith (2011) provide evidence that attentional bias changes while performing moderate intensity exercise, and Barnes and colleagues (2010) provide evidence that attentional bias changes after an acute bout of exercise. In 2012, a systematic replication of research performed by Tian and Smith (2011) and Barnes et al. (2010) was completed in the Cognition and Skill Acquisition Laboratory at the University of Georgia. The results of the systematic replication failed to support the previous findings that exercise alters attention deployment (Cooper, 2012).

Two follow-up studies were developed to enhance the research protocol and extend the findings from the systematic replication completed in 2012. Women reporting either low-trait or high-trait anxiety were recruited for both studies to determine if level of trait anxiety modified exercise-induced changes in attentional bias. Only women were recruited because there is evidence to support sex-based differences in anxiety prevalence (Kessler et al., 2012), neural circuitry related to anxiety disorders (Farrell, Sengelaub, & Wellman, 2013), and attentional bias (Tan, Ma, Gao, Wu, & Fang, 2011; Tran, Lamplmayer, Pitzinger, & Pfabigan, 2013). Anxiety, mood, and attentional bias were assessed pre-exercise, 5 minutes post-exercise, and 20 minutes post-exercise to examine changes mood and attentional bias across time. Additionally, a memory task was added after the final attentional bias task to provide incentive for the participants to attend to the stimuli being displayed on the screen prior to their behavioral response to a dot-probe. The memory task also provides information about potential differences in encoding neutral and threatening stimuli between exercise and rest conditions.

The methods for Study 1 and Study 2 were identical; however, the type of stimuli displayed during the attentional bias task and the memory task differed between studies. Both Tian and Smith (2011) and Barnes et al. (2010) utilized picture stimuli in the task used to evaluate exercise-induced changes in attentional bias. Cooper (2012) employed words rather than pictures because the original dot-probe attention task was developed with words (MacLeod, Mathews, & Tata, 1986), and a meta-analysis has shown that words and pictures are both effective in capturing attentional bias in anxious individuals (Bar-Haim et al., 2007). The null effects of the preliminary systematic replication provided an impetus to examine if type of stimuli presented during the attention task modifies the effect of exercise on attentional bias. Therefore, Study 1 examines word-based attentional bias and Study 2 examines picture-based attentional bias. Meta-analyses report that stimulus type (word vs. picture) does moderate the effect of Attentional Bias Modification training on attentional bias and anxiety symptoms; however, the moderating effects are not uniform across studies (Beard et al., 2012; Hakamata et al., 2010; Mogoase et al., 2014).

In order to better understand the relationship between anxiety, attentional bias, and exercise, the following section provides an in-depth narrative review on the topics. Next, the methods and outcomes for Study 1 and Study 2 are provided. Lastly, a general discussion comparing the findings from Study 1 and Study 2 is presented.

References

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. doi: 10.1037/0033-2909.133.1.1

Barnes, R. T., Coombes, S. A., Armstrong, N. B., Higgins, T. J., & Janelle, C. M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *Journal of Sports Sciences, 28(10),* 1065-1076.

Beard, C., Sawyer, A. T., & Hofmann, S. G. (2012). Efficacy of attention bias moidification using threat and appetitive sitmuli: A meta-analytic review. *Behavior Therapy, 43(4),* 724-740.

Van Bockstaele, B. V., Verschuere, B., Tibboe, 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.

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

Cooper, S. L. (2012). Acute effects of aerobic exercise on positive and negative attentional bias. *Unpublished Manuscript*.

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

Farrell, M. R., Sengelaub, D. R., & Wellman, C. L. (2013). Sex differences and chronic stress effects on the neural circuitry underlying fear conditioning and extinction. *Physiology & Behavior, 122,* 208-215. doi: 10.1016/j.physbeh.2013.04.002

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, 28,* 982-990.

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.

Herring, M. P., Lindheimer, J. B., & O'Connor, P. J. (2013). The effects of exercise training on anxiety. *American Journal of Lifestyle Medicine*. doi: 10.1177/1559827613508542

Kessler, R. C., Petukhova, M., Sampson, N. A., Zaslavsky, A. M., & Wittchen, H. U. (2012). Twelve-month and lifetime prevalence and lifetime morbid risk of anxiety and mood disorders in the United States. *International Journal of Methods in Psychiatric Research, 21(3)*, 169-184. doi: 10.1002/mpr.1359

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

Mogoase, C., David, D., & Koster, E. H. W. (2014). Clinical efficacy of attentional bias modification procedures: An updated meta-analysis. *Journal of Clinical Psychology*, 1-25. doi: 10.1002/jclp.22081

Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kuitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11(3)*, 143-182.

Tan, J., Ma, Z., Gao, X., Wu, Y., & Fang, F. (2011). Gender difference of unconscious attentional bias in high trait anxiety individuals. *PLoS One, 6*(5), e20305. doi: 10.1371/journal.pone.0020305

Tian, Q., & Smith, J. C. (2011). Attentional bias to emotional stimuli is altered during moderate- but not high-intensity exercise. *Emotion, 11(6)*, 1415-1424.

Tran, U. S., Lamplmayer, E., Pitzinger, N. M., & Pfabigan, D. M. (2013). Happy and angry faces: Subclinical levels of anxiety are differentially related to attentional biases in men and women. *Journal of Research in Personality, 47*, 390-397.

CHAPTER 2

LITERATURE REVIEW

THE EFFECTS OF ACUTE EXERCISE ON ANXIETY AND ATTENTIONAL BIAS: A NARRATIVE REVIEW[1]

[1]Cooper, S.L. and P.D. Tomporowski. Submitted to *Journal of Sport and Health Science*, 6/26/14.

Abstract

Anxious individuals attend to threatening information differently than those who are not anxious. The impact of acute bouts of exercise on adults' attentional bias is understudied. Studies examining alteration of attention during and following bouts of exercise were reviewed. They provide preliminary evidence that exercise leads to shifts of attention away from unpleasant stimuli and towards pleasant stimuli. Sample characteristics, attention task features, exercise modality, and exercise intensity were not uniform across studies, which limits the ability to explain how exercise impacts attention deployment. Theory-based research is needed to better understand attentional bias and the influence that exercise may have on both anxious and non-anxious populations.

KEYWORDS: *Physical Activity, Dot-probe Task, Bias Modification*

Introduction

The anxiolytic effects of exercise have been well documented; however, the specific mechanisms by which exercise alleviates symptoms of anxiety are not clear-cut. Individuals with anxiety are purported to experience performance deficits in cognitive tasks resulting from an overactive stimulus-driven attention system and an underactive goal-directed attention system (Corbetta & Shulman, 2002; Eysenck, 2010). Specifically, individuals with anxiety preferentially allocate their attention toward threatening stimuli in their environment, which hinders their ability to inhibit and shift attention (Eysenck, 2010; Miyake et al., 2000). The inability to efficiently shift attention away from and/or inhibit attention towards threatening information leads to attentional bias (i.e. preferential allocation of attention towards threat stimuli) (Eysenck et al., 2007). It is important to be able to find methods that alter attentional bias in order to attenuate deficits in cognitive performance associated with anxiety.

Anxiety is the most prevalent mental disorder in the United States; therefore, it is important to find affordable and effective treatments to alleviate anxiety and minimize the cognitive deficits associated with clinical and non-clinical anxiety (Kessler, Chiu, Demler, & Walters, 2005). The incidence of anxiety is higher in women than men, and sex-dependent differences in attention deployment toward stimuli linked to mood disorders have been previously reported (Kessler et al., 2005; Tan et al., 2011; Tran et al., 2013). The imbalance in anxiety prevalence and differences in attention deployment creates the possibility that treatment outcomes may be sex-dependent; therefore, it is important to explore the anxiolytic effects of exercise as it varies by sex. In order to provide effective treatment for individuals reporting heightened anxiety levels, the impact of exercise on attention control is necessary to determine if attention deficits associated with anxiety are attenuated.

The purpose of this review is to provide a background on the relationship between anxiety, deployment of attention, and exercise, as well as, provide recommendations for future research examining exercise-induced changes in cognition and anxiety.

Anxiety

Anxiety is the most common mental disorder in the United States, with a lifetime prevalence of 33.7% for adults experiencing any anxiety disorder (Kessler et al., 2005; Kessler et al., 2012). Women consistently report higher levels of anxiety compared to men across different cultures, ages, and survey methods (Comer & Olfson, 2010; Steel et al., 2014). In the United States, the lifetime prevalence of anxiety for women is 40.4% and 26.4% for men (Kessler et al., 2012). Individuals with anxiety disorders are likely to have psychiatric comorbidities; many anxious individuals meet the criteria for multiple anxiety disorders and some experience mood disorders (e.g. depression) in addition to their primary anxiety disorder (Comer & Olfson, 2010). Finding ways to treat anxiety is important because it negatively impacts one's quality of life and creates an economic burden (Kessler & Greenberg, 2002).

Anxiety is an innate, universal human emotion that prepares individuals to respond to threat; however, if anxiety remains when a threat is no longer present or if threat is misperceived, it can become debilitating (Simpson, Neria, Lewis-Fernandez, & Schneier, 2010). Anxiety can be described as either a transitory state that is provoked by a stimulus or a trait that is enduring and predisposes an individual to perceive threat in the presence or absence of a discrete stimulus (Glick & Roose, 2010; Spielberger, 1983). Anxiety that is maladaptive involves cognitive, behavioral, and somatic responses that interfere with an individual's ability to perform daily functions, including cognitive tasks (Loflin, Vaughn, & Dziegielewski, 2002). Anxiety disorders are categorized based on specific triggers, distinctive symptoms, illness trajectory, and treatment response (Simpson et al., 2010). Subtypes of anxiety, such as, Post Traumatic Stress Disorder (PTSD), Obsessive-Compulsive Disorder (OCD), Generalized Anxiety Disorder (GAD), and phobias have specific symptoms; however, all anxiety conditions involve unrealistic fears due to misinterpretation of a situation (Loflin et al., 2002). Symptoms of anxiety may include: obsessive thoughts, nervousness, poor concentration, excessive worry, fear, avoidance behavior, sweating, trembling, and sleeplessness (Loflin et al., 2002). These symptoms negatively impact one's life; therefore, in order to treat the symptoms, it is important to understand theories that describe the development and maintenance of anxiety.

Theories have been proposed to explain the nature, development, and maintenance of anxiety disorders. Anxiety theories are typically categorized under one of the following perspectives: behavioral (e.g. Watson & Raynor, 1920), cognitive (e.g. Beck & Clark, 1997), cognitive-behavioral (e.g. Bandura, 1982), and neurobiological (e.g. Kalueff & Nutt, 2007) (Freeman & Freeman, 2012; Wolfe, 2005). Each perspective provides assumptions for the mechanisms that are responsible for anxiety disorders with varying importance placed on specific components. For example, behavioral theories focus solely on observable behavioral responses that are a result of learning, cognitive theories focus on the interpretation of danger that is linked to memory, and cognitive-behavioral theories focus on both the observable behavioral responses that result from learning and the cognitive representations associated with the environment (Wolfe, 2005). Despite differences among theories of anxiety, there are underlying commonalities about the nature, etiology, and maintenance of anxiety disorders.

Most, if not all, anxiety theories indicate that anxiety is an essential response to perceived danger, which is necessary for survival; it is an emotion that is an adaptive response to threat, and prepares the individual to react (Freeman & Freeman, 2012; Wolfe, 2005). However, if an individual is overly sensitive to threat, has unrealistic perceptions of danger, or sustains a heightened level of anxiety once threat or danger has subsided, an anxiety disorder develops and will interfere with one's daily living (Freeman & Freeman, 2012).

Attentional Control Theory

The attentional control theory (ACT), developed by Eysenck and colleagues (2007) focuses on the effects of anxiety on the central control system, which controls and directs attention, as described by Baddeley and Hitch's working memory model (Baddeley & Hitch, 1974). Attentional control depends on two theoretical attention systems: goal-directed and stimulus-driven (Corbetta & Shulman, 2002). The goal-directed attention system controls attention via 'higher' centers of the brain, such as the frontal cortex, and involves top-down processing that relies on information from previous experiences rather than sensory stimulation to allocate attention. The stimulus-driven system processes sensory information without feedback from 'higher' centers; the system detects behaviorally relevant, salient, or unexpected stimuli. This system is of particular interest because it directs attention to salient events that are outside of focused processing and is relevant for survival. The stimulus-driven system can be considered a 'circuit breaker' because it can disrupt focus processing when a behaviorally relevant stimulus or event is presented. ACT proposes that anxiety leads to an imbalance between the two systems, such that the stimulus-driven attentional system is overactive when threat stimuli is present, while activation in the goal-directed attentional system decreases (Eysenck et al., 2007).

The central executive and goal-directed attentional system can be further divided into functions that can be operationalized according to Miyake and colleagues based on psychometric measures and latent analyses (2012; 2000). The functions of the central executive (i.e. executive functions) have been identified as: updating, shifting, and inhibition. (Miyake et al., 2000) Miyake describes the three executive functions as follows: 1) Updating - the exploitation of working memory such that information is coded, monitored, and manipulated based on relevance to the present task; 2) Shifting – disengagement from a non-relevant task set and engagement in a relevant task set, which has also been called “attention switching”, and 3) Inhibition – purposeful prevention of a dominant or automatic response (Miyake et al., 2000). All three executive functions are moderately correlated, yet clearly separable based on latent variable analysis performed by Miyake et al. (2012; 2000); which suggests that there is unity and diversity between updating, shifting, and inhibition functions within the central executive. As a result, it is believed that all three executive functions involve top-down control by the central executive since they are partially interdependent based on latent variable analysis. There is evidence to support executive function impairments are associated with major depressive disorder (MDD), with MDD impairing inhibition by an effect size of $d=0.58$, $k=48$, shifting $d=0.47$, $k = 69$, and updating $d = 0.57$, $k = 10$; this brings forth the question of how anxiety could affect executive functions (Snyder, 2013).

Attentional Control Theory proposes several hypotheses concerning attentional control deficits observed in anxious individuals (Eysenck et al., 2007). As task demands placed on the central executive increase, anxious individuals are predicted to: have greater impairments in processing efficiency; evidence changes in increased activity in the stimulus-driven system (bottom-up processing) and decreased activity in the goal-directed system (top-down processing), creating an imbalance between the two attentional systems; demonstrate heightened influence of the stimulus-driven attentional system through impaired inhibitory functions and/or shifting functions compared to non-anxious individuals.

The hypotheses set forth by ACT are important in understanding the effects of anxiety on cognitive processes; of particular interest is the imbalance between the stimulus-driven and goal-directed attentional system in anxious individuals. The imbalance balance between systems is proposed to lead to an inability of the goal-directed attentional system to supersede the increased activation of the stimulus-driven system, which affects attention allocation. The failure to override the stimulus-driven system decreases the ability to inhibit and shift attention, which leads anxious individuals to be easily distracted by non-task relevant stimuli. Specifically, the stimulus-driven system is influenced the most by stimuli perceived as threatening. As a result, anxious individual's attention is strongly influenced by threat stimuli in their environment, which leads to an inability to inhibit attention towards threat stimuli and/or shift attention away from threat stimuli, leading to attentional bias. Attentional bias is the predisposition to preferentially allocate attention towards threat stimuli in anxious individuals. It is important to understand how anxiety affects performance by altering attention because deficits in executive function may cause anxious individuals to be less efficient performers in their daily tasks.

Attentional Bias

Attentional bias towards threatening stimuli has been observed in anxious individuals of many ages, across many types of anxiety disorders, in clinically and non-clinically diagnosed anxious individuals, utilizing numerous laboratory tasks, and with various types of stimuli (Bar-Haim et al., 2007). Attentional bias in anxious individuals has been observed in both children (e.g. Roy et al., 2008) and adults (e.g. MacLeod, Mathews, & Tata, 1986). Clinically diagnosed patients with various types of anxiety disorders, such as, generalized anxiety disorder (e.g. Bradley, Mogg, White, Groom & de Bono, 1999), obsessive-compulsive disorder (e.g. Tata, Leibowitz, Prunty, Cameron, & Pickering, 1996), panic disorder (e.g. McNally, Riemann, &

Kim, 1990), post traumatic stress disorder (e.g. Paunovic, Lundh, & Oest, 2002), social phobias (e.g. Amir, Elias, Klumpp, & Przeworski, 2003), and simple phobias (e.g. Watts, McKenna, Sharrock, & Trezise, 1986), demonstrate attentional bias towards threat. In addition to clinically anxious patients, non-clinically anxious individuals possess an attentional bias towards threat (e.g. MacLeod & Mathews, 1988). The widespread nature of attentional bias across many different types of anxiety, as well as, clinical status, has created numerous studies that examine this measure.

In order to have a comprehensive understanding of the strength of the relationship between attentional bias and anxiety, Bar-Haim et al. (2007) performed a meta-analysis of 172 studies to determine the observed effect of attentional bias towards threat stimuli in anxious individuals and non-anxious individuals. Studies included in the meta-analysis measured attentional bias via paradigms that rely on response time data to infer attentional bias. The overall effect size (ES) for attentional threat bias was determined to be $d = 0.45$ ($p < .01$) for anxious individuals, and $d = -0.007$ ($p = .85$) for non-anxious controls (Bar-Haim et al., 2007). The non-significant ES for non-anxious individuals, and significant ES for anxious individuals indicate that attentional threat bias *only* exists in anxious individuals and is absent in non-anxious individuals. Another meta-analysis examining attentional bias confirmed the results from Bar-Haim's findings (2007); Armstrong and colleagues (2012) performed a meta-analysis examining attentional bias via eye-tracking technology. Similar to the results of Bar-Haim et al. (2007), anxious individuals oriented their gaze towards threatening stimuli during a free viewing task significantly more than non-anxious individuals by an effects size of $g = .47$ in a sample of 20 studies (Armstrong & Olatunji, 2012). The results from Bar-Haim et al. (2007) and Armstrong et al. (2012) suggest that attentional bias towards threat is only observed in anxious individuals with various anxiety disorders and clinical status, and the bias is not observed in non-anxious individuals (Armstrong & Olatunji, 2012; Bar-Haim et al., 2007).

Attentional Bias Paradigms

Numerous assessments have been developed to measure attentional bias. The three most prominent paradigms are: modified Stroop, dot-probe, and modified Posner tasks (Bar-Haim et al., 2007). Each task relies on response times to infer difficulty disengaging from a specific category of stimuli (e.g. threatening) or heightened vigilance towards a specific category of stimuli. For example, the dot-probe task developed by MacLeod, Mathews, and Tata (1986) presents a pair of words or pictures (one neutral, one threat) on a computer screen for a set duration (subliminal to ≥1,000 ms). Following a fixed interval, a dot-probe replaces one of the two stimuli. The participant is instructed to make a behavioral response (i.e. a button press) based on the location of the dot. It is purported that shorter response times indicate that the individual was attending to the area of the computer screen just prior to the placement of the dot, whereas a delayed response indicates that the individual was attending to the other area of the computer screen and was forced to disengage, shift, and re-engage their attention to where the dot-probe appeared. When utilizing the dot-probe task as a measure of attentional bias towards threat for anxious individuals, the dot-probe replaces the threat stimuli at the same frequency as the neutral stimuli that it is paired. The category of non-neutral stimuli (e.g. threat) is selected based on the sample being tested, as well as the purpose of the research. For example, different categories of stimuli used in the dot-probe task include: threat (e.g. MacLeod & Mathews, 1988), unpleasant/negative (e.g. Tian & Smith, 2011), pleasant/positive (e.g. Koster et al., 2005), pain-related cues (e.g. Crombez et al., 2013), alcohol-related cues (e.g. White et al., 2014), and smoking cues (e.g Ehrman et al., 2002). In addition to using the dot-probe task as a measurement of attentional bias towards a specific category of stimuli that is related to a disorder, the paradigm has been altered and used as a treatment to diminish attentional bias associated with specific disorders, such as anxiety.

Attention Bias Modification

Attention bias modification (ABM), attention modification program (AMP), and cognitive bias modification (CBM) tasks have been developed to attenuate attentional bias for many disorders, including anxiety. This form of treatment uses an altered version of the dot-probe task; the dot-probe always replaces the neutral stimuli and never the stimuli associated with the disorder (e.g. threat) with the aim of training the individual to inhibit and shift their attention away from the stimuli that they are biased towards. A review by MacLeod and Mathews (2012) provides evidence that a single session of CBM can have an acute effect of reducing anxiety, decreasing emotional reactivity to a stressor, and lowering state anxiety prior to delivering a speech. Additionally, multiple sessions of CBM can lead to decreased trait anxiety scores, decreased perceived stress, and improve Generalized Anxiety Disorder (GAD) symptoms (MacLeod & Mathews, 2012). This highlights the importance of attenuating attentional bias in order for individuals to be able to perform activities of daily living (e.g. give a speech) with lower levels of state anxiety, less emotional reactivity to stressors, and decrease perceived stress. A meta-analysis examining the effectiveness of ABM on anxiety measures and attentional bias for twelve studies reports a moderate effect on anxiety measures ($d = 0.61$) and large overall effect for attentional bias ($d = 1.16$) (Hakamata et al., 2010). Perhaps most important, is the correlation between the magnitude of change in anxiety measures and attentional bias ($r = 0.75$, $p = 0.52$) (Hakamata et al., 2010). Innovative research has provided evidence that exercise may alter attentional bias, providing another method to dampen emotional reactivity to stressors and improve anxiety symptoms (Barnes et al., 2010; Tian & Smith, 2011).

Anxiety and Exercise

Epidemiological and cross-sectional studies have examined the association between physical activity and mental health. According to the National Comorbidity Survey, self-reported physical activity was associated with a lower prevalence of current major depression and anxiety disorders (Goodwin, 2003). Exercise has been purported to alleviate anxiety symptoms and protect against reactivity to stressors in patients with panic disorder, social anxiety disorder (SAD), generalized anxiety disorder (GAD), post-traumatic stress disorder (PTSD), and obsessive-compulsive disorder (OCD), as well as, healthy adults and chronically ill patients (Asmundson et al., 2013; Herring et al., 2013).

It is plausible that individuals with anxiety would utilize exercise as a means to treat symptoms because many anxiety patients seek non-traditional methods to alleviate their symptoms. In a cross-sectional and longitudinal survey, 43% of anxiety patients utilized one or more types of complimentary and alternative medicine (CAM) to treat their disorder (Bystritsky et al., 2012). This coincides with the findings of Kessler et al. (2001) in which 56.7% of individuals that reported experiencing anxiety attacks utilized a type of CAM within a 12-month period. One type of CAM used by anxious individuals is yoga: a practice that incorporates movement, specific body postures, breathing, and meditation into a single practice (Patel, Tranguch, & Muskin, 2010). Yoga is a low-intensity form of exercise, and is often included in reviews examining the effects of exercise on depression and anxiety (Asmundson et al., 2013; Herring, O'Connor, & Dishman, 2010; Kirkwood, Rampes, Tuffrey, Richardson, & Pilkington, 2005). In addition to yoga, other exercise modalities have been employed to decrease anxiety, which includes both aerobic exercise and resistance training.

Previous research has examined the acute effects and chronic effects of various exercise modalities on anxiety. The first meta-analysis examining the effects of exercise on anxiety reported that an acute bout of exercise decreases self-reported state anxiety by an effect size of 0.23 (Petruzzello et al., 1991). The majority of studies included in the meta-analysis consisted of aerobic exercise (n = 173) and very few were non-aerobic exercise modes (n = 13). Both aerobic exercise and resistance training exercise (non-aerobic) have been reported to decrease state anxiety post-exercise, with evidence suggesting that each modality is equally as effective (Bibeau, Moore, Mitchell, Vargas-Tonsing, & Bartholomew, 2010; Breus & O'Connor, 1998; Martinsen, Hoffart, & Solberg, 1989; O'Connor, Bryant, Veltri, & Gebhardt, 1993). The optimal duration of a single bout of exercise required to elicit anxiolytic effects has yet to be determined, but Petruzzello and colleagues (1991) suggest that a duration of 21-30 minutes of exercise leads to the greatest improvements in both state and trait anxiety; however, improvements may be dependent on baseline anxiety levels (Guszkowska, 2009).

In addition to examining the acute effects of exercise, the chronic effects have been studied by evaluating changes in anxiety before and after exercise training programs. The anxiolytic effects of exercise training programs have been reported in meta-analyses with effects ranging from 0.02 to 0.34, and samples consisting of individuals with anxiety disorders (Bartley, Hay, & Bloch, 2013), patients with chronic illness (Herring et al., 2010), healthy adults (Conn, 2010), and non-specified samples (Petruzzello et al., 1991). The large range in effect sizes provided by meta-analyses highlights the lack of uniformity in research examining the relationship between exercise and anxiety. Moderator analyses have provided evidence that studies that utilize randomization or matching for group allocation report the greatest improvements in anxiety post-intervention (Conn, 2010; Petruzzello et al., 1991), and the type of control group used as a comparison to exercise moderates the effect as well (Bartley et al., 2013). Chronic exercise training studies have also examined the effects of various modes of exercise. For example, a recent randomized controlled trial by Herring, Jacob, Suveg, & O'Connor (2011) reported that resistance training twice a week or performing aerobic exercise twice a week led to decreased anxiety levels and symptoms associated with generalized anxiety disorder (GAD) after six weeks of training. There was not a significant difference in the effectiveness of program modality (i.e. resistance training vs. aerobic training); however, resistance training lead to the highest remission rate of 60%, followed by a 40% remission rate for aerobic training, and a 30% remission rate for the waitlist control (Herring, Jacob, Suveg, Dishman, & O'Connor, 2012). It is imperative that researchers to continue to collect information about the acute and chronic effects of exercise on anxiety in order for exercise to be properly prescribed as a means to alleviate symptoms of anxiety, the most prevalent mental disorder in the United States (Kessler et al., 2005; Kessler et al., 2012).

Exercise and Attentional Bias: A Review of the Literature

Previous studies have reported the acute and chronic anxiolytic effects of exercise; however, the mechanisms that are responsible for changes in anxiety have yet to be clearly defined. Very few cognitive theories have been developed to explain changes in anxiety associated with exercise; the distraction hypothesis is one of few, if not the only, cognitive theory proposed (Breus & O'Connor, 1998). Although the distraction hypothesis possesses face validity, it lacks precision. It is important to develop a more precise, theoretically driven hypothesis that explains cognitive mechanisms that may be responsible for the anxiolytic effects of exercise. Recent research has utilized the dot-probe task to establish if exercise alters deployment of attention when unpleasant stimuli are present. It is important to understand if exercise alters attentional bias because these changes may be linked to changes in mood and anxiety post-exercise (Van Bockstaele et al., 2014).

Barnes et al. (2010) provides evidence that deployment of attention may be altered post-exercise. Thirty individuals with high trait anxiety [mean STAI-Trait score = 53.6 (4.2)] performed 48 trials of a dot-probe task that consisted of pleasant/neutral and unpleasant/neutral picture pairs. Each picture pair was displayed for 500 ms. A dot immediately replaced one of the two pictures and the participant made a button press to indicate where the dot was located on the screen. Attention allocation was inferred by the response time of the participant, which indicates if the participant is disproportionately attending to one type of stimuli compared to another (i.e. attentional bias). Participants completed two, 30-minute testing sessions. One session consisted of resting for 30 minutes, and participants were given the option to read school materials to pass the time. The other session consisted of 30 minutes of cycling at 70% heart rate reserve. The dot-probe task was administered before and after the 30 minutes of rest or exercise. Results indicate that there was a Condition x Valence interaction for the dot-probe task with positive bias increasing post-exercise and negative bias decreasing post-exercise; however, the follow-up analyses did not reach statistical significance. The authors note that post-exercise response times were quicker when the dot-probe replaced a positive or negative picture compared to a neutral picture, suggesting that a broadening of attention for positive and negative stimuli may occur post-exercise. This coincides with the findings of Hummer and McClintock (2009) that report significant changes in attentional bias when androstadienone, a pheromone found in sweat and saliva, is applied just above the lip. It is purported that androstadienone significantly alters attention towards pleasant and unpleasant stimuli, but does not alter response times towards neutral stimuli. This may provide a rationale for why exercise increased vigilance towards emotional stimuli compared to neutral stimuli: sweat produced by exercise containing pheromones altered attention when emotional stimuli were presented. State anxiety decreased similarly after both testing conditions; however, self-report positive affect increased only post-exercise.

Barnes and colleagues were the first to examine changes in attentional bias pre- to post-exercise. The interaction between condition and valence (i.e. bias scores) suggests that exercise could alter attention allocation to positive and/or negative stimuli; however, the number of trials completed by participants may not have been enough to produce meaningful comparisons. Salthouse and Hedden (2002) suggest 50-200 trials of each condition be completed in order to have enough information to make meaningful evaluations of response times. Participants only completed 48 trials (24 pleasant/neutral, 24 negative/neutral) for each dot-probe task, which may have limited the ability to find changes in attentional bias. Another limitation to the research is the category of stimuli used for this specific sample. According to the Attention Control Theory, anxious individuals possess an attentional bias towards threat related information (Eysenck et al., 2007). Barnes et al. (2010) displayed "unpleasant" stimuli that were selected from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 2005) based on valence and arousal. Perhaps greater attentional biases would have been elicited in the sample of high anxious individuals had the stimuli been selected based on dominance rather than unpleasantness, assuming that a picture that elicits a feeling of low dominance is synonymous to threatening. Presenting stimuli that are theoretically related to the samples' characteristics could impact the magnitude of change measured post-exercise. Despite its limitations, this research is important because it is the first to demonstrate a relationship between exercise and attentional bias.

Exercise induced changes in attentional bias towards pleasant and unpleasant stimuli have also been reported by Tian and Smith (2011). Participants completed 256 dot-probe trials that included picture pairs of pleasant/neutral and unpleasant/neutral facial expressions while at rest, cycling at 45% VO_{2peak}, and cycling at 80% $VO2_{peak}$. Results indicate a statistically significant Condition x Valence interaction. During moderate intensity exercise, participants exhibited a significantly greater attentional bias towards pleasant stimuli compared to unpleasant stimuli. Additionally, attentional bias towards unpleasant stimuli was significantly less during moderate intensity exercise compared to seated rest. Attentional bias towards unpleasant stimuli was the greatest in the seated rest condition. State anxiety was only measured prior to each condition; this prevents conclusions to be drawn about the relationship between exercise-induced changes in state anxiety and attentional bias. It is important to note that the changes in attentional bias during exercise occurred in a healthy, non-anxious sample. Previous research has provided evidence that individuals with dysphoria and anxiety possess attentional bias towards unpleasant and threatening stimuli, respectively (Bar-Haim et al., 2007; Koster et al., 2005). Depression symptoms were not evaluated in Tian and Smith's study; only anxiety was assessed (Tian & Smith, 2011). This research provides evidence that the type of emotional stimuli that one attends to can be altered while exercising at a moderate intensity.

A third study examined the acute effects of exercise on attentional bias; however, it also included an attentional modification program (AMP) to determine if there was an additive effect of exercise in altering attention deployment. Julian et al. (2012) examined changes in attentional bias towards socially threatening words in a between-groups research design that included four conditions: exercise + AMP, rest + AMP, exercise + attention control, rest + attention control. Individuals assigned to exercise performed moderate intensity exercise (50-70% HR_{max}) on a treadmill for 20 minutes with an additional 5-minute warm-up and 5-minute cool-down. Participants in the rest condition rested for 30-minutes (no further details were provided). A modified dot-probe task with pictures of facial expressions was used for the AMP treatment and a dot-probe task with pictures of facial expressions was used for the attention control (ACC) condition. For the AMP, the dot-probe always replaced the neutral facial expression, whereas in the ACC condition, the dot-probe replaced the neutral facial expression and the socially threatening facial expression at an equal frequency. AMP is purported to force individuals to improve their ability to disengage their attention from threatening stimuli more rapidly. Participants completed a modified Posner task with words to assess attentional bias task four times throughout the testing session: Assessment 1 → Exercise/Rest → Assessment 2 → AMP/ACC → Assessment 3 → Speech Stressor Task → Assessment 4. Results indicate that exercise did not alter attentional bias towards socially threatening stimuli. Additionally, AMP did not alter attentional bias towards socially threatening stimuli, which fails to support previous research providing evidence for the efficacy of attention modification paradigms. It should be noted that the type of stimuli was not uniform between the treatment conditions (AMP/ACC) and the attentional bias assessment. The AMP/ACC tasks consisted of pictures of facial expressions and the attentional bias assessments utilized words, which may confound the results. Additionally, the AMP/ACC conditions used the dot-probe task as a treatment or control condition, and a modified Posner paradigm was used to assess attentional bias. The null findings may indicate that AMP only elicits changes in attentional bias when both the treatment and measurement task are the same. Further research should be performed to determine if AMP outcomes are dependent on the type of paradigm used to measure bias, as well as, the type of stimuli used for both treatment and assessment.

In summary, there is limited research examining the impact of exercise on attentional bias, a measure that is theoretically linked to mood disorders, such as anxiety (Eysenck, 2010). Research indicates that there are changes in attention allocation to stimuli categorized as pleasant and unpleasant; however, it is important to examine changes in attention towards stimuli categorized as threatening since it is related to the most prevalent psychological disorder in the United States: anxiety (Eysenck, 2010; Kessler et al., 2012). Investigators should continue to explore this area of research in order to determine if changes in attentional bias are associated with changes in anxiety, which would provide a cognitive hypothesis for the anxiolytic effects of exercise.

Future Direction

Future research examining exercise-induced changes in attention and anxiety should focus on samples of high anxious individuals. By selecting a sample that is predisposed to attentional bias towards threat, the magnitude of exercise-induced changes could be greater than observed in the previous studies that utilized non-anxious samples and studies that used stimuli that are not theoretically associated with anxiety (e.g. positive valence stimuli). Additionally, to determine if the anxiolytic effects of exercise are related to changes in processing emotional stimuli, measures of state anxiety should be measured with the attentional bias task. The relationship between attentional bias and anxiety is purported to be bidirectional; therefore, it is important that future research administer a measure of state anxiety immediately before and after assessing attentional bias to examine the sequence of change (Bockstaele et al., 2014). Perhaps exercise-induced changes in attentional bias precede changes in self-report anxiety or vice versa;

therefore, the order in which the tasks and questionnaires are presented will impact the generalizability of the results.

Lastly, women consistently report a higher lifetime prevalence of anxiety disorders than men (Comer & Olfson, 2010; Kessler et al., 2005; Kessler et al., 2012). Animal studies examining behavior suggest that fear conditioning and fear extinction differ between sexes and sex steroids that differ between males and females (e.g. estrogen and progesterone) may modify neural circuitry in areas of the brain related to anxiety (e.g. prefrontal cortex, amygdala, hippocampus) (Farrell et al., 2013). A recent meta-analysis reports significant regional difference in male and female brain structures that may be linked to the unequal prevalence of psychological disorders experienced between the two sexes (Ruigrok et al., 2014). Specifically, sex differences in regional grey matter volume and tissue density have been observed in the amygdala, hippocampus, putamen, and other areas of the limbic system that are associated with anxiety (Ruigrok et al., 2014). In addition to structural and physiological differences between sexes, there is evidence supporting sex-related differences in attention measured by performance on the dot-probe task: women possess a significantly greater bias towards negative stimuli compared to men (Tan, Ma, Gao, Wu, & Fang, 2011; Tran et al., 2013). Sex differences observed in behavior and neural circuitry in animal studies, neuroimaging studies in humans, and attentional bias measures provide rationale to explore sex-dependent changes in both attentional bias and anxiolytic effects of exercise. Future studies should either a) examine samples consisting only of men or only of women, or b) perform statistical analysis that control for sex differences in attentional bias. Previous research examining exercise-induced changes in attentional bias overlooked sex-related differences, which may have masked changes in bias that may be sex-dependent. Exploring sex-related differences and understanding the impact of exercise on attention allocation in anxious individuals is needed to provide effective treatments for individuals experiencing difficulty inhibiting and shifting attention, which leads to cognitive performance deficits.

Table 2.1 Description of studies examining exercise-induced changes in attentional bias.

AUTHORS	PARTICIPANTS	ATTENTIONAL BIAS PARADIGM VARIABLES	CONDITIONS	RESULTS
Barnes et al. (2010)	n = 30 19 female, 11 male High-anxious	Dot-probe task: 48 trials Pictures: pleasant, unpleasant, & neutral scenes Duration stimulus displayed: 500 ms Assessed: pre- & post-	Exercise: 30 min of cycling at 70% HRR Rest: 30 min of rest; studying optional	Condition x Valence interaction Positive bias increased post-exercise Negative bias decreased post-exercise
Tian & Smith (2011)	n = 34 17 female, 17 male Healthy students	Dot-probe task: 256 trials Pictures: pleasant, unpleasant, & neutral facial expressions Duration stimulus displayed: 1000 ms Assessed: during	Moderate Intensity Exercise: 45% VO_{2peak} High Intensity Exercise: 80% VO_{2peak} Rest	Condition x Valence interaction Positive bias was significantly greater than negative bias during moderate intensity exercise Negative bias was the lowest during moderate intensity exercise
Julian et al. (2012)	n = 112 91 female, 26 male Elevated social anxiety	Posner paradigm: 192 trials Words: socially threatening, & neutral words Duration stimulus displayed: information not provided Assessed: pre- & post-	EX+AMP: 30 min exercise & AMP Rest+AMP: 30 min rest & AMP EX+ACC: 30 min exercise & ACC Rest+ACC: 30 minutes rest & ACC	No changes in attentional bias across all conditions

References

Amir, N., Elias, J., Klumpp, H., & Przeworski, A. (2003). Attentional bias to threat in social phobia: facilitated processing of threat or difficulty disengaging attention from threat? *Behaviour Research and Therapy, 41*, 1325-1335.

Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: a meta-analytic review and synthesis. *Clinical Psychology Review, 32*(8), 704-723. doi: 10.1016/j.cpr.2012.09.004

Asmundson, G. J., Fetzner, M. G., Deboer, L. B., Powers, M. B., Otto, M. W., & Smits, J. A. (2013). Let's get physical: a contemporary review of the anxiolytic effects of exercise for anxiety and its disorders. *Depression and Anxiety, 30(4)*, 362-373. doi: 10.1002/da.22043

Baddeley, A. D., & Hitch, G. (1974). Working Memory. *Psychology of Learning and Motivation, 8*, 47-89.

Bandura, A. (1982). The assessment and predictive generality of self-percepts of efficacy. *Journal of Behavior Therapy and Experimental Psychiatry, 13*, 195-199.

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. doi: 10.1037/0033-2909.133.1.1

Barnes, R. T., Coombes, S. A., Armstrong, N. B., Higgins, T. J., & Janelle, C. M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *Journal of Sports Sciences, 28(10)*, 1065-1076.

Bartley, C. A., Hay, M., & Bloch, M. H. (2013). Meta-analysis: aerobic exercise for the treatment of anxiety disorders. *Progress in Neuro-psycholpharmacology & Biological Psychiatry, 45*, 34-39. doi: 10.1016/j.pnpbp.2013.04.016

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.

Bibeau, W. S., Moore, J. B., Mitchell, N. G., Vargas-Tonsing, T., & Bartholomew, J. B. (2010). Effects of acute resistance training of different intensitites and rest periods on anxiety and affect. *Journal of Strength and Conditioning Research, 24(8)*, 2184-2191.

Van Bockstaele, B., Verschuere, B., Tibboe, 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.

Bradley, B. P., Mogg, K., White, J., Groom, C., & de Boono, J. (1999). Attentional bias for emotional faces in generalized anxiety disorder. *The British Journal of Clinical Psychology, 38*, 267 - 278.

Breus, M. J., & O'Connor, P. J. (1998). Exercise-induced anxiolysis: a test of the "time out" hypothesis in high anxious females. *Medicine & Science in Sports & Exercise, 30(7),* 1107-1112.

Bystritsky, A., Hovav, S., Sherbourne, C., Stein, M. B., Rose, R. D., Campbell-Sills, L., . . . Roy-Byrne, P. P. (2012). Use of complementary and alternative medicine in a large sample of anxiety patients. *Psychosomatics, 53*, 266-272.

Comer, J. S., & Olfson, M. (2010). The epidemiology of anxiety disorders. In H. B. Simpson, Y. Neria, R. Lewis-Fernandez & F. Schneier (Eds.), *Anxiety Disorders: Theory, Research, and Clinical Perspectives* (pp. 6-19). New York, NY: Cambridge University Press.

Conn, V. S. (2010). Anxiety outcomes after physical activity interventions: meta-analysis findings. *Nursing research, 59(3)*, 224-231. doi: 10.1097/NNR.0b013e3181dbb2f8

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3(3)*, 201-215. doi: 10.1038/nrn755

Crombez, G., Van Ryckeghem, D. M. L., Eccleston, C., & Van Damme, S. (2013). Attentional bias to pain-related information: A meta-analysis. *Pain, 154(4)*, 497-510.

Ehrman, R. N., Robbins, S. J., Bromwell, M. A., Lankford, M. E., Monterosso, J. R., & O'Brian, C. P. (2002). Comparing attentional bias to smoking cues in current smokers, former smokers, and non-smokers using a dot-probe task. *Drug and Alcohol Dependence, 67*, 185-191.

Eysenck, M. W. (2010). Attentional control theory of anxiety: Recent developments. In A. Gruszka (Ed.), *Handbook of Individual Differences in Cognition: Attention, Memory, and Executive Control.* (pp. 195-204): Springer Science+Business Media.

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

Farrell, M. R., Sengelaub, D. R., & Wellman, C. L. (2013). Sex differences and chronic stress effects on the neural circuitry underlying fear conditioning and extinction. *Physiology & Behavior, 122*, 208-215. doi: 10.1016/j.physbeh.2013.04.002

Freeman, D., & Freeman, J. (2012). *Anxiety: A very short introduction*. United Kingdom: Oxford University Press.

Glick, R. A., & Roose, S. P. (2010). Anxiety as a signal, symptom, and syndrome. In H. B. Simpson, Y. Neria, R. Lewis-Fernandez & F. Schneier (Eds.), *Anxiety Disorders: Theory, Research and Clinical Perspectives* (pp. 50-58). New York, NY: Cambridge University Press.

Goodwin, R. D. (2003). Association between physical activity and mental disorders among adults in the United States. *Preventive Medicine, 36(6),* 698-703. doi: 10.1016/s0091-7435(03)00042-2

Guszkowska, M. (2009). State/trait anxiety and anxiolytic effects of acute physical exercises. *Biomedical Human Kinetics, 1*, 6-10.

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, 28*, 982-990.

Herring, M. P., Jacob, M. L., Suveg, C., Dishman, R. K., & O'Connor, P. J. (2012). Feasibility of exercise training for the short-term treatment of generalized anxiety disorder: a randomized controlled trial. *Psychotherapy and Psychosomatics, 81(1)*, 21-28. doi: 10.1159/000327898

Herring, M. P., Jacob, M. L., Suveg, C., & O'Connor, P. J. (2011). Effects of short-term exercise training on signs and symptoms of generalized anxiety disorder. *Mental Health and Physical Activity, 4(2),* 71-77. doi: 10.1016/j.mhpa.2011.07.002

Herring, M. P., Lindheimer, J. B., & O'Connor, P. J. (2013). The effects of exercise training on anxiety. *American Journal of Lifestyle Medicine, 8,* 388-403. doi: 10.1177/1559827613508542

Herring, M. P., O'Connor, P. J., & Dishman, R. K. (2010). The effect of exercise training on anxiety symptoms among patients. *Archives of Internal Medicine, 170(4),* 321-331.

Hummer, T. A., & McClintock, M. K. (2009). Putative human pheromone androstadienone attunes the mind specifically to emotional information. *Hormones and Behavior, 55(4),* 548-559. doi: 10.1016/j.yhbeh.2009.01.002

Julian, K., Beard, C., Schmidt, N. B., Powers, M. B., & Smits, J. A. (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. doi: 10.1016/j.brat.2012.02.015

Kalueff, A. V., & Nutt, D. J. (2007). Role of GABA in anxiety and depression. *Depression and Anxiety, 24(7)*, 495-517.

Kessler, R. C., Chiu, W. T., Demler, O., & Walters, E. E. (2005). Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the national comorbidity survey replication. *Archives of General Psychiatry, 62*, 617- 627.

Kessler, R. C., Petukhova, M., Sampson, N. A., Zaslavsky, A. M., & Wittchen, H. U. (2012). Twelve-month and lifetime prevalence and lifetime morbid risk of anxiety and mood disorders in the United States. *Internal Journal of Methods in Psychiatric Research, 21(3)*, 169-184. doi: 10.1002/mpr.1359

Kessler, R. C., Soukup, J., Davis, R. B., Foster, D. F., Wilkey, S. A., Van Rompay, M. I., & Eisenberg, D. M. (2001). The use of complementary and alternative therapies to treat anxiety and depression in the United States. *The American Journal Of Psychiatry, 158(2)*, 289 - 294.

Kirkwood, G., Rampes, H., Tuffrey, V., Richardson, J., & Pilkington, K. (2005). Yoga for anxiety: A systematic review of the research evidence. *Br J Sports Med, 39(12)*, 884-891; discussion 891. doi: 10.1136/bjsm.2005.018069

Koster, E. H., De Raedt, R., Goeleven, E., Franck, E., & Crombez, G. (2005). Mood-congruent attentional bias in dysphoria: maintained attention to and impaired disengagement from negative information. *Emotion, 5(4)*, 446-455. doi: 10.1037/1528-3542.5.4.446

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). International Affective Picture System (IAPS): Instruction manual and affective ratings. *Technical Report #A-6*. Gainsville, FL: University of Florida.

Loflin, J., Vaughn, C. J., & Dziegielewski, S. F. (2002). Anxiety Disorders: Obsessive Compulsive Disorder. In S. F. Dziegielewski (Ed.), *DSM-IV-TR In Action*: John Wiley & Sons, Inc.

MacLeod, C., & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *The Quarterly Journal of Experimental Psychology Section A, 40(4)*, 653-670. doi: 10.1080/14640748808402292

MacLeod, C., & Mathews, A. (2012). Cognitive bias modification approaches to anxiety. *Annual Review of Clinical Psychology, 8*, 189-217. doi: 10.1146/annurev-clinpsy-032511-143052

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional Bias in Emotional Disorders. *Journal of Abnormal Psychology, 95(1)*, 15-20.

Martinsen, E. W., Hoffart, A., & Solberg, O. Y. (1989). Aerobic and non-aerobic forms of exercise in the treatment of anxiety disorders. *Stress Medicine, 5*, 115-120.

McNally, R. J., Riemann, B. C., & Kim, E. (1990). Selective processing of threat cues in panic disorder. *Behaviour Research and Therapy, 28(5)*, 407-412.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: four general conclusions. *Current Directions in Psychological Science, 21(1)*, 8-14.

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

O'Connor, P. J., Bryant, C. X., Veltri, J. P., & Gebhardt, S. M. (1993). State anxiety and ambulatory blood pressure following resistance exercise in females. *Medicine & Science in Sports & Exercise, 25(4),* 516-521.

Patel, S., Tranguch, A. J., & Muskin, P. R. (2010). Complementary and alternative medicine approaches to the treatment of anxiety. In H. B. Simpson, Y. Neria, R. Lewis-Fernandez & F. Schneier (Eds.), *Anxiety Disorders: Theory, Research and Clinical Perspectives* (pp. 336-347). New York, NY: Cambridge University Press.

Paunovic, N., Lundh, L.-G., & Ost, L.-G. (2002). Attentional and memory bias for emotional information in crime victims with acute posttraumatic stress disorder (PTSD). *Journal Of Anxiety Disorders, 16*, 675-692.

Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kuitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11(3)*, 143-182.

Roy, A. K., Vesa, R. A., Bruck, M., Mogg, K., Bradley, B. P., Sweeney, M., . . . Team, C. (2008). Attention bias toward threat in pediatric anxiety disorders. *Journal of the American Academy of Child & Adolescent Psychiatry, 47(10),* 1189-1196.

Ruigrok, A. N., Salimi-Khorshidi, G., Lai, M. C., Baron-Cohen, S., Lombardo, M. V., Tait, R. J., & Suckling, J. (2014). A meta-analysis of sex differences in human brain structure. *Neuroscience and Biobehavioral Reviews, 39*, 34-50. doi: 10.1016/j.neubiorev.2013.12.004

Salthouse, T. A., & Hedden, T. (2002). Interpreting reaction time measures in between-group comparisons. *Journal Of Clinical And Experimental Neuropsychology, 24(7),* 858-872.

Simpson, H. B., Neria, Y., Lewis-Fernandez, R., & Schneier, F. (2010). Introduction: The need for interdisciplinary approaches. In H. B. Simpson, Y. Neria, R. Lewis-Fernandez & F. Schneier (Eds.), *Anxiety Disorders: Theory, Research and Clinical Perspectives*. New York, NY: Cambridge University Press.

Snyder, H. R. (2013). Major depressive disorder is associated with broad impairments on neuropsychological measures of executive function: a meta-analysis and review. *Psychological Bulletin, 139(1),* 81-132. doi: 10.1037/a0028727

Spielberger, C. D. (1983). *State-trait inventory for adults*: Mind Garden, Inc.

Tan, J., Ma, Z., Gao, X., Wu, Y., & Fang, F. (2011). Gender difference of unconscious attentional bias in high trait anxiety individuals. *PLoS One, 6(5)*. doi: 10.1371/journal.pone.0020305

Tata, P. R., Leibowitz, J. A., Prunty, M. J., Cameron, M., & Pickering, A. D. (1996). Attentional bias in obsessional compulsive disorder. *Behaviour Research and Therapy*, *34(1)*, 53 - 60.

Tian, Q., & Smith, J. C. (2011). Attentional Bias to Emotional Stimuli is Altered During Moderate- but Not High-Intensity Exercise. *Emotion*, *11(6)*, 1415-1424.

Tran, U. S., Lamplmayer, E., Pitzinger, N. M., & Pfabigan, D. M. (2013). Happy and angry faces: subclinical levels of anxiety are differentially related to attentional biases in men and women. *Journal of Research in Personality*, *47*, 390-397.

Watson, J. B., & Rayner, R. (1920). Conditioned emotional reactions. *Journal of Experimental Psychology*, *3*, 1-14.

Watts, F. N., McKenna, F. P., Sharrock, R., & Trezise, L. (1986). Colour naming of phobia-related words. *British Journal of Psychology*, *77*, 97-108.

White, M. J., Cunningham, L. C., Pearce, R., & Newnam, S. (2014). Reward sensitivity predicts attentional bias towards alcohol-related cues in young binge drinkers. *Personality and Individual Differences*, *60(S)*, S13-S14.

Wolfe, B. E. (2005). *Understanding and Treating Anxiety Disorders: An Integrative Approach to Healing the Wounded Self*. Washington, DC: American Psychological Association.

CHAPTER 3

ACUTE EXERCISE ALTERS MEMORY PERFORMANCE AND ENHANCES MOOD, BUT DOES NOT INFLUENCE WORD-BASED ATTENTIONAL BIAS IN FEMALES WITH LOW- AND HIGH-TRAIT ANXIETY[1]

[1]Cooper, S.L. and P.D. Tomporowski. To be submitted to *Health Psychology*.

Abstract

Attentional bias, a processing style that is linked to anxiety, can be modified through attention training. Numerous studies have reported improvements in anxiety and attention after an acute bout of exercise; however, very little research has examined the impact of exercise on attentional bias. The present study was conducted to determine the acute effects of exercise on word-based attentional bias, memory, and mood. Sixty-four females between the ages of 18-34 years were randomly assigned to either a seated rest control condition, or an exercise condition that involved cycling at 45% VO_2R for 20 minutes. Measures of attentional bias and mood were collected three times throughout the session, and a memory task was performed at the conclusion of the session. Results indicate that an acute bout of exercise had a small effect on word-based attentional bias post-exercise (d = 0.23), but these changes were not statistically significant. Significant differences between conditions were observed for memory performance, as well as, exercise-induced changes in mood. Compared to the control condition, individuals in the exercise condition performed the memory task with fewer false alarms and were more successful in recognizing stimuli that had been previously presented. Participants in the exercise condition experienced improvements in ratings of overall mood (d = 0.98), decreased confusion (d = 0.52), decreased tension (d = 0.59), and improved feelings of vigor (d = 0.65) post-exercise.

KEYWORDS: *Physical Activity, Dot-Probe, Anxiety, Recognition, Signal Detection*

Introduction

Individuals with clinical and non-clinical anxiety disproportionally allocate their attention towards threatening stimuli compared to neutral and/or pleasant stimuli (Cisler & Koster, 2010). The robust relationship between attentional bias towards threat and anxiety has been observed across many anxiety disorders, measured by several attentional bias paradigms, and within various samples of people (Bar-Haim et al., 2007). Theories have been developed to explain the relationship between attentional bias and anxiety (Cisler & Koster, 2010). The Attentional Control Theory (ACT) (2007) provides six hypotheses about the relationship between anxiety, executive function, and attentional bias. According to ACT, attentional bias arises from executive function impairments that develop from unbalanced top-down (goal-directed) and bottom-up (stimulus-driven) control of the attention systems in anxious individuals. As a result, individuals with anxiety have difficulty shifting attention away from threatening stimuli and inhibiting attention deployment towards threatening stimuli, which results in disproportionate attention to threat (i.e. attentional bias) (Eysenck et al., 2007).

The relationship between anxiety and attentional bias has been described as reciprocal or bidirectional (Bockstaele et al., 2014); therefore, it is important to find treatment methods that alleviate both anxiety and attentional bias towards threat. Attention training has been presented as a valuable tool to regulate emotion (Wadlinger & Isaacowitz, 2011). Computer-based Attentional Bias Modification programs (ABM) have been established to train anxious individuals to be more efficient at diverting attention away from threatening information, and have profound effects on both attenuating attentional bias and decreasing anxiety symptoms (Beard et al., 2012; Hakamata et al., 2010; Mogoase et al., 2014).

Anxiety symptoms can also be alleviated through acute and chronic bouts of exercise (Herring et al., 2013; Petruzzello et al., 1991). Recently, acute exercise has been utilized as a method for altering attentional bias. Two studies utilized unpleasant and pleasant picture stimuli to measure attentional bias. Tian and Smith (2011) and Barnes et al (2010) observed exercise-related changes in attentional bias. Cooper (2012) performed a systematic replication to confirm and expand the findings of the previous studies. Utilizing word stimuli and methods employed by Tian and Smith, as well as Barnes and colleagues, the systematic replication examined changes in attentional bias before, during, and after a moderate intensity bout of cycling in a sample of 39 males and females. Cooper (2012) failed to replicate the exercise-induced changes in attentional bias previously reported. Although the pattern of change in attentional bias was similar to prior studies, the change did not reach the critical p-value of .05. As a result, the present study was developed to improve the research methodology in order to maximize the likelihood that exercise-induced changes in attentional bias would be observed.

The present study was developed to extend the findings of Cooper (2012). Differences from the 2012 study design were as follows: First, threatening word stimuli were selected based on the theory that attentional bias towards threatening information is linked to anxiety (Eysenck et al., 2007). Second, only females were selected to participate in the study to minimize variance from sex-based differences in attentional bias and anxiety prevalence (Kessler et al., 2012; McLean, Asnaani, Litz, & Hofmann, 2011; Tan et al., 2011). Third, low- and high-trait anxious women were selected to participate to determine if exercise-induced changes in attentional bias vary by trait anxiety status. Fourth, measures of attentional bias were obtained before, 5 minutes after, and 20 minutes after an acute bout of moderate intensity exercise because the greatest exercise-induced changes in anxiety have been observed post-exercise (Petruzzello et al., 1991).

The present study is the first of two studies examining the exercise-induced changes in attentional bias in low-trait and high-trait anxious women between the ages of 19-34 years. The current study employs word stimuli for the attentional bias task, and the second study employs picture stimuli for the attentional bias task in order to determine if exercise-induced changes vary based on type of stimuli displayed. ABM has been found to be effective in alleviating anxiety symptoms and altering attentional bias towards threatening information; however, it is purported that the type of stimuli (word vs. picture) used during ABM modifies the effect of the attention training (Bar-Haim, 2010; Beard et al., 2012; Hakamata et al., 2010; Mogoase et al., 2014). Bar-Haim (2010) stated that the type of stimuli presented during ABM that is most effective in eliciting changes in attentional bias and anxiety symptoms may be linked to the type of anxiety disorder an individual possesses. For example, individuals with generalized anxiety disorder (GAD) or post-traumatic stress disorder (PTSD) may have a greater response to ABM treatment that utilizes words stimuli because of the abstract nature of the disorder, whereas specific phobias may need to utilize picture-based attention training to be more effective (Bar-Haim, 2010). As a result of differences in treatment outcomes for word-based and picture-based ABM, as well as differences in brain activation when observing emotional word stimuli and pictures stimuli, the second study was performed utilizing pictures as stimuli (Kensinger & Schacter, 2006).

In addition to measuring changes in attentional bias, memory was assessed at the end of the testing session to determine if differences in memory performance occurred between conditions. The memory recognition task was developed to assess the participant's memory of stimuli presented during the attention task and to provide a rationale for reading the word stimuli during the attention task. Mood states were assessed pre-exercise, 5 minutes post-exercise and 20 minutes post-exercise to be able to examine acute exercise-induced changes in mood.

The three hypotheses set forth for this study were as follows: Word-based attentional bias towards threat was predicted to decrease in the exercise condition 5 minutes and 20 minutes post-exercise for only participants in the exercise condition. Individuals in the exercise condition were expected to perform better on the recognition memory task post-exercise compared to the resting control condition. Measures of mood (e.g. anxiety/tension, vigor, etc.) were anticipated to improve post-exercise for only the exercise condition.

Methods

Participants

Participants were recruited via flyers and classroom presentations in the department of Kinesiology at the University of Georgia. Individuals who were interested in participating in the study completed the following forms online: consent form, medical history questionnaire, and the State-Trait Anxiety Inventory for Trait Anxiety (STAI-T) in order to determine if they met the following inclusionary criteria: (a) female, (b) between the ages of 18-35, (c) no predisposition to experience an adverse event while exercising (d) score ≤ 33 or ≥ 40 on the STAI-T. Based on the online screening, 71 females qualified for the study. Seven participants were unable to schedule their two testing sessions; therefore, a total of 64 females (mean age = 22.3, SD = 3.95) completed two testing sessions in the laboratory. Participants were categorized as low anxious if their online STAI-T score was ≤ 33 and high anxious if their online STAI-T score was ≥ 39. According to the norms provided by the State-Trait Anxiety Inventory, the average anxiety score for women between 18-39 years old is approximately 36; the cutoff points selected were one-third of a standard deviation above and below the average for this population (Spielberger, 1983).

Procedure

The research protocol followed APA guidelines for ethical research methods, and The University of Georgia Institutional Review Board approved the protocol. All participants completed two testing sessions. During session 1, participants completed the following: consent form, 24-hour history questionnaire for sleep, medication, exercise, and caffeine intake, STAI-T, and Beck Depression Inventory (BDI-II). Once all forms were completed, the participant learned and practiced 4 dot-probe tasks with 30 trials per task (see dot-probe task below). Next, a VO_{2peak} test was completed on the cycle ergometer (Lode Corival) to determine cardiovascular fitness. Participants were instructed to put on a heart rate monitor strap (Polar Electro Inc, Lake Success, NY) and the appropriate adjustments were made to the cycle ergometer (Lode Corival) to ensure proper cycling form. Once the participant was setup on the cycling ergometer, they were connected to the Truemax 2400 metabolic measurement system (Parvo Medics, Sandy, UT) to measure gas exchange. The VO_{2peak} test started with a 1-minute resting period, followed by a 2-minute warm-up with a resistance of 25 watts. Throughout the duration of the staged protocol participants were instructed to maintain a cadence of 60-80 rpm. Following the warm-up, resistance provided by the cycle ergometer increased by 33 watts every 2 minutes until volitional exhaustion was achieved. Heart rate and rating of perceived exertion (RPE) were recorded approximately 30 seconds before the end of each resistance stage. A 2-minute cool-down began when the participant terminated the test.

Session 2 occurred within 2 weeks of session 1 (mean = 3.9 days, range = 1-11 days). Blocked randomization was used to determine the testing condition for the session; participants were categorized as low- or high-anxious based on their online STAI-T score and were then randomly assigned to either an exercise or seated rest control condition. The control condition (n=32) consisted of 14 low-anxious and 18 high-anxious individuals; the exercise condition (n=32) consisted of 15 low-anxious and 17 high-anxious individuals. All participants completed a 24-hour history questionnaire for sleep, medication, exercise, and caffeine intake upon arriving to the lab. Additionally, two practice dot-probe tasks were completed. Next, participants sat on the cycle ergometer for the duration of the session; therefore, seat height was adjusted for each participant so they could sit or pedal comfortably and a heart rate monitor was put on to obtain heart rate data.

Control condition. Individuals assigned to the control condition sat quietly for 1 minute then completed the State and Trait Anxiety Inventory for State Anxiety (STAI-S), Profile of Mood States (POMS) questionnaire, and dot-probe task (see dot-probe task description below). Next, the participants sat quietly for 45 minutes and completed the STAI-S, POMS, and dot-probe task at minute 30 and again at minute 45. Upon completion of the last dot-probe task, participants completed a memory recognition task (see recognition task description below). Heart rate and rating of perceived exertion were recorded throughout the session as a manipulation check for physical exertion. See Figure 3.1 below.

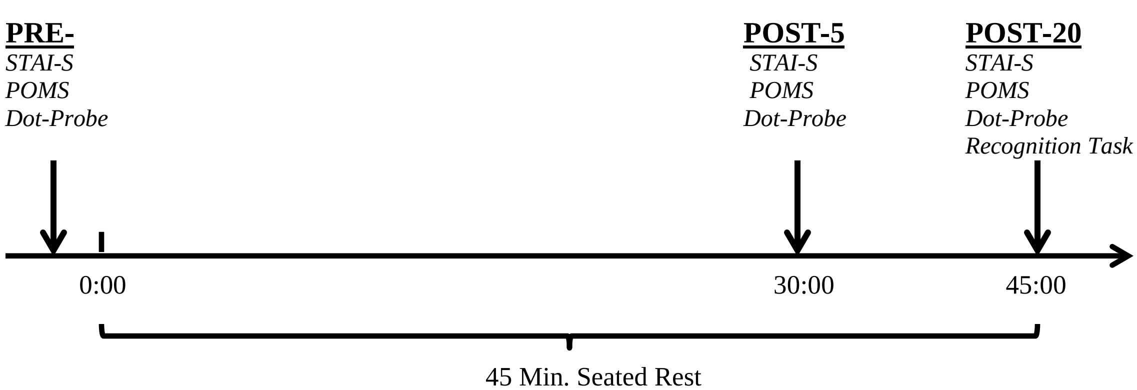

Figure 3.1. Session 2 timeline for participants in the resting condition.

Exercise condition. The exercise condition was administered the STAI-S, POMS, and dot-probe tasks at the same time points as the control condition. First, participants sat quietly for 1 minute then completed the POMS, STAI-S, and dot-probe task. Upon completing the dot-probe task, a 1-minute resting period followed by a 2-minute warm-up with a resistance of 25 watts was completed. Next, the resistance on the cycle ergometer increased to elicit a moderate intensity of 45% VO_2R. This resistance was determined by the participant's VO_{2peak} results and the following equations (*ACSM's Guidelines for Exercise Testing and Prescription*, 2006):

$$\text{Target } VO_2 = [(VO_{2peak} - VO_{2rest})(\text{exercise intensity}) + VO_{2rest}]$$

$$VO_2 = [(1.8*(\text{work rate})/(\text{body mass})) + (VO_{2rest}) + (3.5 \text{ mL/kg/min})]$$

Participants maintained a cadence of 60-80 rpms during the 20-minute bout of moderate-intensity cycling. Measures of RPE, heart rate, VO_2, watts, and cadence were recorded throughout the session, and adjustments to resistance were made 10 minutes into the exercise bout if needed. After 20-minutes of cycling at 45% VO_2R, a 2-minute cool-down was completed with 25 watts of resistance. Next, a 20-minute resting period began with the participant continuing to sit on the cycle ergometer. The second and third STAI-S, POMS, and dot-probe tasks were administered at minute 5 and minute 20 of the rest period. Following the final dot-probe task, participants completed the memory recognition task. See Figure 3.2 below.

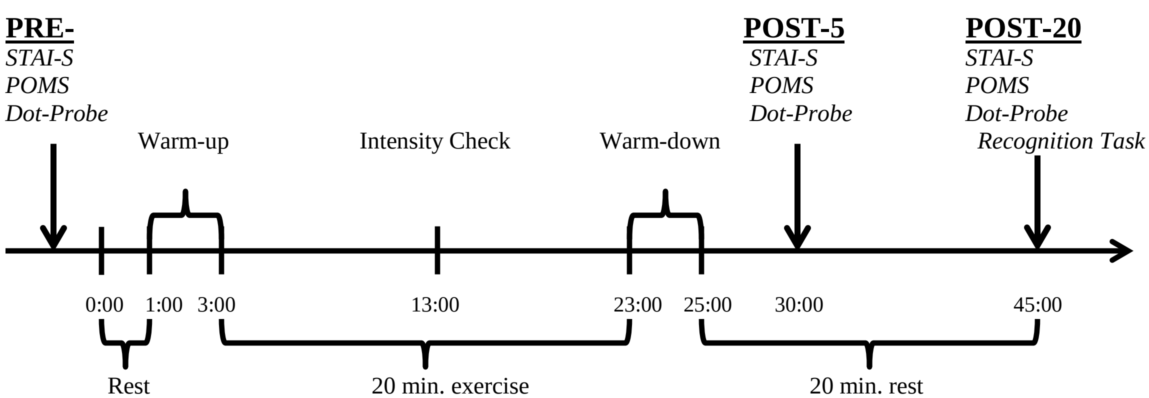

Figure 3.2. Session 2 timeline for participants in the exercise condition.

Attentional Bias: Dot-probe Task

The dot-probe task was developed and presented via SuperLab 4.5 (Cedrus Corporation, San Pedro, CA) and displayed on a computer monitor (20.1-inch Dell 2007FP) 61 centimeters away from the participant. Each trial of the dot-probe task consisted of three events: a) fixation cross (500 ms), b) two words vertically aligned with 3-cm of separation (500 ms), and c) dot-probe (displayed until a button was pressed). The participants were instructed to read both words; when the dot-probe appeared, they were instructed to make a quick and accurate button press to indicate the location of the dot-probe. A two-key response pad was used to record accuracy and response time data (Cedrus Response Pad, Model RB-620, San Pedro, CA). If the dot-probe replaced the top word, the left button was depressed; if the dot-probe replaced the bottom word, the right button was depressed. Words were selected from the ANEW word bank created by Bradley and Lang (2010), which has established norms for dominance, pleasantness, and arousal. The list was ordered by ratings of dominance, pleasantness, and arousal, respectively. Threatening words were selected from the top of this list in ascending order. Words with equal length were paired to create 84 neutral-neutral and 80 threat-neutral word pairs (e.g. neutral-neutral: *revise-science, mantel-nature, stop-lake*; threat-neutral: *failure-science, die-bus, suffer-flight*). The complete word list is provided in Appendix A and Appendix B. Three dot-probe tasks were developed using the same words, but word pairs were unique for each task and task order was counterbalanced among participants. All dot-probe tasks began with four neutral-neutral trials that were practice trials; therefore, they were not included in the analyses.

Reliability for the dot-probe task was determined during pilot testing. All trials were categorized as neutral, congruent, or incongruent. Neutral trials consist of neutral-neutral word pairs. Congruent and incongruent trials consist of threat-neutral word pairs. For congruent trials, the dot-probe replaces the threat word; for incongruent trials, the dot-probe replaces the neutral word. Reliability for response times for neutral, congruent, and incongruent trials were acceptable with intra-class correlations ranging from 0.95 - 0.96.

Memory Task: Recognition Task

A recognition task was programmed and administered through the SuperLab 4.5 computer program (Cedrus Corporation, San Pedro, CA). One word was presented on the monitor and the participants made a yes-no decision as to whether or not the word was presented during the dot-probe tasks. Once the participants depressed a button to indicate "yes" or "no," the next word appeared. A total of 80 words were displayed; 40 threat words and 40 neutral words were presented. Half of the words for each category had been displayed during the dot-probe task and half of the words were new. Accuracy and response times were recorded.

Data Reduction

Attentional Bias. Data for the dot-probe task were trimmed based on previous recommendations (Koster, Crombez, Verschuere, & De Houwer, 2004); errors, individual outliers, and response times greater than 2,000 ms were removed from the analyses. Individual outliers were identified as response times that differed from the individual's mean response time by three or more standard deviations. In total, 3.3%, 1.3% and 0.1% of the data consisted of errors, outliers, and response times greater than 2,000 ms, respectively.

Dot-probe task response times were prepared for two methods of analysis: congruency effect method and bias assessment method. The congruency method, which was developed by Koster et al. (2004) involved grouping response times into three categories: neutral, congruent, and incongruent response times. Congruent trials occur when a threat-neutral word pair is displayed on the screen and the dot-probe replaces the threat word. Anxious individuals have been found to have a quicker response to the dot-probe that replaces the threat word due to a heightened vigilance towards threatening stimuli. An incongruent trial consists of a threat-neutral word pair, and the dot-probe replaces the neutral word. Individuals with anxiety evidence a delayed response to the incongruent dot-probe; the slowing is explained as a result of difficulty disengaging attention away from the threat stimuli and shifting attention towards the neutral stimuli. Lastly, neutral trials consist only of neutral word pairs and provide a baseline for response times.

The bias assessment method yields an index of an individual's disproportional allocation of attention towards or away from threatening stimuli (MacLeod et al., 1986). A positive bias score suggests that attention is allocated towards threatening stimuli more than neutral stimuli, and a negative bias score suggests that an individual is avoiding allocating attention towards threatening stimuli. The single index bias score is calculated as follows (MacLeod & Mathews, 1988):

Attentional Bias Score = ½ [(UpLt – UpUt) + (LpUt – LpLt)]

U = Upper Position

L = Lower Position

p = Probe

t = Threat Word

Memory Task. Participants' responses to items were prepared for two methods of analyses: an explicit memory analysis and signal detection analysis. Explicit memory requires an individual to intentionally recollect information previously stored in memory, and it has been used to determine if anxious individuals possess a memory bias for threatening stimuli (Graf & Schacter, 1985; MacLeod & McLaughlin, 1995). The explicit memory index (EMI) was computed to examine differences in performance on the recognition task between conditions (MacLeod & McLaughlin, 1995). In order to calculate the EMI, two performance measures are needed: the number of pictures correctly identified (hits) and the number of pictures falsely assumed (false alarms). Below is the equation for the EMI scores:

EMI = hits – false alarms

Signal detection theory was applied to the recognition task data to determine differences in performance between groups (i.e. hit rate, false alarm rate, d'). Signal detection theory is used to analyze one's ability to make correct decisions (Green & Swets, 1974). The hit rate provides the probability that a participant correctly identifies a word that was previously displayed during the dot-probe task, and the false alarm rate reflects the probability that an individual falsely assumes a word was presented during the dot-probe task. By combining the hit rate and false alarm rate, a measure of d' can be attained, which provides a measure of how well one can correctly discriminate between previously seen words and words that have not been previously seen. The signal detection method was used to examine threat only trials, as well as all trials on the recognition task. Below are the equations for each of the signal detection measures (Murdock, 1982):

Hit rate (H) = # words correctly identified / # words previously presented

False alarm rate (FA) = # words falsely assumed / # words not previously presented

d' = z(FA) – z(H)

The signal detection method examining only threat stimuli utilized a denominator of 20 for the above equations, and the signal detection analyses for all stimuli utilized a denominator of 40 for the above equation.

Data Analyses. Planned contrasts (Helmert) were used to examine the critical Condition x Time interactions in the mixed-model design to determine if there were significant differences pre- to post-exercise for measures obtained from the dot-probe task (attentional bias) and mood questionnaires. This comparison is of interest because it utilizes the combined post-exercise measures and compares it to the pre-exercise measures. Additionally, mixed model ANOVAs, 2 (Group: low-trait anxiety, high-trait anxiety) x 2 (Condition: control, exercise) x 3 (Time: before, post-5, post-20), for all measures of attentional bias and mood were completed. Maulchy's Test was used to determine if the assumption of sphericity was met; if Maulchy's Test was significant ($p < .05$), then the degrees of freedom were adjusted by the Huynh-Feldt correction. Separate factorial-model ANOVAs, 2 (Group: low-trait anxiety, high-trait anxiety) x 2 (Condition: control, exercise), were performed for each of the memory task measures. Paired samples t-tests were performed to determine if the number of hits and false alarms differed between types of stimuli (threat and neutral). Independent samples t-tests were used to determine differences between groups or conditions for baseline measures; adjustments to degrees of freedom were made if unequal variances were detected by Levene's Test. Adjusted p-values and t-scores are reported with the original degrees of freedom for measures with unequal variances. All analyses were performed through SPSS 22.0 (IBM Corp.). An *a priori* alpha level of $p = .05$ was chosen to reject null hypotheses.

Results

Participant Characteristics

Psychological measures. There was a high correlation between the trait anxiety scores (STAI-T) obtained from the online screening and the STAI-T scores collected during session 1, $r = .94$, $p < .001$. Trait anxiety was significantly different between low- and high-anxious individuals within the control, $t(30) = -10.36$, $p < .001$, and exercise, $t(30) = -10.19$, $p < .001$, conditions (Table 3.1). Additionally, depression scores (BDI-II) differed between trait anxiety levels. High-trait anxious individuals reported more depressive symptoms in both the control condition, $t(30) = -7.72$, $p < .001$, and exercise condition, $t(30) = -3.35$, $p = .003$. See Table 3.1 for baseline measures.

Physical measures. Participants were randomized to either the control or exercise conditions; however, differences in weight and VO_{2peak} were observed between conditions at baseline. Participants assigned to the control condition had less body mass, $t(62) = -2.14$, $p = .04$, and obtained higher VO_{2peak} values, $t(62) = 2.11$, $p = .04$, than those assigned to the exercise condition. There was no difference in height between groups. See Table 3.1 for baseline measures.

Table 3.1. Participant characteristics at baseline (Mean ± SD).

	ANXIETY	N	AGE	ONLINE TRAIT	BDI-II	WEIGHT (KG)	HEIGHT (IN)	$VO2_{PEAK}$ (ml/kg/min)
CON	LA	14	22 (3.3)	27.0 (3.2)$^+$	1.9 (1.5)$^+$	58.0 (5.2)	65.5 (2.6)	38.0 (7.0)$^+$
	HA	18	24 (4.6)	51.2 (9.3)$^+$	15.9 (7.6)$^+$	62.2 (10.0)	65.1 (2.3)	32.8 (6.8)$^+$
	ALL	**32**	**23 (4.0)**	**40.6 (14.3)**	**9.8 (9.1)**	**60.4 (8.4)***	**65.3 (2.4)**	**35.1 (7.2)***
EX	LA	15	21 (3.5)	29.3 (3.3)$^+$	4.7 (2.9)$^+$	68.7 (14.1)	65.6 (2.1)	32.2 (4.4)
	HA	17	23 (4.3)	46.7 (6.1)$^+$	12.4 (8.9)$^+$	63.7 (10.6)	64.9 (2.6)	31.4 (5.9)
	ALL	**32**	**22 (4.0)**	**38.5 (10.1)**	**8.8 (7.7)**	**66.1 (12.4)***	**65.3 (2.4)**	**31.8 (5.2)***

CON = control condition, EX = exercise condition; * $p < .05$ between conditions; + $p < .001$ within condition, between anxiety levels

Attentional Bias: Dot-Probe Task

Congruency Effect Analyses. Helmert contrasts and 2 (Group) x 2 (Condition) x 3 (Time) ANOVAs were conducted separately on overall, neutral, congruent, and incongruent response times.

Overall Response Time. Planned contrasts (Helmert) revealed a non-significant difference in overall response time from pre- to post-exercise, $F(1, 60) = 0.61$, $p = .44$, $\eta_p^2 = .01$. Additionally, the omnibus ANOVA provided a non-significant main effect of group for overall response time was non-significant, $F(1, 60) = 0.67$, $p = .67$, $\eta_p^2 = .003$, and the main effect of condition was also non-significant, $F(1, 60) = 0.05$, $p = .82$, $\eta_p^2 = .001$. The main effect of time was significant, $F(1.6, 96.2) = 19.15$, $p < .001$, $\eta_p^2 = .24$. No significant interactions emerged for the following interactions: Group x Time, $F(1.6, 96.2) = 0.60$, $p = .52$, $\eta_p^2 = .01$, Condition x Time, $F(1.6, 96.2) = 1.8$, $p = .58$, $\eta_p^2 = .01$, nor Group x Condition x Time, $F(1.6, 96.2) = 1.83$, $p = .17$, $\eta_p^2 = .03$. See Figure 3.3 below.

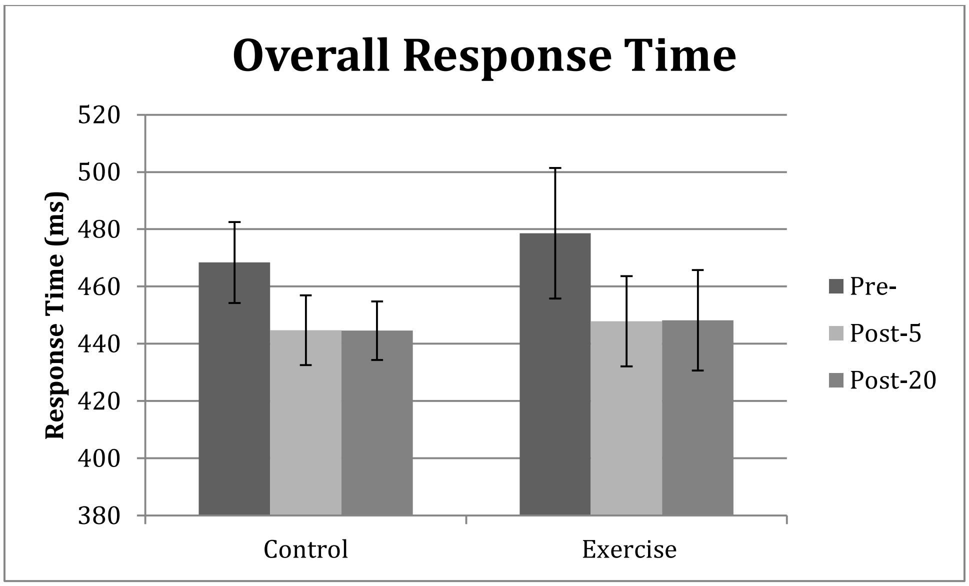

Figure 3.3. Overall response times on the dot-probe task (Mean ± SE). Lower response times indicate quicker responses to the dot-probe for all trials.

Neutral Response Time. Response time for trials consisting of neutral-neutral word pairs did not change pre- to post-exercise, according to the planned contrasts (Helmert) for the Condition x Time interaction, $F(1, 60) = 0.58$, $p = .45$, $\eta_p^2 = .01$. For neutral-neutral trials, the omnibus ANOVA provided non-significant main effects of group, $F(1, 60) = 0.19$, $p = .67$, $\eta_p^2 = .003$, and condition, $F(1, 60) = 0.04$, $p = .85$, $\eta_p^2 = .001$. There was a significant main effect of time, $F(1.6, 93.5) = 16.13$, $p < .001$, $\eta_p^2 = .21$. Individuals responded faster during trials that presented neutral-neutral trials as time passed. There were no significant interactions for Group x

Time, $F(1.6, 93.5) = 0.50$, $p = .56$, $\eta_p^2 = .01$, Condition x Time, $F(1.6, 93.5) = 0.46$, $p = .59$, $\eta_p^2 = .01$, and Group x Condition x Time, $F(1.6, 93.5) = 1.64$, $p = .21$, $\eta_p^2 = .03$. See Figure 3.4 below.

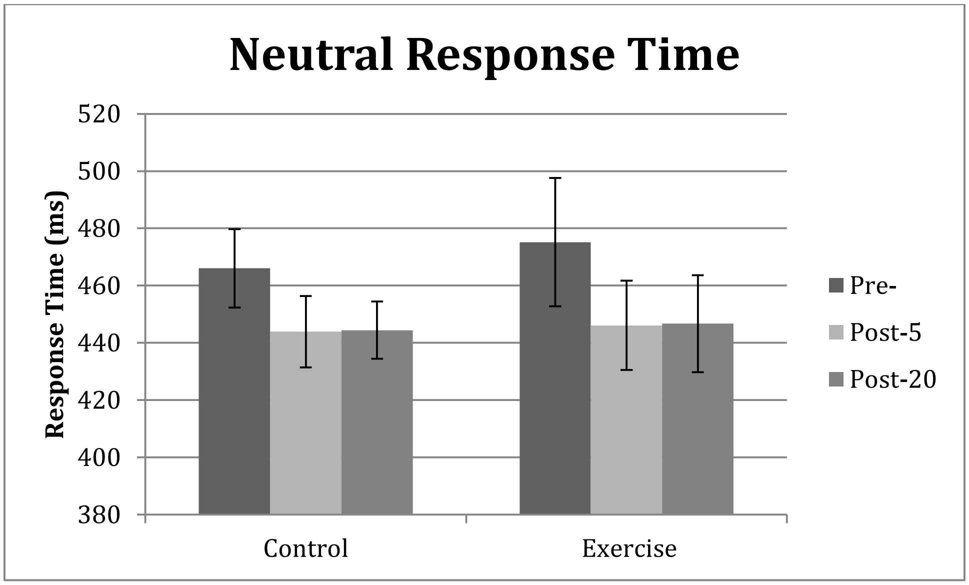

Figure 3.4. Response times for neutral-neutral trials in the dot-probe task (Mean ± SE). Lower response times indicate quicker responses to the dot-probe during neutral-neutral trials.

Congruent Response Time. For congruent trials, there were no changes from pre- to post-exercise for response times based on the Condition x Time planned contrasts (Helmert), $F(1, 60) = 0.27$, $p = .61$, $\eta_p^2 = .004$. The omnibus ANOVA provided non-significant main effects of group, $F(1, 60) = 0.11$, $p = .75$, $\eta_p^2 = .002$, and condition, $F(1, 60) = 0.13$, $p = .72$, $\eta_p^2 = .002$. There was a significant main effect of time, $F(1.7, 103) = 23.78$, $p < .001$, $\eta_p^2 = .28$. This suggests that despite condition, response times to dot-probes that replaced threat word decreased as time passed. There were no significant interactions for Group x Time, $F(1.7, 103) = 0.21$, $p = .78$, $\eta_p^2 = .003$, Condition x Time (F1.7, 103) = 0.19, $p = .80$, $\eta_p^2 = .003$, and Group x Condition x Time, $F(1.7, 103) = 1.63$, $p = .20$, $\eta_p^2 = .03$. See Figure 3.5 below.

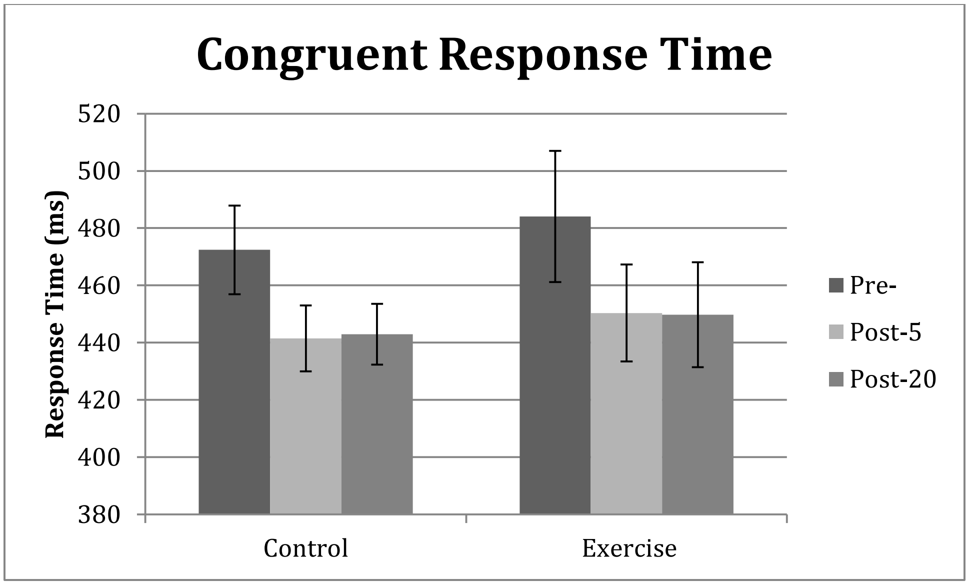

Figure 3.5. Response times for congruent trials in the dot-probe task (Mean ± SE). Quicker response times suggest increased vigilance towards threat words (i.e. greater attentional bias).

Incongruent Response Times. Pre- to post-exercise planned contrasts (Helmert) indicate that incongruent response times did not differ between conditions, $F(1, 60) = 0.97$, $p = .33$, $\eta_p^2 = .02$. The omnibus ANOVA revealed non-significant main effects of group, $F(1, 60) = 0.28$, $p = .60$, $\eta_p^2 = .01$, nor condition, $F(1, 60) = 0.03$, $p = .86$, $\eta_p^2 = .001$, on incongruent response times. There was a significant main effect of time on incongruent response times, $F(1.7, 103.9) = 14.52$, $p < .001$, $\eta_p^2 = .20$; incongruent response times decreased as time progressed for both groups. All interactions were non-significant, which includes: Group x Time, $F(1.7, 103.9) = 1.25$, $p = .29$, $\eta_p^2 = .02$, Condition x Time, $F(1.7, 103.9) = 0.77$, $p = .45$, $\eta_p^2 = .01$, and Group x Condition x Time, $F(1.7, 103.9) = 1.68$, $p = .20$, $\eta_p^2 = .03$. See Figure 3.6 below.

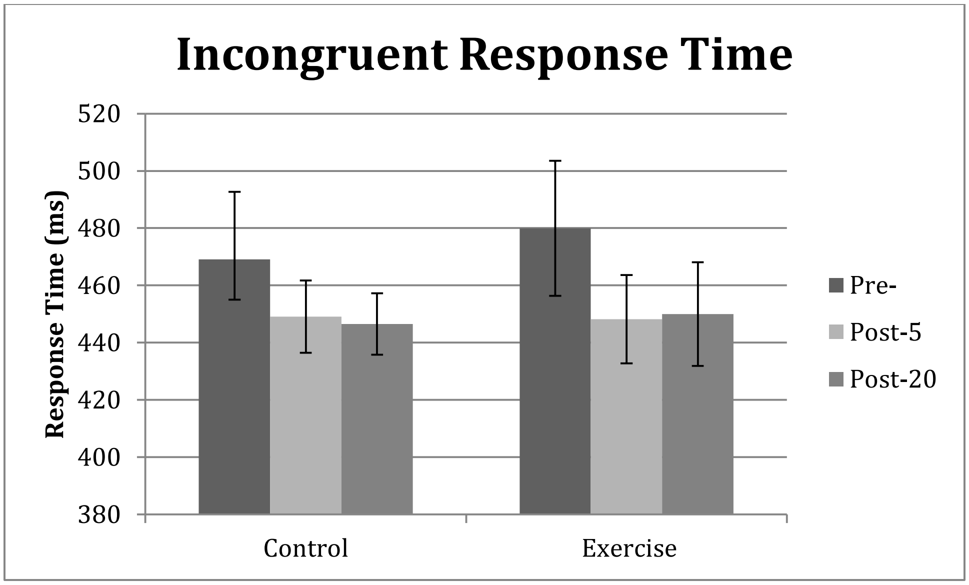

Figure 3.6. Response times for incongruent trials in the dot-probe task (Mean ± SE). Quicker response times suggest an improved ability to disengage and shift attention away from the threat stimuli (i.e. decreased attentional bias).

Bias Score. Condition x Time planned contrasts (Helmert) revealed a non-significant effect of exercise on bias scores when comparing pre- to pooled post-exercise bias scores, $F(1, 60) = 0.82$, $p = .37$, $\eta_p^2 = .01$. A mixed-model ANOVA conducted on bias scores revealed a non-significant main effect of group, $F(1, 60) = 2.17$, $p = .15$, $\eta_p^2 = .04$, non-significant main effect of condition, $F(1, 60) = 1.98$, $p = .16$, $\eta_p^2 = .03$, and non-significant main effect of time, $F(2, 120) = 2.17$, $p = .12$, $\eta_p^2 = .04$. All interactions were non-significant, which includes: Group x Time, $F(2, 120) = 1.68$, $p = .19$, $\eta_p^2 = .03$, Condition x Time, $F(2, 120) = 0.94$, $p = .39$, $\eta_p^2 = .02$, and Group x Condition x Time, $F(2, 120) = .33$, $p = .72$, $\eta_p^2 = .005$. See Figure 3.7 below.

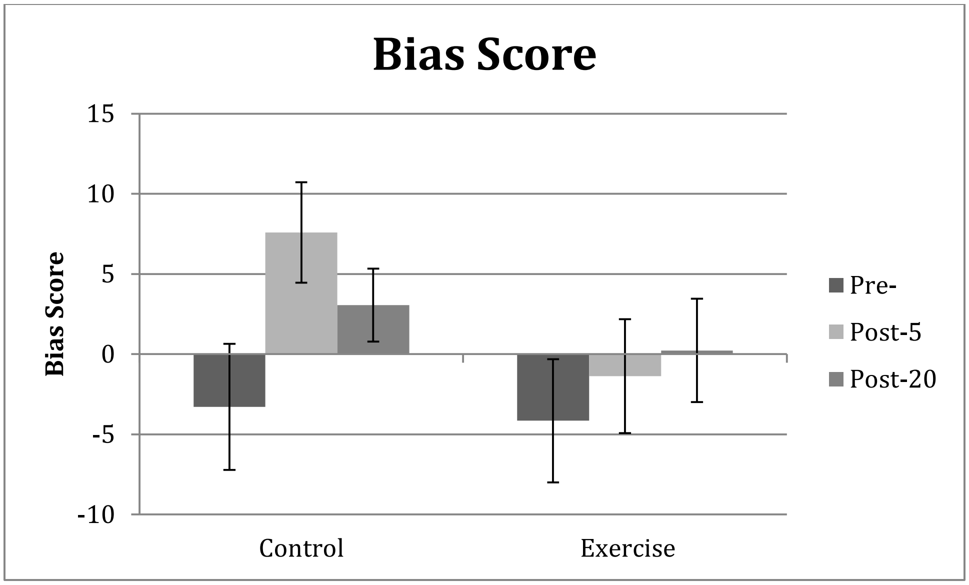

Figure 3.7. Bias scores from the dot-probe task (Mean ± SE). Negative scores indicate avoidance from threat words and positive scores indicate increased vigilance towards threat words.

Memory Task: Recognition Task

Explicit Memory Index (EMI). A 2 (Group) x 2 (Condition) ANOVA was used for EMI. The explicit memory index for threat words (EMI) was significantly greater for the exercise condition compared to the control condition, $F(1, 60) = 5.39$, $p = .024$, $\eta_p^2 = .08$. The ANOVA indicates there were non-significant main effects of group on threat EMI, $F(1, 60) = 2.03$, $p = .16$, $\eta_p^2 = .03$, as well as a non-significant interaction between group and condition, $F(1, 60) = .45$, $p = .507$, $\eta_p^2 = .01$. The difference in EMI between groups was driven by a higher rate of false alarms for threat words in the control condition, $F(1, 59) = 4.93$, $p = .03$, $\eta_p^2 = .08$. See Table 3.2 below for outcome measures.

Table 3.2. Hits (correct answers), false alarms (incorrect answers) and EMI scores from the memory recognition task (Mean ± SD). Higher hit rates indicate more correct responses, higher false alarm rates indicate more incorrect responses, and high EMI scores indicates better explicit memory performance.

		THREAT			NEUTRAL		
	n	*Hits*	*False Alarms*	*EMI*	*Hits*	*False Alarms*	*EMI*
CONTROL	**32**	**15.1 (3.1)⁺**	**8.4 (3.0)*⁺**	**6.6 (3.1)***	**13.1 (3.3)⁺**	**4.8 (2.6)⁺**	**8.3 (3.6)**
LA	14	14.6 (3.4)	9.0 (2.7)	5.5 (2.7)	13.5 (2.9)	5.0 (3.3)	8.5 (3.9)
HA	18	15.4 (2.9)	8.0 (3.3)	7.4 (3.2)	12.8 (3.6)	4.7 (2.1)	8.1 (3.5)
EXERCISE	**32**	**15.2 (3.2)⁺**	**6.6 (3.8)*⁺**	**8.6 (4.0)***	**13.0 (3.6)⁺**	**4.0 (2.7)⁺**	**9.0 (3.1)**
LA	15	14.1 (4.0)	5.9 (4.3)	8.2 (4.3)	12.3 (4.0)	4.1 (3.3)	8.2 (3.5)
HA	17	16.1 (2.1)	7.2 (3.3)	8.9 (3.9)	13.6 (3.2)	4.0 (2.0)	9.6 (2.7)

* p < .05 between conditions; ⁺ p < .001 between valence type (threat vs. neutral)

Signal Detection Assessment. For signal detection measures, 2 (Group) x 2 (Condition) ANOVAs were utilized. Signal detection was used to examine all trails (neutral and threat), as well as, only threat trials. See Table 3.3 below for signal detection measures.

Hit Rate: Threat Only. The hit rate for threat words was not significantly different between groups, F(1, 60) = 3.02, p = .09, η_p^2 = .05, nor conditions, F(1, 60) = 0.02, p = .89, η_p^2 < .001. The Group x Condition interaction as non-significant, F(1, 60) = 0.62, p = .43, η_p^2 = .01.

False Alarm Rate: Threat Only. The main effect of condition on false alarm rates for threat stimuli was significant, F(1, 60) = 4.93, p = .03, η_p^2 = .08; the control condition had a higher rate of false alarms compared to the exercise condition. This indicates that the exercise group correctly rejected new threat words more than the control group, and anxiety level did not impact this difference. There was a non-significant main effect of group on false alarm rate, F(1, 60) = 0.03, p = .86, η_p^2 = .001, and a non-significant Group x Condition interaction, F(1, 60) = 1.78, p = .19, η_p^2 = .03.

Sensitivity Index (d'): Threat Only. Main effects for the sensitivity index (d') for threat words were non-significant for group, F(1, 60) = 0.86, p = .36, η_p^2 =.01, and condition, F(1, 60)

= 1.76, $p = .19$, $\eta_p^2 = .03$. Additionally, the Group x Condition interaction was non-significant, $F(1, 60) = 0.93$, $p = .34$, $\eta_p^2 = .02$.

Hit Rate: All Trials. The main effect of group, $F(1, 60) = 1.53$, $p = .22$, $\eta_p^2 = .02$, and condition, $F(1, 60) = 1.53$, $p = .22$, $\eta_p^2 < .001$, were non-significant for the hit rate for all recognition trials. Additionally, the interaction between group and condition was absent, $F(1, 60) = 1.49$, $p = .23$, $\eta_p^2 =.02$.

False Alarm Rate: All Trials. The main effect of group was non-significant for false alarm rate for all trials, $F(1, 60) = 0.001$, $p = .97$, $\eta_p^2 < .001$; however, there was a higher false alarm rate for individuals in the control condition compared to the exercise condition, $F(1, 60) = 4.08$, $p = .048$, $\eta_p^2 = .06$. Individuals in the control condition were more likely to falsely assume threat and non-threat stimuli as being previously seen in the dot-probe task. The interaction between group and condition was absent, $F(1, 60) = 0.92$, $p = .34$, $\eta_p^2 = .02$.

Sensitivity Index (d'): All Trials. The main effect of group was non-significant for the sensitivity index, d', $F(1, 60) = 0.23$, $p = .63$, $\eta_p^2 = .004$. There was a significant main effect of condition, $F(1, 60) = 5.31$, $p = .03$, $\eta_p^2 = .08$, indicating that the exercise group was more successful in correctly identifying if an item presented during the recognition had been presented in the dot-probe task. The Group x Condition interaction was non-significant, $F(1, 60) = 0.20$, $p = .65$, $\eta_p^2 = .003$.

Table 3.3. Signal detection assessment: hit rate, false alarm rate, and d' for the memory task (Mean ± SD). Higher hit rates indicate greater percentage of correct responses, higher false alarm rates indicate greater percentage of incorrect responses, and higher d' indicates better ability to discriminate between stimuli that were previously presented and those that were not.

		THREAT			ALL		
	n	*Hit Rate*	*False Alarm Rate*	*d'*	*Hit Rate*	*False Alarm Rate*	*d'*
CONTROL	**32**	**0.75 (0.2)**	**0.42 (0.2)***	**1.1 (0.7)**	**0.70 (0.1)**	**0.33 (0.1)***	**1.05 (0.4)***
LA	14	0.73 (0.2)	0.45 (0.1)	0.9 (0.6)	0.70 (0.1)	0.35 (0.1)	0.99 (0.4)
HA	18	0.77 (0.1)	0.40 (0.2)	1.2 (0.8)	0.70 (0.1)	0.32 (0.1)	1.09 (0.4)
EXERCISE	**32**	**0.76 (0.2)**	**0.33 (0.2)***	**1.3 (0.7)**	**0.70 (0.1)**	**0.26 (0.1)***	**1.30 (0.5)***
LA	15	0.71 (0.2)	0.30 (0.2)	1.3 (0.7)	0.66 (0.2)	0.25 (0.2)	1.30 (0.6)
HA	17	0.81 (0.1)	0.36 (0.2)	1.3 (0.6)	0.74 (0.1)	0.28 (0.1)	1.30 (0.4)

* $p < .05$ between conditions

Mood

State-Trait Anxiety Inventory: State (STAI-S). Planned contrasts (Helmert) were performed to determine differences in state anxiety from pre- to post-exercise between conditions; the results were non-significant, $F(1, 60) = 2.69$, $p = .11$, $\eta_p^2 = .04$. The 2 (Group) x 2 (Condition) x 3 (Time) ANOVA revealed a significant main effect of group, $F(1, 60) = 32.73$, $p < .001$, $\eta_p^2 = .35$; individuals with high trait anxiety possessed higher state anxiety than those with low trait anxiety. There were a non-significant main effects of condition, $F(1, 60) = 2.73$, $p = .10$, $\eta_p^2 = .04$, and time, $F(2, 117.1) = 0.33$, $p = .721$, $\eta_p^2 = .005$. The Group x Time interaction was non-significant, $F(2, 117.1) = 2.46$, $p = .09$, $\eta_p^2 = .04$, as well as the Condition x Time interaction, $F(2, 117.1) = 1.76$, $p = .18$, $\eta_p^2 = .03$, and the Group x Condition x Time interaction, $F(2, 117.1) = 0.02$, $p = .98$, $\eta_p^2 < .001$. See Figure 3.8 below.

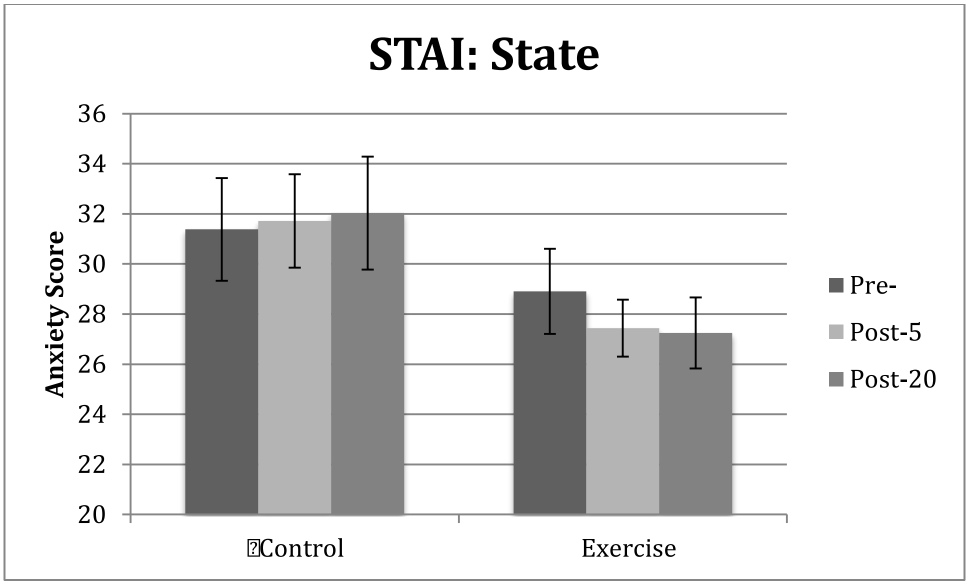

Figure 3.8. STAI State anxiety scores (Mean ± SE). Higher scores indicate higher levels of state anxiety.

POMS: Total mood disturbance (TMD). Planned contrasts (Helmert) revealed significant changes in total mood disturbance from pre- to post-exercise for participants in the exercise condition compared to the control condition, $F(1, 60) = 14.92$, $p < .001$, $\eta_p^2 = .20$. The omnibus ANOVA indicated a significant main effect of group, $F(1, 60) = 13.75$, $p < .001$, $\eta_p^2 = .19$ and condition, $F(1, 60) = 4.81$, $p = .03$, $\eta_p^2 = .07$. Individuals with high trait anxiety reported higher levels of total mood disturbance compared to individuals with low trait anxiety. The main effect of time was non-significant, $F(2, 120) = 0.61$, $p = .55$, $\eta_p^2 = .01$. Significant interactions emerged: Group x Time, $F(2, 120) = 6.63$, $p = .02$, $\eta_p^2 = .10$, and Condition x Time, $F(2, 120) = 9.52$, $p < .001$, $\eta_p^2 = .14$. Reductions in total mood disturbance as a result of exercise were not influenced by anxiety levels according to the non-significant Group x Condition x Time interaction, $F(2, 120) = 1.34$, $p = .27$, $\eta_p^2 = .02$. See Figure 3.9 below.

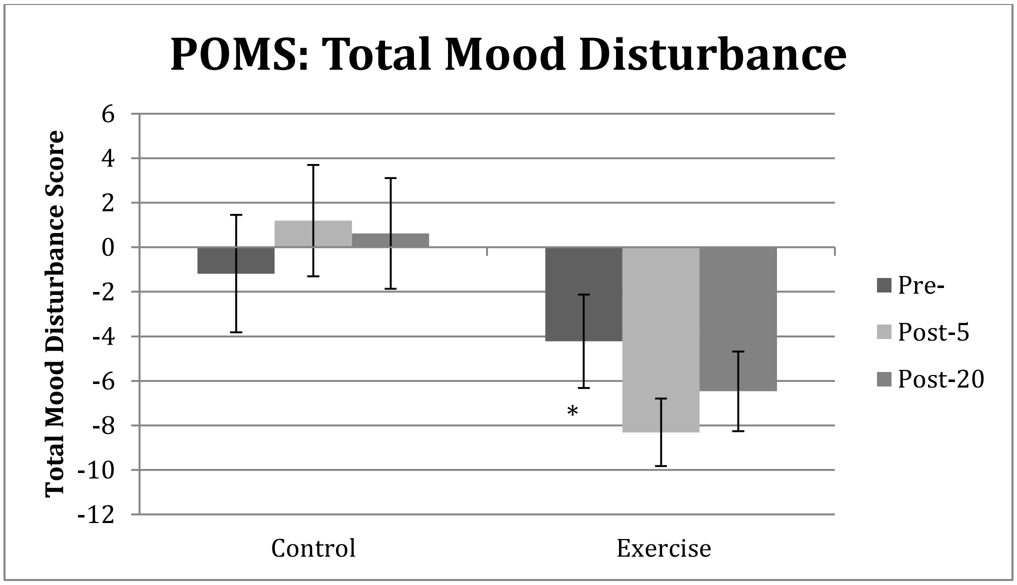

Figure 3.9. POMS total mood disturbance scores (Mean ± SE). Lower scores indicate better overall mood. * = $p < .05$ for pre- to combined post-exercise planned contrasts between conditions.

POMS: Confusion. Planned contrasts (Helmert) indicate that exercise significantly decreased ratings of confusion post-exercise for the exercise condition compared to the control condition, $F(1, 60) = 4.25$, $p = .04$, $\eta_p^2 = .07$. The 2 x 2 x 3 ANOVA revealed a significant main effect of group, $F(1, 60) = 13.32$, $p = .001$, $\eta_p^2 = .18$, significant main effect of condition, $F(1, 60) = 4.87$, $p = .03$, $\eta_p^2 = .08$, and non-significant main effect of time, $F(1.7, 101) = 1.46$, $p = .24$, $\eta_p^2 = .02$. The Group x Time interaction was non-significant, $F(1.7, 101) = 2.01$, $p = .15$, $\eta_p^2 = .03$; however, the Condition x Time interaction was significant, $F(1.7, 101) = 3.26$, $p = .05$, $\eta_p^2 = .05$. Lastly, the Group x Condition x Time interaction was non-significant, $F(1.7, 101) = 0.001$, $p = .99$, $\eta_p^2 < .001$. See Figure 3.10 below.

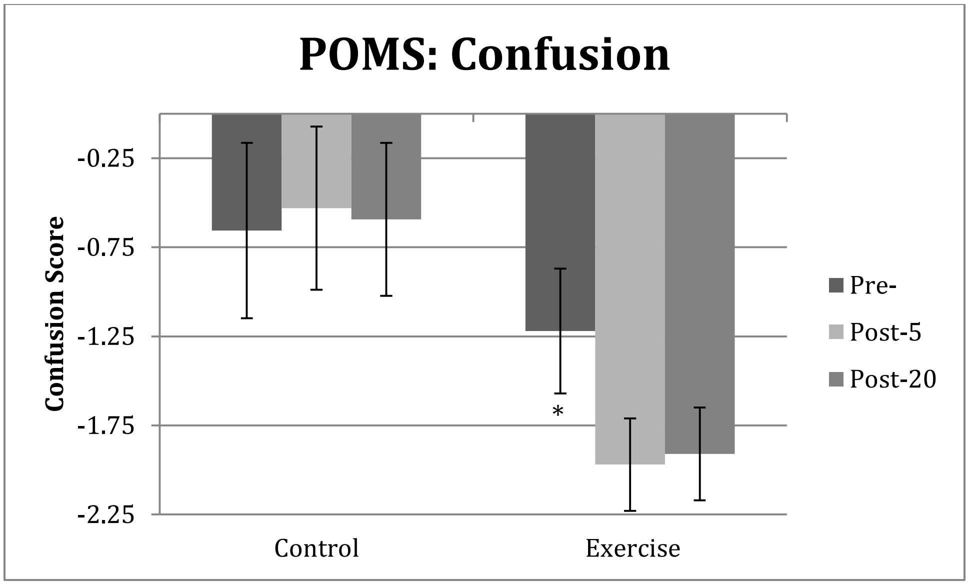

Figure 3.10. POMS confusion scores (Mean ± SE). A lower score indicates less confusion.
* = $p < .05$ for planned contrasts pre- to combined post-exercise scores between conditions.

POMS: Tension. Condition x Time planned contrasts (Helmert) indicate a significant decrease in tension occurred post-exercise, $F(1, 60) = 5.45$, $p = .02$, $\eta_p^2 = .08$. The repeated measures ANOVA results indicate a significant main effect of group on tension scores, $F(1, 60) = 14.25$, $p < .001$, $\eta_p^2 = .19$; individuals with high trait anxiety reported having higher levels of tension than the low-trait anxiety group. A non-significant main effect of condition was revealed, $F(1, 60) = 2.09$, $p = .15$, $\eta_p^2 =.03$, but there was a significant main effect of time, $F(1.8, 106.9) = 4.59$, $p = .01$, $\eta_p^2 = .07$. Two significant interactions occurred; Group x Time, $F(1.8, 106.9) = 3.27$, $p = .03$, $\eta_p^2 = .05$, and Condition x Time, $F(1.8, 106.9) = 3.86$, $p = .03$, $\eta_p^2 = .06$. The Group x Condition x Time interaction was non-significant, $F(1.8, 106.9) = 1.4$, $p = .25$, $\eta_p^2 = .02$. See Figure 3.11 below.

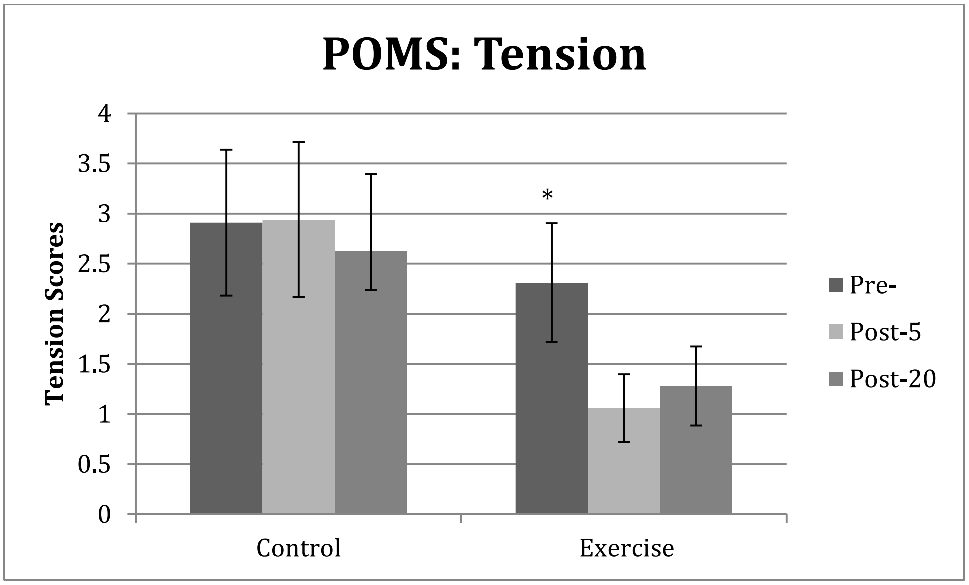

Figure 3.11. POMS tension scores (Mean ± SE). Lower scores indicate lower levels of tension-anxiety. * = p < .05 for planned contrasts pre- to combined post-exercise scores between conditions.

POMS: Vigor. Ratings of vigor pre- to post-exercise were compared by planned contrasts (Helmert); results indicate a significant change in vigor post-exercise for the exercise condition. Significant changes were revealed for pre- to pooled post-exercise contrast, $F(1, 60) = 6.53$, $p = .01$, $\eta_p^2 = .10$, as well as 5 minutes post-exercise to 20 minutes post-exercise contrast, $F(1,60) = 6.15$, $p = .02$, $\eta_p^2 = .09$. The omnibus ANOVA provided the following results for vigor: non-significant effect of group, $F(1, 60) = 1.84$, $p = .18$, $\eta_p^2 = .03$, significant main effect of condition, $F(1, 60) = 8.14$, $p = .006$, $\eta_p^2 = .12$, and a significant main effect of time, $F(1.9, 114.9) = 7.21$, $p = .001$, $\eta_p^2 = .11$. The Condition x Time interaction was significant, $F(1.9, 114.9) = 6.38$, $p = .003$, $\eta_p^2 = .10$. The Group x Time, $F(1.9, 114.9) = 2.01$, $p = .14$, $\eta_p^2 = .03$, and Group x Condition x Time, $F(1.9, 114.9) = 0.09$, $p = .09$, $\eta_p^2 = .002$, interactions were non-significant. See Figure 3.12 below.

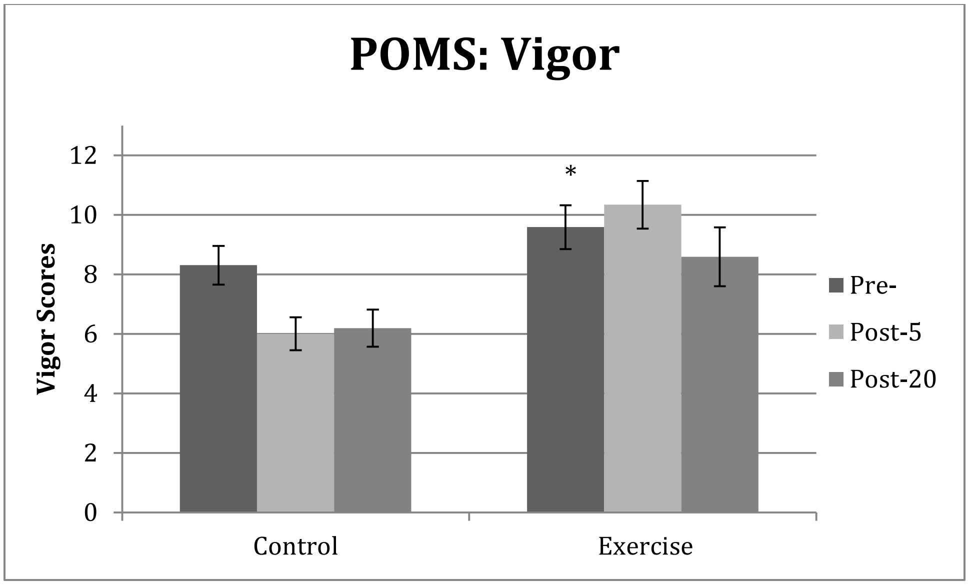

Figure 3.12. POMS vigor scores (Mean ± SE). Higher scores indicate greater feelings of vigor. * = p < .05 for planned contrasts pre- to combined post-exercise scores between conditions.

Discussion

The present study examined the effects of exercise on attentional bias, memory, and mood in a sample of women with low-trait and high-trait anxiety. Results reveal that exercising at a moderate intensity for 20 minutes did not lead to changes in attentional bias to word stimuli 5 minutes and 20 minutes post-exercise; however, there were significant differences in performance on the memory task between the rest and exercise conditions. Additionally, exercise-induced changes in mood were exhibited 5 minutes and 20 minutes post-exercise. The following section will describe the differences and similarities between the current study and previous studies.

Attentional bias occurs when an individual preferentially allocates attention towards a specific type of stimuli, such as threat (Bockstaele et al., 2014; Cisler & Koster, 2010). Individuals with clinical and non-clinical anxiety possess an attentional bias towards threat (Bar-Haim et al., 2007; Cisler & Koster, 2010), and this bias can be modified through attention training (Hakamata et al., 2010; C. MacLeod & Mathews, 2012; Mogoase et al., 2014). It is believed that the relationship between attentional bias and anxiety is reciprocal in nature; therefore it is of interest to find ways to attenuate attentional bias in addition to finding effective treatment for anxiety symptoms (Bockstaele et al., 2014). Acute bouts of exercise have been found to impact both attentional bias, as well as self-reported anxiety (Barnes et al., 2010; Herring et al., 2013; Petruzzello et al., 1991; Tian & Smith, 2011).

The prediction that exercise would significantly change attentional bias towards threat words post-exercise was not supported, and this finding is similar to the findings of Cooper (2012). The current study and Cooper (2012) are the only two studies that have examined changes in word-based attentional bias during and after an acute bout of exercise. The present study was designed to maximize the likelihood that individuals would experience a change in attentional bias post-exercise by a) presenting word-stimuli that are theoretically linked to anxiety (i.e. threatening) b) including only women, c) selecting women based on self-reported trait anxiety levels, d) assessing attentional bias at time points that coincide with the greatest acute changes in anxiety post-exercise, and e) presenting a sufficient number of trials in the dot-probe task to obtain reliable response time data.

Only women were recruited to participate because sex differences have been observed in the prevalence of anxiety disorders (Kessler et al., 2005), neural circuitry involved in anxiety (Farrell et al., 2013; McLaughlin, Baran, & Conrad, 2009), and attentional bias (Tan et al., 2011; Tran et al., 2013). Women with low- and high-trait anxiety were selected because individuals with clinical and non-clinical anxiety exhibit an attentional bias towards threatening information (Bar-Haim et al., 2007); therefore, including high-anxious women provided the opportunity to determine if changes in attentional bias varied based on level of trait anxiety. Based on the non-significant three-way interactions for the repeated measure ANOVAs, it can be concluded that anxiety level did not affect the magnitude of change that was observed pre- to post-exercise for measures of attentional bias and mood in the present sample. Lastly, the dot-probe task used to measure attentional bias included enough trials to obtain good measures of reliability based on the recommendations of Salthouse and Hedden (2002). Despite efforts to maximize the likelihood of detecting changes in attentional bias, they were not observed and the hypothesis was not supported.

Exercise-induced changes in attentional bias were not observed in the present study; however, there were significant differences between conditions for the memory task that was completed 20 minutes post-exercise. Participants in the exercise condition were predicted to perform better than the control condition on the memory task, and this hypothesis was supported. Individuals in the exercise group had fewer false alarms for both neutral and threat stimuli. This indicates that the control group was more likely to falsely assumed a word had been previously presented in the dot-probe task when, indeed, it had not. Additionally, the individuals who completed the exercise bout had greater sensitivity scores (d') for the recognition task, implying that individuals who exercised were more proficient at detecting when a word had been previously presented and when it had not been presented. The enhancement of post-exercise memory performance coincides with the results of previous meta-analyses. Acute bouts of exercise have small to moderate effects on memory performance post-exercise (Chang, Labban, Gapin, & Etnier, 2012; Lambourne & Tomporowski, 2010; Roig, Nordbrandt, Geersten, & Nielsen, 2013). Lastly, independent of condition, participants were more likely to produce higher hits and false alarms for threat stimuli compared to neutral stimuli, which is similar to previous study outcomes (MacLeod & McLaughlin, 1995).

Compared to earlier studies that examined the impact of exercise on attentional bias, the present study is unique in that it included a post-exercise measurement of memory to increase the likelihood that participants were attending to the stimuli presented in the dot-probe task. Earlier research examining exercise-induced changes in attentional bias did not provide a motivating reason to attend to the stimuli presented in the dot-probe task. The results of the present study indicate that there were differences in memory post-exercise, but differences in measures of attention did not vary based on condition. Future research is needed to examine the relationship between exercise-induced changes in attention and memory to determine if changes in attention modify processing and encoding of the stimuli, which may impact memory performance.

Improvements in mood states were detected post-exercise for the participants in the exercise condition compared to the seated rest condition. Specifically, exercise-induced changes in total mood disturbance, confusion, tension, and vigor scores from the Profile of Mood States (POMS) were observed post-exercise. Enhancements in mood did not vary by anxiety group. Based on the total mood disturbance scores from the POMS, participants in the exercise condition experienced a significantly greater improvement in overall mood, which was expected based on previous research (Sibold & Berg, 2010). Additionally, ratings of confusion decreased for the participants in the exercise group post-exercise. Studies have provided evidence of exercise-induced changes in confusion, and the present study supported the hypothesis that confusion would decrease post-exercise (Rokka, Mavridis, & Kouli, 2010). Tension also decreased post-exercise for only the exercise group, which coincides previous reports of the anxiolytic effects of an acute bout of exercise (Petruzzello, et al., 1991). Lastly, self-reported scores of vigor increased post-exercise for the participants who completed 20 minutes of moderate intensity exercise while the participants that sat quietly for 20 minutes did not report increased scores of vigor. These findings are supported by previous research that provides evidence that exercise produces improvements in vigor post-exercise (Loy, O'Connor, & Dishman, 2013; Reed & Ones, 2006).

Limitations of the present study may have precluded significant changes in attentional bias. First, earlier findings that report changes in attentional bias during and post-exercise utilized picture stimuli (Barnes et al., 2010; Tian & Smith, 2011). Currently, there are no studies that provide evidence of exercise-induced changes in word-based attentional bias. Although word stimuli were used in the original dot-probe task developed by MacLeod, Mathews, and Tata (1986), continue to be used in attentional bias paradigms (Bar-Haim et al., 2007), and have been used for word-based attention bias modification programs (Beard et al., 2012; Hakamata et al., 2010; Mogoase et al., 2014), the predicted effects of exercise were not observed in the present study. It has been purported that differences in processing affective words and pictures exists (De Houwer & Hermans, 1994), and differences in brain activation have also been observed when comparing picture and word stimuli with similar valences (Kensinger & Schacter, 2006). These processing differences may modify the effects of exercise on attentional bias; therefore, it is of interest to further explore the seemingly non-equivalent impact that exercise has on word-based attentional bias compared to picture-based attentional bias.

References

Bar-Haim, Y. (2010). Research review: Attention bias modification (ABM): A novel treatment for anxiety disorders. *The Journal of Child Psychology and Psychiatry, 51(8)*, 859-870.

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. doi: 10.1037/0033-2909.133.1.1

Barnes, R. T., Coombes, S. A., Armstrong, N. B., Higgins, T. J., & Janelle, C. M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *Journal of Sports Sciences, 28(10)*, 1065-1076.

Beard, C., Sawyer, A. T., & Hofmann, S. G. (2012). Efficacy of attention bias moidification using threat and appetitive sitmuli: A meta-analytic review. *Behavior Therapy, 43(4),* 724-740.

Bockstaele, B. V., Verschuere, B., Tibboe, 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.

Bradley, M. M., & Lang, P. J. (2010). Affective Norms for English Words (ANEW): Stimuli, instruction manual, and affective ratings. *Technical Report C-2*. Gainseville, FL: The Center for Research in Psychophysiology, University of Florida

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Research, 1453*, 87-101. doi: 10.1016/j.brainres.2012.02.068

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

Cooper, S. L. (2012). Acute effects of aerobic exercise on positive and negative attentional bias. *Unpublished Manuscript*.

De Houwer, J. & Hermans, D. (1994). Differences in the affective processing of words and pictures. *Cognition and Emotion, 8(1),* 1-20.

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

Farrell, M. R., Sengelaub, D. R., & Wellman, C. L. (2013). Sex differences and chronic stress effects on the neural circuitry underlying fear conditioning and extinction. *Physiology & Behavior, 122*, 208-215. doi: 10.1016/j.physbeh.2013.04.002

Graf, P., & Schacter, D. L. (1985). Implicit and cxplicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*(3), 501-518.

Green, D. M., & Swets, J. A. (1974). *Signal Detection Theory and Psychophysics*. Huntington, NY: Krieger.

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, 28*, 982-990.

Herring, M. P., Lindheimer, J. B., & O'Connor, P. J. (2013). The effects of exercise training on anxiety. *American Journal of Lifestyle Medicine, 8,* 388-403. doi: 10.1177/1559827613508542

Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional pictures and words: effects of valence and arousal. *Cognitive, Affective, & Behavioral Neuroscience, 6(2),* 110-126.

Kessler, R. C., Chiu, W. T., Demler, O., & Walters, E. E. (2005). Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the national comorbidity survey replication. *Archives of General Psychiatry, 62*, 617- 627.

Kessler, R. C., Petukhova, M., Sampson, N. A., Zaslavsky, A. M., & Wittchen, H. U. (2012). Twelve-month and lifetime prevalence and lifetime morbid risk of anxiety and mood disorders in the United States. *International Journal of Methods in Psychiatric Research, 21(3),* 169-184. doi: 10.1002/mpr.1359

Koster, E. H., 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. doi: 10.1016/j.brat.2003.08.001

Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research, 1341,* 12-24. doi: 10.1016/j.brainres.2010.03.091

Loy, B. D., O'Connor, P. J., & Dishman, R. K. (2013). The effect of a single bout of exercise on energy and fatigue states: A systematic review and meta-analysis. *Fatigue: Biomedicine, Health & Behavior, 1(4),* 223-242.

MacLeod, C., & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *The Quarterly Journal of Experimental Psychology Section A, 40*(*4*)*,* 653-670. doi: 10.1080/14640748808402292

MacLeod, C., & Mathews, A. (2012). Cognitive bias modification approaches to anxiety. *Annual Review of Clinical Psychology, 8*, 189-217. doi: 10.1146/annurev-clinpsy-032511-143052

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

MacLeod, C., & McLaughlin, K. (1995). Implicit and explicit memory bias in anxiety: A conceptual replication. *Behaviour Research and Therapy, 33(1),* 1-14.

McLaughlin, K. J., Baran, S. E., & Conrad, C. D. (2009). Chronic stress- and sex-specific neuromorphological and functional changes in limbic structures. *Molecular Neurobiology, 40(2),* 166-182. doi: 10.1007/s12035-009-8079-7

McLean, C. P., Asnaani, A., Litz, B. T., & Hofmann, S. G. (2011). Gender differences in anxiety disorders: Prevalence, course of illness, comorbidity and burden of illness. *Journal of Psychiatric Research, 45(8),* 1027-1035. doi: 10.1016/j.jpsychires.2011.03.006

Mogoase, C., David, D., & Koster, E. H. W. (2014). Clinical efficacy of attentional bias modification procedures: An updated meta-analysis. *Journal of Clinical Psychology*, 1-25. doi: 10.1002/jclp.22081

Murdock, B. B. (1982). *Recognition Memory*. New York, NY: Academic Press.

Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kuitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11(3),* 143-182.

Reed, J., & Ones, D. S. (2006). The effect of acute aerobic exercise on positive activated affect: A meta-analysis. *Psychology of Sport and Exercise, 7(5),* 477-514. doi: 10.1016/j.psychsport.2005.11.003

Roig, M., Nordbrandt, S., Geersten, S. S., & Nielsen, J. B. (2013). The effects of cardiovscular exercise on human memory: A review with meta-analysis. *Neuroscience and Biobehavioral Reviews*, *37*, 1645-1666.

Rokka, S., Mavridis, G., & Kouli, O. (2010). The impact of exercise intensity on mood state of participants in dance aerobics programs. *Studies in Physical Culture and Tourism, 17(3),* 241-245.

Salthouse, T. A., & Hedden, T. (2002). Interpreting reaction time measures in between-group comparisons. *Journal Of Clinical And Experimental Neuropsychology, 24(7),* 858-872.

Sibold, J. S., & Berg, K. M. (2010). Mood enhancement persists for up to 12 hours following aerobic exercise: A pilot study. *Perceptual and Motor Skills, 111(2),* 333-342.

Spielberger, C. D. (1983). *State-trait inventory for adults*: Mind Garden, Inc.

Tan, J., Ma, Z., Gao, X., Wu, Y., & Fang, F. (2011). Gender difference of unconscious attentional bias in high trait anxiety individuals. *PLoS One, 6*(5), e20305. doi: 10.1371/journal.pone.0020305

Tian, Q., & Smith, J. C. (2011). Attentional bias to emotional stimuli is altered during moderate- but not high-intensity exercise. *Emotion*, *11(6)*, 1415-1424.

Tran, U. S., Lamplmayer, E., Pitzinger, N. M., & Pfabigan, D. M. (2013). Happy and angry faces: Subclinical levels of anxiety are differentially related to attentional biases in men and women. *Journal of Research in Personality*, *47*, 390-397.

Wadlinger, H. A., & Isaacowitz, D. M. (2011). Fixing our focus: Training attention to regulate emotion. *Personality and Social Psychology Review*, *15(1)*, 75-102.

CHAPTER 4

ACUTE EXERCISE ALTERS PICTURE-BASED ATTENTIONAL BIAS AND MEMORY PERFORMANCE, AND IMPROVES MOOD IN WOMEN WITH LOW- AND HIGH-TRAIT ANXIETY[1]

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Abstract

Previous research indicates that individuals with anxiety preferentially allocate attention towards threatening stimuli; this attentional bias towards threat can be attenuated with attention training. Limited research suggests that attentional bias can also be modified by acute bouts of exercise. The purpose of the present study was to evaluate the exercise-induced changes in picture-based attentional bias, memory, and mood in a sample of women (n = 64) between the ages of 19-34 with low- and high-trait anxiety. Participants were randomly assigned to a seated rest control or an exercise condition consisting of 20 minutes of cycling at 45% VO_2R. Results indicate that exercise-induced changes in picture-based attentional bias occurred in the same pattern as previous research. Congruency-effect analyses revealed that response times to trials that did not include a threatening stimulus significantly decreased post-exercise (d = 0.6), and response times on incongruent trials suggests that exercise improved the participants' ability to disengage and shift attention away from threat stimuli post-exercise (d = 0.48). The greatest changes in incongruent trial response times occurred 5-minutes post-exercise (d = 0.5). Bias-score analyses revealed small to moderate effects of exercise on picture-based attentional bias (d = 0.45); however, the decrease in attentional bias scores pre- to post-exercise did not reach the critical p-value of .05, (p= .09). Performance on the memory task differed between conditions; participants in the exercise condition made significantly more false positive responses to non-target pictures. Exercise-induced changes in mood were revealed post-exercise: state anxiety decreased (d = 0.6), total mood disturbance decreased (d = 1.04), confusion decreased (d = 0.46), and vigor (d = 0.84). Future research is needed to determine the relationship between changes in picture-based attentional bias and memory performance.

KEYWORDS: *Physical Activity, Dot-Probe, Anxiety, Recognition, Signal Detection*

Introduction

Approximately 30% of individuals worldwide report experiencing a mental disorder within their lifetime, and the greatest prevalence is reported in English-speaking countries (Eysenck et al., 2007; Steel et al., 2014). Women report disproportionate lifetime prevalence of both mood disorders and anxiety disorders compared to men on the global scale (Steel et al., 2014). This unequal prevalence is reflected in the United States with approximately 40% of adult females and 34% of adult males report experiencing an anxiety disorder within their lifetime (Kessler et al., 2012). The high prevalence of anxiety disorders suggests there is a need for effective, affordable, and attainable treatments in order to minimize the social and economic burdens associated with anxiety (Kessler & Greenberg, 2002).

Individuals with anxiety report significantly greater work cutbacks, suggesting that anxious individuals work less efficiently than their non-anxious counterparts (Kessler & Greenberg, 2002). Eysenck and colleagues (2007) developed the Attention Control Theory (ACT) to explain how anxiety leads to cognitive impairments (i.e. inefficiency). According to ACT, anxiety is linked to an imbalance between the goal-directed (top-down) attention system and stimulus-directed (bottom-up) attention system when threatening stimuli are presented during a cognitive task, resulting in executive function deficits (Eysenck et al., 2007). Specifically, individuals with anxiety have difficulty shifting their attention away from threatening stimuli and inhibiting attention towards threatening stimuli (Eysenck, 2010; Eysenck et al., 2007). This imbalance leads to an attentional bias towards threatening information.

Attentional bias is the predisposition to preferentially allocate attention towards threatening stimuli in the presence of neutral or positive stimuli (Cisler & Koster, 2010). Research indicates that attentional bias towards threat is observed in individuals with clinical and non-clinical anxiety, across many attentional bias paradigms, and can be measured with either word-based or picture-based attention tasks (Bar-Haim et al., 2007). It is suggested that the relationship between anxiety and attentional bias is bidirectional, and that attentional bias may indicate one's vulnerability to experience anxiety (Bockstaele et al., 2014). The reciprocal nature of attentional bias and anxiety highlights the need for effective treatments that lessen both anxiety symptoms and attentional bias towards threat.

Computer-based Attention Bias Modification (ABM) programs have been developed to attenuate attentional bias and decrease anxiety symptoms in anxious individuals (Bar-Haim, 2010; Beard et al., 2012; Hakamata et al., 2010; Mogoase et al., 2014). The success of ABM has led researchers to examine if other treatment modalities can diminish attentional bias towards threat and decrease symptoms of anxiety. Evidence supports the anxiolytic effects of both acute and chronic bouts of exercise; therefore, it is of interest to determine if exercise also impacts attentional bias in addition to anxiety symptoms (Herring et al., 2013; Petruzzello et al., 1991).

Four studies have examined the impact of acute exercise on attentional bias. Tian and Smith (2011) and Barnes et al. (2010) provide evidence that exercise attenuates attentional bias towards unpleasant picture stimuli during and after moderate intensity exercise. Additionally, attentional bias towards pleasant picture stimuli increased during and after exercise (Barnes et al., 2010; Tian & Smith, 2011). Cooper (2012) performed a systematic replication of the two studies; 39 male and female participants completed an attentional bias task before, during, and after either seated rest or exercise. The stimuli presented in the attention task differed from the previous studies and included word stimuli rather than picture stimuli. The null results suggest that word-based attentional bias is not altered during and post-exercise. In order to strengthen the design of the systematic replication, adjustments were made and two follow-up studies were performed.

The additional follow-up studies were developed to determine if exercise-induced changes in attentional bias are dependent on type of stimuli presented (i.e. word vs. picture). A female only sample was utilized because sex differences have been observed in self-reported anxiety (Kessler et al., 2012; McLean et al., 2011), attentional bias (Sass et al., 2010; Tan et al., 2011; Tran et al., 2013), and brain structure and function (Farrell et al., 2013; McLaughlin et al., 2009). The first follow-up study implemented a word-based attention task (Cooper, 2014), and results indicate that exercise did not attenuate word-based attentional bias post-exercise. The null results suggest that the exercise-induced changes in attentional bias that were previously reported (Barnes et al., 2010; Tian & Smith, 2011), may be dependent on type of stimuli presented (i.e. pictures); therefore, the present study was designed to determine if exercise could alter picture-based attentional bias in a female sample with low- and high-trait anxiety.

In addition to investigating exercise-induced changes in picture-based attentional bias, the current study assessed memory performance and mood. The hypotheses were as follows: a) attentional bias towards threat pictures were predicted to decrease from pre- to post-exercise in the exercise condition b) individuals in the exercise condition were expected to perform better on a memory task that included both neutral and threat pictures, and c) the exercise condition would experience greater improvements in mood (e.g. overall mood, state anxiety, vigor, etc.).

Methods

The following research protocol was approved by the University of Georgia Institutional Review Board and followed APA guidelines for ethical research practices.

Participants

Participants were recruited through the Department of Kinesiology at the University of Georgia in addition to flyers displayed in fitness facilities, health centers, and coffee shops in Athens, GA. Seventy-one participants qualified for the study based on an online screening that included: a consent form, medical history questionnaire, and trait anxiety questionnaire (STAI-Trait). The following inclusionary criteria were implemented: a) female, b) between the ages of 18-35, c) no predispositions to experiencing an adverse event while exercising, d) STAI-T score ≤ 33 or ≥ 39. The STAI-T cutoff scores represent scores that are 1/3 standard deviation lower and higher than the average STAI-T score for women between the ages of 18-39 (Spielberger, 1983). Seven participants were lost to follow-up scheduling; therefore, a total of 64 females between the ages of 18-34 with low- or high-trait anxiety completed the study.

Procedure

Participants were required to complete two lab sessions. Session 1 consisted of three phases. First, participants completed a consent form, 24-hour history form for sleep/medication/caffeine/exercise, depression inventory (BDI-II), and the State-Trait Anxiety Inventory for trait anxiety (STAI-T). Next, the research investigator explained how to perform the dot-probe task (see dot-probe task below). The participant practiced the dot-probe task 4 times; each task was comprised of 30 trials. Lastly, the participant completed a VO_{2peak} test on the cycle ergometer (Lode Corival). Prior to beginning the test, the participant placed a heart rate monitor (Polar Electro Inc, Lake Success, NY) around their chest and adjusted the seat height on the cycle ergometer to a position that allowed for comfortable pedaling. Once seated on the cycle ergometer, the participant was connected to the metabolic cart (Truemax 2400 Metabolic Measurement System, Parvo Medics, Sandy, UT) and sat at rest for 1 minute. Following the resting period, participants began a 2-minute warm-up at 60-80 rpms with a resistance of 25 watts. The staged VO_{2peak} protocol began immediately after the warm-up was complete. Each stage was 2 minutes in duration, and resistance increased by 33 watts. Participants were asked to maintain a cadence of 60-80 rpms throughout the course of the metabolic test and measures of heart rate, rating of perceived exertion (RPE), and VO_2 were monitored throughout the test. Once the participant indicated that volitional exhaustion had been reached, a 2-minute warm down began with a resistance of 25 watts.

Session 2 occurred within approximately 2 weeks of session 1, (mean = 6.5 days, range = 2 – 15 days). Participants were categorized as low anxious or high anxious based on their online STAI-T score, then randomly allocated to either the seated rest condition or exercise condition. Block randomization was used to try to equate the number of low anxious and high anxious individuals in each condition. The control condition (n = 32) consisted of 15 low anxious and 17 high anxious individuals; the exercise condition (n = 32) consisted of 14 low anxious and 18 high anxious individuals. A 24-hour history form for sleep/medication/caffeine/exercise was completed at the beginning of the testing session. Next, a heart rate monitor was placed around the participant's chest and the cycle ergometer was adjusted so it was comfortable for the participant to either sit or cycle.

Control Condition. Individuals in the control condition sat quietly on the cycle ergometer for 1 minute. Next, the State-Trait Anxiety Inventory for state anxiety (STAI-S), Profile of Mood States (POMS), and dot-probe task were completed. Once the dot-probe task was completed, a timer was started. After sitting quietly on the cycle ergometer for 30 minutes, the participant completed the STAI-S, POMS, and dot-probe task, and then once again at minute

45. Lastly, the participants completed a memory recognition task (see “memory task: recognition task” below). See Figure 4.1 below.

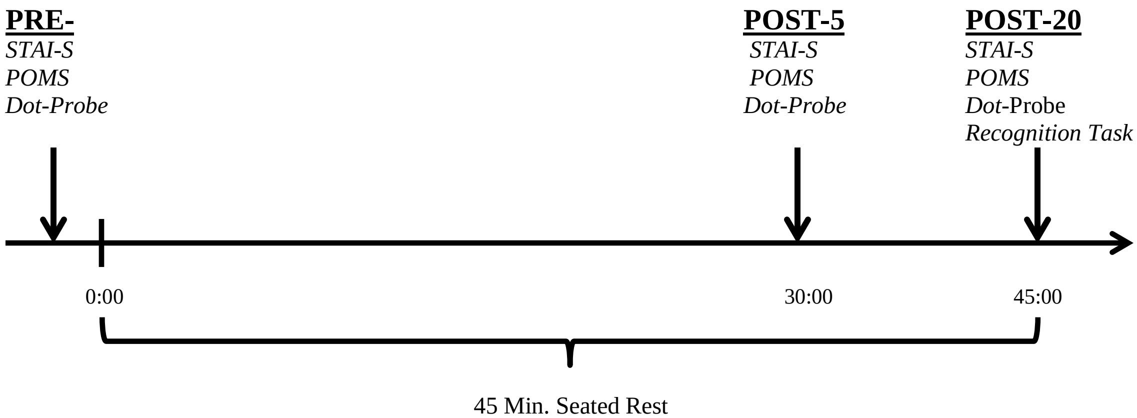

Figure 4.1. Session 2 timeline for participants in the resting condition.

Exercise Condition. Participants in the exercise group sat quietly on the cycle ergometer for 1 minute and then completed the STAI-S, POMS, and dot-probe task. Upon completing the dot-probe task, the timer was started and the participant sat quietly for 1 minute. Next, a 2-minute warm-up with 25 watts was performed and followed by an increase in resistance to elicit an intensity of 45% VO_2R for a 20-minute duration. The following equations were used to determine the proper resistance and intensity for each participant (*ACSM's Guidelines for Exercise Testing and Prescription*, 2006):

$$\text{Target } VO_2 = [(VO_{2peak} - VO_{2rest})(\text{exercise intensity}) + VO_{2rest}]$$

$$VO_2 = [(1.8*(\text{work rate})/(\text{body mass})) + (VO_{2rest}) + (3.5 \text{ mL/kg/min})]$$

If needed, resistance was adjusted halfway through the 20-minute bout of exercise to elicit an intensity of 45% VO_2R. After 20 minutes of moderate intensity cycling, the participants performed a 2-minute warm-down with a resistance of 25 watts. Following the warm-down, a 20-minute rest period began. Participants completed the STAI-S, POMS, and dot-probe task at 5 minutes post-exercise, and again at 20 minutes post-exercise. After completing the dot-probe task, the participants performed a recognition task (see “memory task: recognition task” below). See Figure 4.2 below.

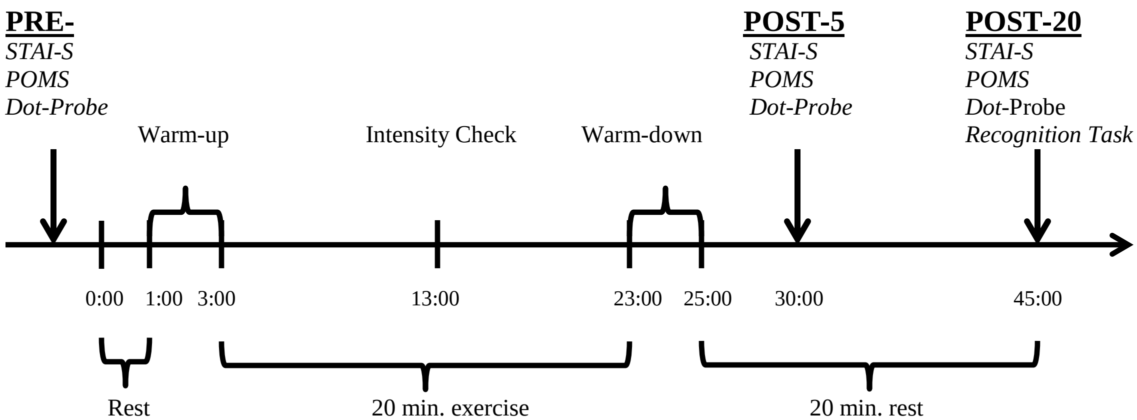

Figure 4.2. Session 2 timeline for participants in the exercise condition.

Attentional Bias: Dot-probe Task

The dot-probe task was developed and administered through a computer program, SuperLab 4.5 (Cedrus Corporation, San Pedro, CA), and required participants to make a button press with a two-key response pad (Cedrus Response Pad, Model RB-620, San Pedro, CA). Each dot-probe task consisted of 164 trials that entailed a 500 ms fixation cross, followed by two pictures vertically aligned and displayed for 500 ms, and concluded with a dot-probe that replaced one of the two pictures. The dot-probe remained on the screen until the participant made a response by depressing the left or right key on the response keypad. Once a response was made, the next trial was initiated. Participants were asked to look at both pictures and respond to the dot-probe as quickly and accurately as possible. If the dot-probe replaced the top picture, the left button was depressed, if the dot-probe replaced the bottom picture, the right button was depressed. Accuracy and response times were recorded during the task.

Pictures for the task were selected from the International Affective Picture System (IAPS) developed by Bradley and Lang (2005). Norms for ratings of dominance, valence, and arousal have been established for both males and females. Pictures were ordered based on female ratings of dominance, valence, and arousal; threat pictures were taken from the top of the ascending list, and neutral pictures were taken from the middle of the list. In total, 164 picture pairs were created with 84 neutral-neutral and 80 threat-neutral pairs. See Appendix C and Appendix D for the list of IAPS pictures used. Three versions of the dot-probe task were created with the same pictures, but picture pairs differed between the three tasks. The order of dot-probe tasks was counterbalanced among participants, and each dot-probe task began with four neutral-neutral trials that were used as practice and not analyzed.

Reliability for the three dot-probe tasks was determined by examining the consistency of response times for the control group. Four trial types were analyzed for reliability. Overall response time consists of all response times, and neutral response times only include trials that present neutral-neutral stimuli. Congruent and incongruent response times involve trials that present threat-neutral stimuli. Congruent trials occur when the dot-probe replaces the threat picture and incongruent trials occur when the dot-probe replaces the neutral picture. Neutral, congruent, and incongruent trials are important because the response times gathered from these trials can be used to infer attention allocation. Cronbach's Alpha for the four types of response times ranged from 0.95 to 0.97, suggesting good consistency between the dot-probe tasks.

Memory Task: Recognition Task

The recognition task was administered on the computer through the SuperLab 4.5 (Cedrus Corporation, San Pedro, CA) program. The participant was instructed to look at a single picture on the computer monitor and make a yes/no decision as to whether or not the picture was included in the dot-probe tasks. The picture was displayed until the participant made a button press on the two-key response pad ('yes' = left, 'no' = right). Eighty pictures were displayed during the recognition task; 40 threat pictures and 40 neutral pictures were included. Half of the threat pictures and half of the neutral pictures had been previously presented in the dot-probe task. Accuracy and response time were recorded.

Data Reduction

Attentional Bias. Response times for the dot-probe task were examined for errors, latencies greater than 2,000 ms, and individual outliers (Koster et al., 2004). Errors and response times greater than 2,000 ms were removed from the data. Next, individual outliers (response times greater than 3 standard deviations from an individual's mean response time) were removed. In total, 3.1%, 1.4%, 0.03%, of the data were removed as errors, individual outliers, and latencies greater than 2,000 ms, respectively. After the data was trimmed, attentional bias was analyzed.

Response times for the dot-probe task were prepared for two types of analyses: congruency effect method and bias score method (Koster et al., 2004; MacLeod & Mathews, 1988). In addition to overall response time, response times were categorized into groups for the congruency effect analysis: neutral, congruent, and incongruent (Koster et al., 2004). Neutral response times were recorded from trials consisting of neutral-neutral images. Congruent and incongruent response times evolve from trials consisting of threat-neutral images. Specifically, congruent response times represent the time it takes for a person to respond to a dot-probe that replaces a threat picture. Incongruent response times represent the duration it takes to respond when a dot-probe replaces a neutral imagine in the presence of a threat image; anxious individuals have been found to have prolonged response times on incongruent trails because they have difficulty disengaging attention from the threat stimuli and shifting attention to the neutral stimuli (Koster et al., 2004).

In addition to examining response times based on the congruency effect, response times from the dot-probe task were used to calculate a single index bias score (MacLeod & Mathews, 1988). The bias score was created to give a general indication of how one deploys their attention in the presence of a threat stimulus. A positive bias score suggests that the individual is disproportionately attending to the threat stimuli relative to the neutral stimuli, and a negative bias score suggests that the individual is avoiding the threat stimuli. Below is the single index bias score equation:

Attentional Bias Score = ½ [(UpLt – UpUt) + (LpUt – LpLt)]

U = Upper Position

L = Lower Position

p = Probe

t = Threat Word

Memory Task. Recognition task performance was analyzed by two methods: the explicit memory index (EMI), and the signal detection method (i.e. hit rate, false alarm rate, d'). Explicit memory is used in tasks that require intentional recall of information from memory; the EMI has previously been used to determine if individuals with anxiety possess a memory bias for threat words (Graf & Schacter, 1985; MacLeod & McLaughlin, 1995). In order to calculate an EMI score, the number of pictures correctly identified (hits) and number of pictures wrongly assumed (false alarms) must be obtained, and then those numbers are plugged into the following equation:

EMI = # of threat pictures correctly identified - # threat pictures wrongly assumed

Signal detection theory was developed to analyze decision-making tasks, and provides information about the ability of an individual to discriminate between correct or incorrect responses (Green & Swets, 1974). The present study examined hit rate, false alarm rate, and d' for only the threat words in the recognition task, and then again for all words in the recognition task (threat and neutral). The hit rate provides the probability that someone correctly identified a picture that was displayed during the dot-probe task, and the false alarm rate indicates the probability that a participant falsely assumed a picture had been previously displayed during the dot-probe task. Combining the hit rate and false alarm rate leads to d', a single index that provides information about an individual's ability to discriminate between what words they had previously been exposed to and what threat words were new. Below are the equations used to obtain hit rate, false alarm rate, and d' (Murdock, 1982).

Hit rate (H) = # pictures correctly identified / # pictures previously presented

False alarm rate (FA) = # pictures falsely assumed / # pictures not previously presented

$d' = z(FA) - z(H)$

Signal detection analyses were used to examine differences in memory for threat stimuli only, and then all stimuli (neutral and threat). For threat-only analyses, the denominator on the above equations was 20, and for analyses involving all stimuli, the denominator on the above equations was 40.

Data Analyses

Planned contrasts were performed for measurements taken prior to exercise (baseline), 5-min post exercise, and 20-min post exercise. Helmert planned-contrasts were selected to analyze the critical Condition x Time interaction in the mixed-model statistical designs. Additionally, Helmert planned contrasts were used to examine the Anxiety Level x Condition x Time interaction only for the STAI state anxiety measure. The Helmert analysis provides the contrast for pre- to pooled-post measures. Additionally, separate omnibus mixed-model ANOVAs, 2 (Group: low-anxiety, high-anxiety) x 2 (Condition: control, exercise) x 3 (Time: pre-, post-5, post-20), were performed on attentional bias and mood measures. Maulchy's test of sphericity was used and, if significant ($p < .05$), adjustments to degrees of freedom were made by the

Huynh-Feldt correction. Main effects and interactions are reported for the 2 x 2 x 3 ANOVAs. Separate factorial-model ANOVAs, 2 (Group: low-trait anxiety, high-trait anxiety) x 2 (Condition: control, exercise), were performed for the memory task measures; main effects and interactions are reported. Paired samples t-tests were used to examine differences in performance for different valence photos in the memory task (i.e. threat and neutral). Lastly, t-tests were used to determine if differences were present at baseline. If Levene's test indicated unequal variances for measures ($p < .05$), then adjustments were made to the degrees of freedom for the t-test. Corrected t-scores and p-values are reported with the original degrees of freedom for the variables that had unequal variances. All data were analyzed via SPSS 22.0 (IBM Corp.) with an *a priori* alpha level set to $p = .05$.

Results

Participant Characteristics

Due to extreme outliers, the data of a high anxious participant in the exercise condition was not included in the analyses. As a result, data analyses included 32 participants in the control condition (15 low anxious, 17 high anxious) and 31 participants in the exercise condition (14 low anxious, 17 high anxious).

Psychological Measures. The correlation between the trait anxiety score (STAI-T) collected during the online screening and the STAI-T collected in the lab was strong, $r = 0.94$, $p < .001$. There was a significant difference between trait anxiety scores between individuals categorized as low- and high-anxious in the control condition, $t(30) = -10.19$, $p < .001$, as well as the exercise condition, $t(29) = -9.91$, $p < .001$. Individuals with high-trait anxiety also reported having significantly greater depressive symptoms in both the control condition, $t(30) = -3.35$, $p = .003$, and exercise condition, $t(29) = -7.48$, $p < .001$ (TABLE 4.1).

Physical Measures. Despite block randomization, there were two significant differences at baseline between individuals in the control condition and exercise condition. The average body mass was greater for the control group than the exercise group, t(61) = 2.14, p = .04. Additionally, the average VO_{2peak} for the control group was lower than the exercise group, t(61) = -2.50, p = .02. Height did not differ between the two conditions. (TABLE 4.1)

Table 4.1. Participant characteristics at baseline (Mean ± SD).

	ANXIETY	N	AGE	ONLINE TRAIT	BDI-II	WEIGHT (KG)	HEIGHT (IN)	VO2 PEAK
CON	**ALL**	**32**	**22(4.0)**	**38.5(10.1)**	**8.8(7.7)**	**66.1(12.4)***	**65.3(2.4)**	**31.8(5.2)***
	LA	15	21(3.5)	29.3(3.3)+	4.7(2.9)+	68.7(14.1)	65.6(2.1)	32.2(4.4)
	HA	17	23(4.3)	46.7(6.1)+	12.4(8.9)+	63.7(10.6)	64.9(2.6)	31.4(5.9)
EX	**ALL**	**31**	**23(4.0)**	**40.4(14.3)**	**9.7(9.2)**	**60.3(8.3)***	**65.2(2.5)**	**35.6(6.8)***
	LA	14	22(3.3)	27.0(3.2)+	1.9(1.5)+	58.0(5.2)	65.5(2.6)	38.0(7.0)
	HA	17	24(4.4)	51.4(9.5)+	16.2(7.7)+	61.1(10.3)	65.0(2.4)	33.5(6.2)

CON = control condition, EX = exercise condition; * p < .05 between conditions; + p < .001 within condition, between anxiety levels

Attentional Bias: Dot-probe Task

Congruency Effect Analyses. For the congruency method, planned contrasts (Helmert) and 2 (Group) x 2 (Condition) x 3 (Time) ANOVAs were conducted separately for each of the following types of response times: overall, neutral, congruent, and incongruent.

Overall Response Time. The planned contrast **(**Helmet) revealed a non-significant difference between pre-exercise and post-exercise response times between conditions, F(1, 59) = 2.99, p = .09, η_p^2 = .05. The omnibus ANOVA yielded non-significant main effects of group and condition, F(1, 59) = 0.03, p = .86, η_p^2 = .001, and F(1, 59) = 0.64, p = .43, η_p^2 = .01, respectively. The main effect of time was significant, with response time decreasing as time progressed, F(2, 118) = 19.52, p < .001, η_p^2 = .25. All interactions were non-significant: Group x

Time, F(2, 118) = 0.27, p = .76, η_p^2 = .005, Condition x Time = 2.25, p = .11, η_p^2 = .04, and Group x Condition x Time, F(2, 118) = 0.14, p = .97, p = .002. See Figure 4.3 below.

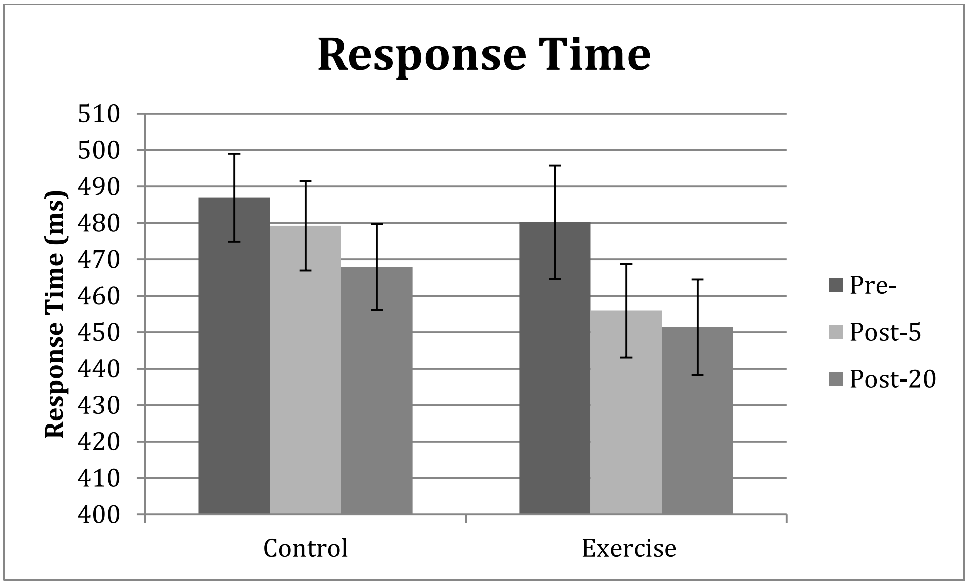

Figure 4.3 Overall response times on the dot-probe task (Mean ± SE). Lower response times indicate quicker responses to the dot-probe for all trials.

Neutral Response Time. Planned contrasts (Helmert) revealed that neutral response times decreased significantly from pre- to post-exercise for only for participants in the exercise condition, F(1, 59) = 5.41, p = .02, η_p^2 = .08. The omnibus ANOVA revealed that the main effect of group on neutral response time was non-significant, F(1, 59) = 0.06, p = .81, η_p^2 = .001, and the main effect of condition was also non-significant, F(1, 59) = 0.60, p = .44, η_p^2 = .01. The main effect of time was significant, F(1.9, 111) = 13.09, p < .001, η_p^2 = .18; neutral response times decreased as time progressed for both conditions. There was not an interaction between group and time, F(1.9, 111) = 0.36, p = .69, η_p^2 = .01; however, there was a significant interaction between condition and time, F(1.9, 111), = 4.24, p = .02, η_p^2 = .07, indicating that the exercise condition had a greater decrease in neutral response time post-exercise. The Group x Condition x Time interaction was non-significant, F(1.9, 111) = 0.41, p = .65, η_p^2 = .01. See Figure 4.4 below.

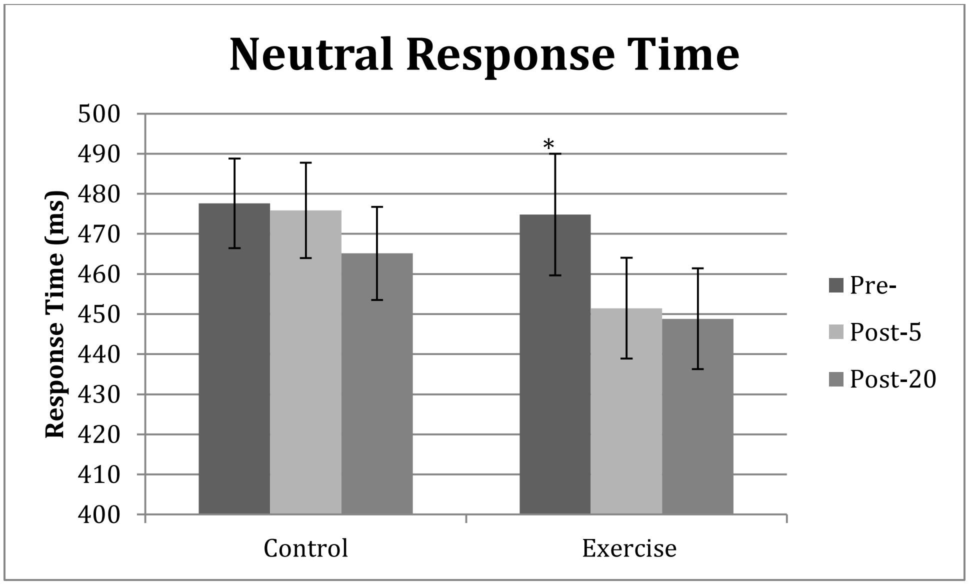

Figure 4.4. Response times for neutral-neutral trials in the dot-probe task (Mean ± SE). Lower response times indicate quicker responses to the dot-probe during neutral-neutral trials.
* = p < .05 for planned contrasts pre- to combined post-exercise response times between conditions.

Congruent Response Time. There were no differences in congruent response times from pre- to post-exercise between conditions, as indicated by the planned contrasts (Helmert), $F(1, 59) = 0.79$, $p = .38$, $\eta_p^2 = .01$. The omnibus ANOVA revealed non-significant main effects for group, $F(1, 59) = 0.02$, $p = .90$, $\eta_p^2 < .01$, and condition, $F(1, 59) = 0.57$, $p = .45$, $\eta_p^2 = .01$. The main effect of time was significant, $F(2, 118) = 16.6$, $p < .001$, $\eta_p^2 = .22$, indicating a decrease in congruent response times as time progressed for both conditions. Interactions between group and time, $F(2, 118) = 0.12$, $p = .89$, $\eta_p^2 = .01$, and condition and time, $F(2, 118) = 0.83$, $p = .44$, $\eta_p^2 = .01$, were non-significant. Additionally, the Group x Condition x Time interaction was non-significant, $F(2, 118) = 0.39$, $p = .68$, $\eta_p^2 = .01$. See Figure 4.5 below.

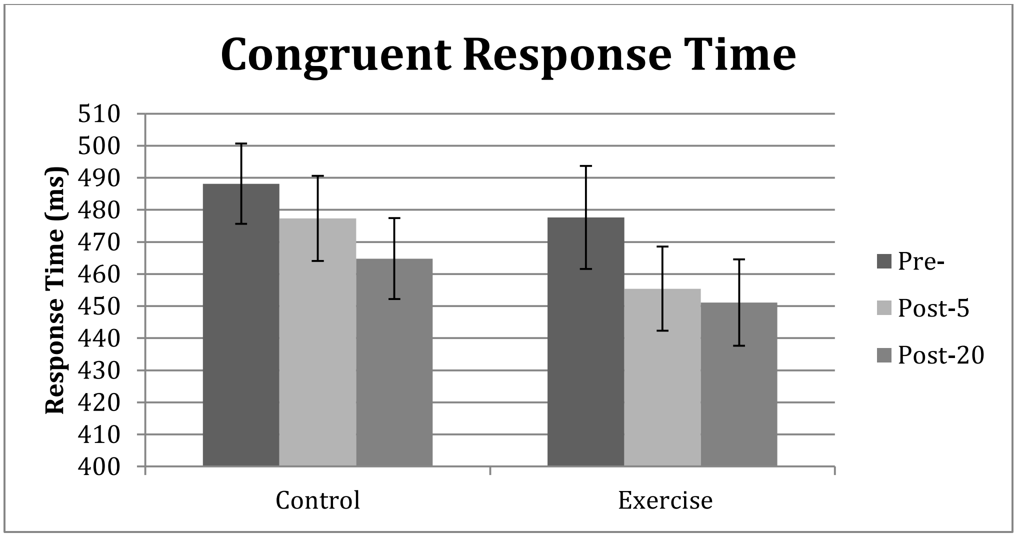

Figure 4.5. Response times for congruent trials in the dot-probe task (Mean ± SE). Quicker response times indicate increased vigilance towards threat words (i.e. great attentional bias).

Incongruent Response Time. Incongruent response times did not significantly change pre- to pooled post-exercise according to the planned contrasts (Helmert), $F(1, 59) = 3.45$, $p = .07$, $\eta_p^2 = .06$. However, repeated contrasts indicate a stronger Condition x Time interaction between pre- to 5-minutes post-exercise, $F(1, 59) = 3.76$, $p = .057$, $\eta_p^2 = .06$. Individuals in the exercise condition were able to disengage and shift their attention away from the area of the threatening stimulus more effectively than the control condition 5-minutes post-exercise. The omnibus ANOVA provided non-significant main effects of group and condition, $F(1, 59) = 0.001$, $p = .98$, $\eta_p^2 < .001$, and $F(1, 59) = 0.57$, $p = .45$, $\eta_p^2 = .01$, respectively. A main effect of time was revealed, $F(2, 118) = 16.82$, $p < .001$, $\eta_p^2 = .22$; incongruent response times decreased in both conditions as time advanced. Non-significant interactions indicate that the change in response time was independent of anxiety level and condition: Group x Time, $F(2, 118) = 0.94$, $p = .39$, $\eta_p^2 = .02$, Condition x Time, $F(2, 118) = 1.96$, $p = .15$, $\eta_p^2 = .03$, and Group x Condition x Time, $F(2, 118) = 0.12$, $p = .89$, $\eta_p^2 = .002$. See Figure 4.6 below.

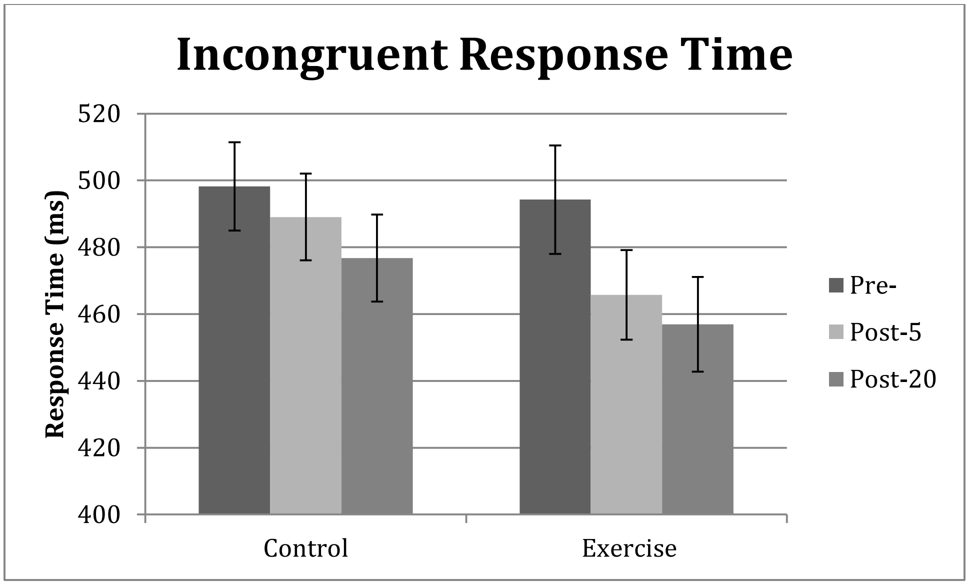

Figure 4.6. Response times for incongruent trials in the dot-probe task (Mean ± SE). Quicker response times indicate an improved ability to disengage and shift attention away from the threat stimuli (i.e. decreased attentional bias).

Bias Score. Planned contrasts (Helmert) reveal a non-significant change in bias scores from pre- to post- exercise, $F(1, 59) = 3.03$, $p = .087$, $\eta_p^2 = .05$. The omnibus ANOVA for the bias score method revealed a non-significant main effect for group, $F(1, 59) = 0.58$, $p = .45$, $\eta_p^2 = .01$, condition, $F(1, 59) = 0.004$, $p = .95$, $\eta_p^2 < .001$, and time, $F(2, 118) = 0.69$, $p = .51$, $\eta_p^2 = .01$. There were no significant interactions for bias scores: Group x Time, $F(2, 118) = 1.22$, $p = .30$, $\eta_p^2 = .02$, Condition x Time, $F(2, 118) = 1.49$, $p = .23$, $p = .03$, and Group x Time x Condition, $F(2, 118) = 0.62$, $p = .54$, $\eta_p^2 = .01$. See Figure 4.7 below.

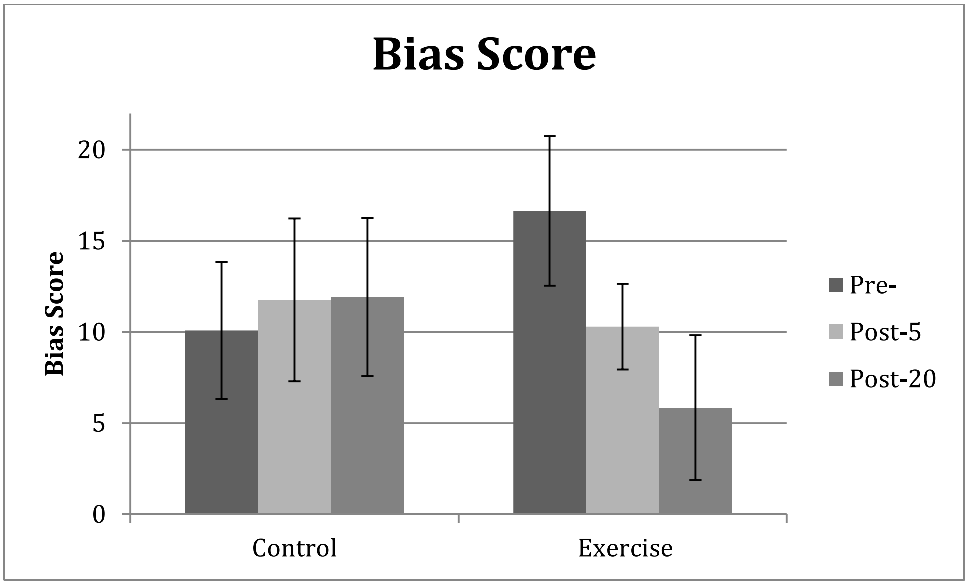

Figure 4.7. Bias scores from the dot-probe task (Mean ± SE). Negative scores indicate avoidance from threat words and positive scores indicate increased vigilance towards threat words.

Memory Task: Recognition Task

Explicit Memory Index (EMI). A 2 (Group) x 2 (Condition) ANOVA was performed to determine differences in performance on the memory task for trials involving threatening pictures, as well as trials involving neutral pictures. Additionally, a paired samples t-test was used to determine if individuals responded differently based on type of stimuli presented: threat or neutral.

EMI: Threat Only. The main effect of group was non-significant, $F(1, 59) = 1.2$, $p = .28$, $\eta_p^2 = .02$. The main effect of condition was significant, $F(1, 59) = 5.47$, $p = .02$, $\eta_p^2 = .09$; participants in the control condition had a higher EMI than the exercise condition. The Group x Condition interaction was non-significant, $F(1, 59) = 0.10$, $p = .75$, $\eta_p^2 = .002$. The difference in EMI scores was driven by the significant difference in false alarm between conditions (see "false alarms: threat only" below). See the Table 4.2 below for recognition task results.

EMI: Neutral Only. There were no differences between groups and conditions for the EMI for neutral pictures. The main effect of group, F(1, 59) < .001, p = .98, $\eta_p^2 < .001$, the main effect of condition, F(1, 59) = 0.65, p = .42, $\eta_p^2 = .01$, and the interaction between group and condition, F(1,59) = 0.01, p = .92, $\eta_p^2 < .001$, were all non-significant. See Table 4.2 below.

Table 4.2. Hits (correct answers), false alarms (incorrect answers) and EMI scores from the memory task (Mean ± SD). Higher hit rates indicate more correct responses, higher false alarm rates indicate more incorrect responses, and high EMI scores indicates better explicit memory performance.

		THREAT			NEUTRAL		
	n	*Hits*	*False Alarms*	*EMI*	*Hits*	*False Alarms*	*EMI*
CONTROL	**32**	**16.2 (3.0)$^+$**	**3.8 (2.4)*$^+$**	**12.5 (3.8)***	**12.7 (3.5)$^+$**	**2.5 (1.7)$^+$**	**10.2 (4.2)**
LA	15	15.4 (2.6)	3.5 (2.5)	11.9 (3.2)	12.3 (3.4)	2.1 (1.7)	10.2 (4.3)
HA	17	16.9 (3.2)	4.1 (2.3)	13.1 (4.2)	13.1 (3.7)	2.9 (1.7)	10.1 (4.3)
EXERCISE	**31**	**16.1 (2.5)$^+$**	**5.6 (3.1)*$^+$**	**10.4 (3.2)***	**12.5 (3.1)$^+$**	**3.1 (2.3)$^+$**	**9.4 (3.6)**
LA	14	16.3 (2.3)	6.2 (3.6)	10.1 (3.5)	12.3 (2.7)	3.0 (2.3)	9.3 (3.3)
HA	17	15.9 (2.6)	5.1 (2.8)	10.8 (3.0)	12.6 (3.5)	3.2 (2.4)	9.4 (3.8)

* p < .05 between conditions, $^+$ p < .001 between valence type (threat vs. neutral)

Signal Detection Assessment. The signal detection method was utilized to examine differences in recognition task performance between anxiety levels and conditions. 2 (Group) x 2 (Condition) ANOVAs were performed for recognition task trials that consisted of only threat stimuli, as well as, all trials. See Table 4.3 below for the recognition task results.

Hit Rate: Threat Only. The hit rate for threat pictures was not impacted by group, F(1,59) = 0.67, p = .42, $\eta_p^2 = .01$, nor condition, F(1, 59) = 0.02, p = .90, $\eta_p^2 < .001$. The interaction between group and condition was also non-significant, F(1, 59) = 1.97, p = .17, $\eta_p^2 = .03$. See Table 4.3.

False Alarm Rate: Threat Only. The false alarm rate for threat pictures on the recognition task did not vary between groups, F(1, 59) = 0.16, p = .69, $\eta_p^2 = .003$; however, there was a significant difference between conditions. The main effect of condition was significant, F(1, 59) = 6.97, p = .01, $\eta_p^2 = .11$; participants in the control condition had a lower false alarm rate than the exercise condition participants. This indicates that the individuals who exercised were more likely to falsely assume a threat picture had been presented during the dot-probe task when, in fact, it had not. The interaction between group and condition was non-significant, F(1, 59) = 1.31, p = .26, η_p^2 =.02. See Table 4.3.

Sensitivity Index d': Threat Only. The main effects of group and condition were non-significant, F(1, 59) = 2.03, p = .16, η_p^2 = .03, and F(1, 59) = 3.34, p = .07, η_p^2 =.05, respectively. The interaction between group and condition was also non-significant, F(1, 59) = 0.19, p = .67, η_p^2 = .003. See Table 4.3.

Hit Rate: All Trials. The main effect of group, F(1, 59) = 0.62, p =.43, η_p^2 = .01, and condition, F(1, 59) = 0.06, p = .80, η_p^2 =.001, were non-significant. The interaction between the two (group and condition), was also non-significant, F(1, 59) = 0.74, p = .39, η_p^2 =.01. See Table 4.3.

False Alarm Rate: All Trials. The false alarm rate for all trials did not vary by group, F(1, 59) = 0.03, p = .87, $\eta_p^2 < .001$; however, it did vary between conditions. The exercise condition had a higher false alarm rate for all trails (threat and neutral) compared to the control condition, F(1, 59) = 5.39, p = .02, η_p^2 = .08. This indicates that the exercise condition was more likely to falsely assume a picture had been previously presented during the dot-probe task when it had not been. The Group x Condition interaction was non-significant, F(1,59) = 1.08, p = .30, η_p^2 = .02.See Table 4.3.

Sensitivity Index d': All Trials. There was not a difference for measures of d' between group, F(1, 59) = 0.28, p = .60, η_p^2 = .005, nor condition, F(1, 59) = 2.87, p = .10, η_p^2 = .05. Additionally, there was not a significant interaction between group and condition, F(1, 59) = 0.27, p = .61, η_p^2 = .004. See Table 4.3.

Table 4.3. Signal detection assessment: hit rate, false alarm rate, and d' for the memory recognition task (Mean ± SD). Higher hit rates indicate greater percentage of correct responses, higher false alarm rates indicate greater percentage of incorrect responses, and higher d' indicates better ability to discriminate between stimuli that were previously presented and those that were not.

		THREAT			ALL		
	n	*Hit Rate*	*False Alarm Rate*	*d'*	*Hit Rate*	*False Alarm Rate*	*d'*
CONTROL	**32**	**0.81 (0.2)**	**0.19 (0.1)***	**2.16 (1.0)**	**0.72 (0.1)**	**0.16 (0.1)***	**1.76 (0.7)**
LA	15	0.77 (0.1)	0.18 (0.1)	1.93 (0.8)	0.69 (0.1)	0.14 (0.1)	1.76 (0.8)
HA	17	0.85 (0.2)	0.20 (0.1)	2.36 (1.1)	0.75 (0.2)	0.17 (0.1)	1.76 (0.6)
EXERCISE	**31**	**0.80 (0.1)**	**0.28 (0.2)***	**1.73 (0.8)**	**0.71 (0.1)**	**0.22 (0.1)***	**1.49 (0.6)**
LA	14	0.81 (0.1)	0.31 (0.2)	1.61 (0.83)	0.71 (0.1)	0.23 (0.1)	1.40 (0.5)
HA	17	0.79 (0.1)	0.26 (0.14)	1.84 (0.84)	0.71 (0.1)	0.21 (0.1)	1.57 (0.6)

* p < .05 between conditions

Mood

STAT-S. Planned contrasts (Helmert) revealed a non-significant pre- to post-exercise change in state anxiety, $F(1,59) = 1.02$, $p = .32$, $\eta_p^2 = .02$. The omnibus ANOVA revealed a main effect of group on state anxiety was significant, $F(1, 59) = 35.17$, $p < .001$, $\eta_p^2 = .37$, as well as the main effect of time, $F(1.6, 95.9) = 3.51$, $p = .04$, $\eta_p^2 = .06$. The main effect of condition was not significant, $F(1, 59) = 0.45$, $p = .51$, $\eta_p^2 = .01$. The Group x Time interaction, $F(1.6, 95.9) = 1.23$, $p = 2.9$, $\eta_p^2 = .02$, and Condition x Time interaction, $F(1.6, 95.9) = 1.31$, $p = .27$, $\eta_p^2 = .02$, were both non-significant. However, the Group x Condition x Time interaction was significant, $F(1.6, 95.9) = 4.23$, $p = .02$, $\eta_p^2 = .07$. Planned contrasts (Helmert) for the Group x Condition x Time interaction revealed a significant decrease in state anxiety pre- to post-exercise for the high-trait anxious individuals, $F(1, 59) = 5.50$, $p = .02$, $\eta_p^2 = .09$. See Figure 4.8 below.

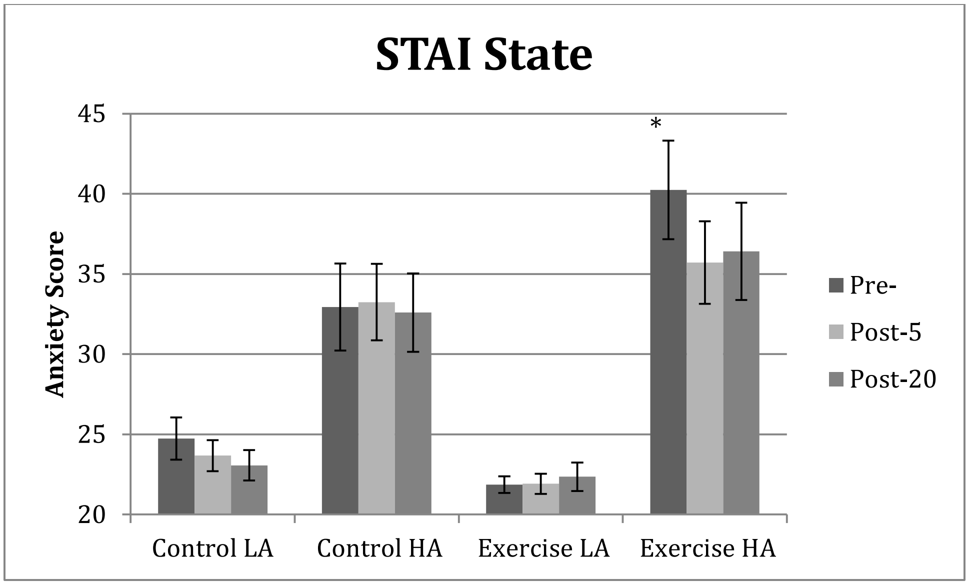

Figure 4.8. STAI State anxiety scores (Mean ± SE). Lower scores indicate lower state anxiety. * = p < .05 for planned contrasts pre- to combined post-exercise scores for high anxious females in the exercise group.

POMS: Total Mood Disturbance (TMD). Helmert planned contrasts revealed a significantly greater improvement in mood from pre- to post-exercise for participants in the exercise condition compared to the non-exercise condition, $F(1,59) = 16.35$, $p < .001$, $\eta_p^2 = .23$. The omnibus ANOVA revealed a significant main effect of group on total mood disturbance, $F(1, 59) = 13.01$, $p = .001$, $\eta_p^2 = .18$. Individuals with high trait anxiety reported higher levels of mood disturbance compared to individuals with low trait anxiety. There was no main effect of condition, $F(1, 59) = 2.21$, $p = .14$, $\eta_p^2 = .04$, nor time, $F(1.6, 93.7) = 2.51$, $p = .10$, $\eta_p^2 = .04$. The Group x Time interaction was non-significant, $F(1.6, 93.7) = 0.75$, $p = .46$, $\eta_p^2 = .01$; however, the Condition x Time interaction was significant, $F(1.6, 93.7) = 13.3$, $p < .001$, $\eta_p^2 = .18$. The Group x Condition x Time interaction was non-significant, $F(1.6, 93.7) = 0.85$, $p = .41$, $\eta_p^2 = .01$. See Figure 4.9 below.

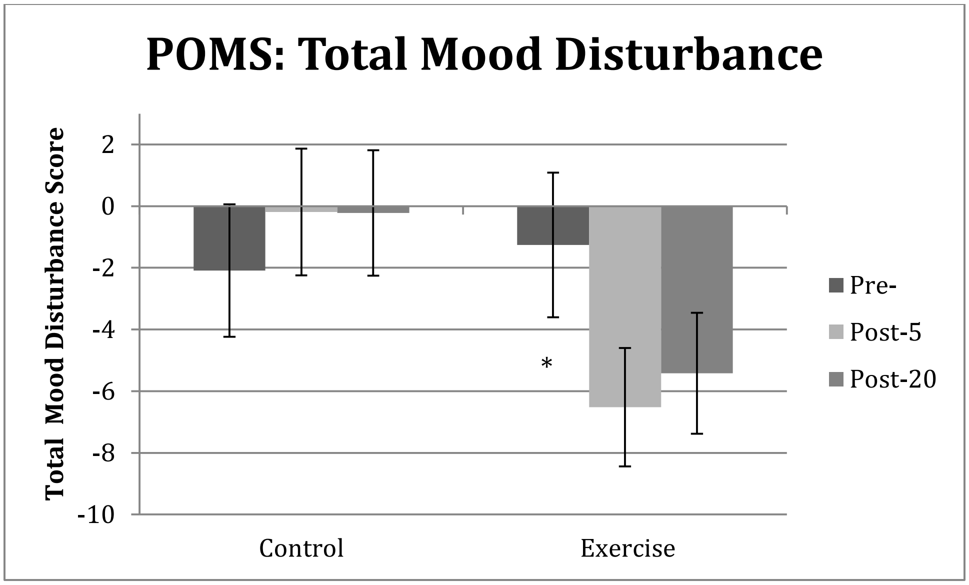

Figure 4.9. POMS total mood disturbance scores (Mean ± SE). Lower scores indicate better overall mood. $p < .001$ for planned contrasts pre- to combined post-exercise scores.

POMS: Anger. Repeated planned contrasts revealed a significant change in feelings of anger pre- to 5-minutes post-exercise, $F(1,59) = 3.99$, $p = .05$, $\eta_p^2 = .06$. Additionally, there were significant differences in anger scores from 5-minutes post-exercise to 20-minutes post-exercise between conditions, $F(1,59) = 8.39$, $p = .04$, $\eta_p^2 = .07$, indicating that the exercise condition's improvement in anger scores attenuated at 20-minutes post exercise. The omnibus ANOVA indicated a non-significant main effect of group, $F(1, 59) = 2.01$, $p = .16$, $\eta_p^2 =.03$, condition, $F(1, 59) = 0.45$, $p = .51$, $\eta_p^2 = .01$, and time, $F(2, 118) = 1.0$, $p = .37$, $\eta_p^2 = .02$. Additionally, interactions were non-significant as well, including: Group x Time, $F(2, 118) = 0.57$, $p = .57$, $\eta_p^2 = .01$, Condition x Time, $F(2, 118) = 2.61$, $p = .08$, $\eta_p^2 = .04$, and Group x Condition x Time, $F(2, 118) = 1.30$, $p = .28$, $\eta_p^2 = .02$. See Figure 4.10 below.

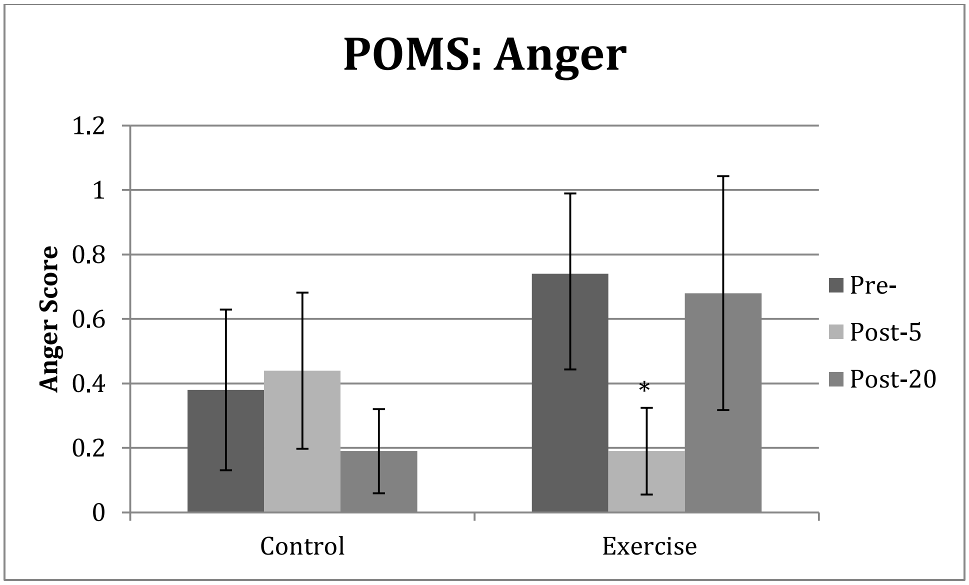

Figure 4.10. POMS anger scores (Mean ± SE). Lower numbers indicate lower levels of anger. * = p < .05 for planned contrasts 5 minutes post-exercise to 20 minutes-post-exercise scores.

POMS: Confusion. Planned Helmert contrasts indicate that ratings of confusion decreased significantly for individuals in the exercise condition compared to the control condition, $F(1,59) = 3.26$, $p = .01$, $\eta_p^2 = .10$, for pre- to pooled-post measures. The omnibus ANOVA revealed a significant main effect of group on ratings of confusion, $F(1, 59) = 13.49$, $p = .001$, $\eta_p^2 = .19$, and non-significant main effects of condition, $F(1, 59) = 1.16$, $p = .29$, $\eta_p^2 = .02$, and time, $F(1.8, 103.4) = 2.68$, $p = .08$, $\eta_p^2 = .04$. Individuals with high trait anxiety reported higher levels of confusion compared to low trait anxious individuals. The interactions between group and time were non-significant, $F(1.8, 103.4) = 5.01$, $p = .07$, $\eta_p^2 = .05$, as well as the Group x Condition x Time interaction, $F(1.8, 103.4) = 1.28$, $p = .28$, $\eta_p^2 = .02$. A significant interaction appeared for Condition x Time, $F(1.8, 103.4) = 5.01$, $p = .011$, $\eta_p^2 = .08$. See Figure 4.11 below.

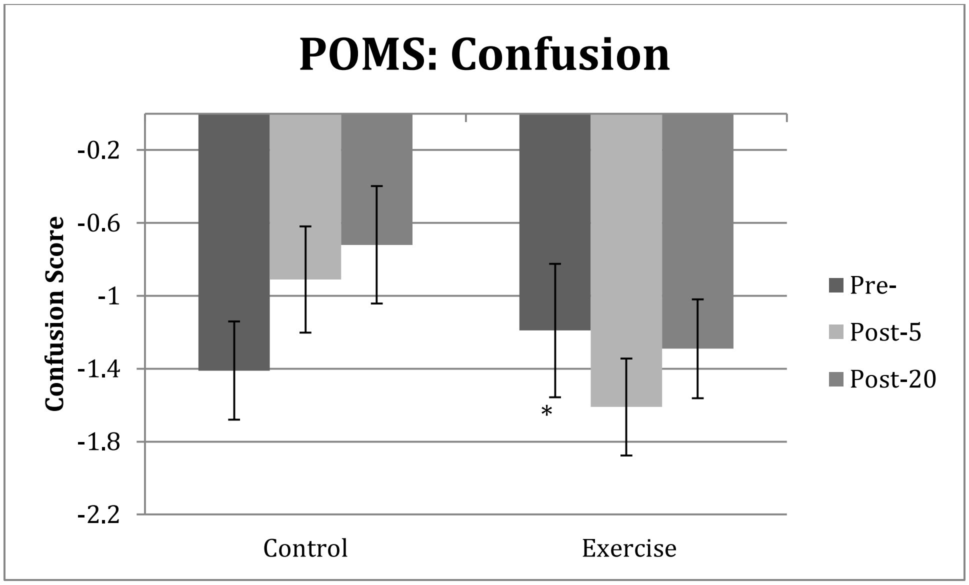

Figure 4.11. POMS confusion scores (Mean ± SE). A lower score indicates less confusion.
* = p < .05 for planned contrasts pre- to combined post-exercise scores.

POMS: Vigor. Planned comparisons (Helmert) indicate a significant increase in feelings of vigor pre- to post-exercise for participants in the exercise condition compared to the control condition, $F(1, 59) = 10.73$, $p = .002$, $\eta_p^2 = .15$. The omnibus ANOVA indicates a non-significant main effect of group, $F(1, 59) = 1.82$, $p = .18$, $\eta_p^2 = .001$, as well as a non-significant main effect of time, $F(1.7, 101.3) = 0.95$, $p = .38$, $\eta_p^2 = .02$. The main effect of condition was significant, $F(1, 59) = 7.24$, $p = .009$, $\eta_p^2 = .03$. The Condition x Time interaction was significant, $F(1.7, 101.3) = 8.35$, $p = .001$, ηp2 = .12. The Group x Time and Group x Condition x Time interactions were non-significant, $F(1.7, 101.3) = 0.12$, $p = .86$, $\eta_p^2 = .002$, and $F(1.7, 101.3) = 0.83$, $p = .42$, $\eta_p^2 = .01$, respectively. See Figure 4.12 below.

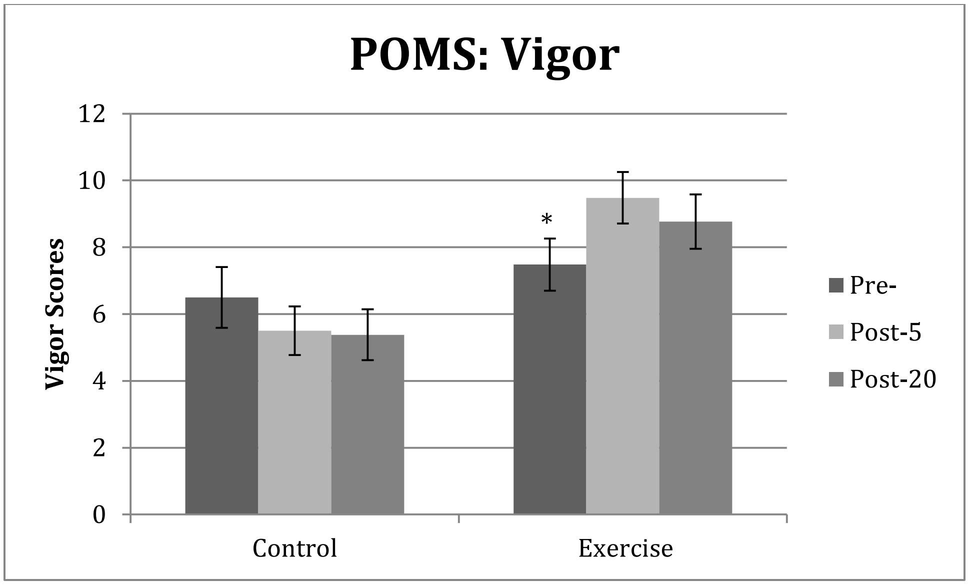

Figure 4.12. POMS vigor scores (Mean ± SE). Higher scores indicate greater feelings of vigor. * = p < .05 for planned contrasts pre- to combined post-exercise scores.

Discussion

The present study examined the effects of an acute bout of moderate intensity exercise on picture-based attentional bias, memory, and mood in a sample of low- and high-trait anxious women. Predicted changes in attentional bias towards threat pictures from pre- to post-exercise were observed in the exercise condition; however, these changes did not meet the critical p-value of .05 ($p = .07$ for incongruent trials, $p = .09$ for bias scores). Additionally, it was predicted that exercise would enhance memory performance on the recognition task; however, this hypothesis was not supported. Lastly, as anticipated, significant improvements in mood pre- to post-exercise were witnessed in the exercise condition for measures of state anxiety, total mood disturbance, anger, confusion, and vigor.

Individuals who are clinically and non-clinically anxious preferentially allocate their attention to threatening stimuli in their environment (Cisler & Koster, 2010; Eysenck et al., 2007). The disproportionate allocation of attention to threat stimuli is attributed to an imbalance between two theoretical attention systems: goal-directed (top-down processing) and stimulus-driven (bottom-up processing) attention systems (Corbetta & Shulman, 2002; Eysenck et al., 2007). Specifically, Eysenck and colleagues (2007) state that the imbalance between attention systems arises from salient threat stimuli capturing the attention of anxious individuals, which leads to over activation of the stimulus-driven system. This attentional bias is reflected when individuals have difficulty disengaging, shifting, and inhibiting attention from threat stimuli, as well as, increased vigilance for threat stimuli during cognitive tasks (Koster et al., 2004).

The dot-probe task was developed by MacLeod, Mathews, and Tata in 1986 to assess attentional bias in anxious individuals, and a single index bias score was developed to provide information about an individual's preference to allocate attention towards or away from threat stimuli (MacLeod & Mathews, 1988). A limitation to interpreting attentional bias based on a single index bias score is that it does not indicate if attentional bias is driven by heightened vigilance or difficulty disengaging from threat stimuli (Koster et al., 2004). In the present study, individuals in the exercise condition decreased their attentional bias, while individuals in the control condition remained relatively the same across time according to the single index bias scores ($p = .09$). This pattern of exercise-induced change in picture-based attentional bias is similar to the changes that Tian and Smith (2011) and Barnes (2010) described. It seems that exercise may have a stronger impact on picture-based attentional bias than word-based bias when comparing exercise induced-changes in picture-based attentional bias observed in the present study and the lack of exercise-induced changes in word-based attentional bias reported by Cooper (2014). Differences in processing affective words and pictures have been previously reported for methodologies relying on response time data (De Houwer & Hermans, 1994), and brain imagining (Kensinger & Schacter, 2006). Research suggests that picture stimuli are processed more rapidly than words stimuli, and differences in brain activation have been reported for individuals viewing emotional pictures compared to reading emotional words (De Houwer & Hermans, 1994, Kensinger & Schacter, 2006). Therefore, it is important to continue to investigate whether differences in stimulus type impacts the magnitude of change in attentional bias that results from exercise.

In order to further examine the changes in picture-based attentional bias, a second method, the congruency method, was used to assess response time data. The congruency method allows researchers to make assumptions about the attentional processes leading to attentional bias (i.e. increased vigilance or difficulty disengaging) (Koster et al., 2004). The congruency method revealed that the change in attentional bias scores was driven by changes in response times on incongruent trials ($p = .07$). The greatest difference in incongruent response time changes occurred pre- to 5-minutes post-exercise ($p = .057$). Incongruent trials occur when a threat picture and a neutral picture are presented simultaneously and the dot-probe replaces the neutral picture. This type of trial requires the participant to disengage their attention from the threat stimuli, and shift attention towards the neutral stimuli in order to respond to the dot-probe (Koster et al., 2004). Individuals in the exercise condition decreased response times on incongruent trials pre- to post-exercise, which suggests that exercise improved the participant's efficiency in disengaging attention from threat stimuli and shifting attention towards neutral stimuli. Additionally, the exercise condition significantly decreased response times for trials containing only neutral stimuli from pre- to post-exercise. Previous research examining exercise-induced changes in attentional bias did not examine changes in bias based on the congruency method, so it is unclear if the changes in incongruent and neutral trails corroborate with previous findings.

A memory task was performed to determine if differences in memory performance varied by condition, and to provide a rationale for the participants to keenly attend to the pictures presented during the dot-probe task. Acute bouts of exercise have been found to improve performance on memory tasks (Chang et al., 2012; Lambourne & Tomporowski, 2010; Roig et al., 2013). Results indicate that individuals in the resting control condition performed better on the memory task compared to individuals in the exercise condition; therefore, the hypothesis that exercise would enhance memory task performance was not supported. Participants in the exercise condition were more likely to assume a picture had been previously presented during the attention task when it had not, leading to a higher false alarm rate on the memory task compared to the control condition. Future research should examine if changes in attentional bias lead to performance differences on the memory task. The exercise condition experienced changes in attention post-exercise; response times to neutral-neutral picture trials and incongruent trials decreased which may have influenced their ability to encode and memorize the pictures for the memory task.

Exercise-induced mood improvements were observed post-exercise for overall mood disturbance, anger, confusion, and vigor scores. These changes support the hypothesis set forth that exercise would enhance mood post-exercise. Total Mood Disturbance (TMD) scores significantly decreased post-exercise in the exercise-condition. This change is supported by previous research that has reported mood enhancement through TMD scores post-exercise (Berger & Motl, 2000; Hansen, Stevens, & Coast, 2001; Sibold & Berg, 2010). Additionally, individuals in the exercise condition reported decreased levels of anger 5-minutes post-exercise, which coincides with previous research (Berger & Motl, 2000). Participants also reported lower levels of confusion post-exercise, as well as increased levels of vigor, which reflects the results of preceding studies (Hansen et al., 2001; Loy et al., 2013). Changes in state anxiety from pre- to post-exercise were observed only in high-anxious women. The anxiolytic effects of an acute bout of exercise are well supported; however, the individuals with low trait anxiety in the present study reported low baseline state anxiety measures: mean = 21.9 (1.92), on a scale of 20-80 (Petruzzello et al., 1991; Spielberger, 1983). This indicates that the scale used to measure anxiety may have limited the participants' ability to report decreased feelings of anxiety post-exercise for individuals with low-trait anxiety.

Limitations may have prevented the observed exercise-induced changes in attentional bias from reaching the critical value of $p < .05$. For example, high-anxious participants reported relatively low levels of state anxiety when they completed session 2. Previous research indicates that individuals with high-trait anxiety exhibit a greater attentional bias towards threat when state anxiety is elevated, and low-anxious individuals exhibit a greater avoidance or decreased attentional bias when state anxiety increases (Bar-Haim et al., 2007). It may be beneficial for future studies to employ a stressor task to elevate anxiety in high anxious individuals to elicit a larger attentional bias. According to the law of initial values, this may allow for greater changes in attentional bias to be observed pre- to post-exercise. Additionally, a stressor task may provide insight to whether or not exercise attenuates the effect of a stressor on both attentional bias and anxiety.

The present study provides evidence that exercise can decrease state anxiety, enhance mood, and may decrease picture-based attentional bias post-exercise. Future research should continue to explore the impact of exercise on attentional bias and how the effect of exercise may vary by stimulus type (i.e. word vs. picture), and how exercise-induced changes in attentional bias may alter performance on a recognition memory task that relies on encoding information during the attentional bias task.

References

ACSM's Guidelines for Exercise Testing and Prescription. (2006). (7th ed.): American College of Sports Medicine.

Bar-Haim, Y. (2010). Research review: Attention bias modification (ABM): A novel treatment for anxiety disorders. *The Journal of Child Psychology and Psychiatry, 51(8)*, 859-870.

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. doi: 10.1037/0033-2909.133.1.1

Barnes, R. T., Coombes, S. A., Armstrong, N. B., Higgins, T. J., & Janelle, C. M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *Journal of Sports Sciences, 28(10)*, 1065-1076.

Beard, C., Sawyer, A. T., & Hofmann, S. G. (2012). Efficacy of attention bias moidification using threat and appetitive sitmuli: A meta-analytic review. *Behavior Therapy, 43(4)*, 724-740.

Berger, B. G., & Motl, R. W. (2000). Exercise and mood: A selective review and synthesis of research employing the profile of mood states. *Journal of Applied Sport Psychology, 12(1)*, 69-92.

Bockstaele, B. V., Verschuere, B., Tibboe, 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.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research, 1453*, 87-101. doi: 10.1016/j.brainres.2012.02.068

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

Cooper, S. L. (2012). Acute effects of aerobic exercise on positive and negative attentional bias. *Unpublished Manuscript*.

Cooper, S. L. (2014). Acute exercise alters memory performance and enhances mood, but does not influence word-based attentional bias. *Unpublished Manuscript*.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3(3)*, 201-215. doi: 10.1038/nrn755

De Houwer, J. & Hermans, D. (1994). Differences in the affective processing of words and pictures. *Cognition and Emotion, 8(1),* 1-20.

Eysenck, M. W. (2010). Attentional control theory of anxiety: Recent developments. In A. Gruszka (Ed.), *Handbook of Individual Differences in Cognition: Attention, Memory, and Executive Control.* (pp. 195-204): Springer Science+Business Media.

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

Farrell, M. R., Sengelaub, D. R., & Wellman, C. L. (2013). Sex differences and chronic stress effects on the neural circuitry underlying fear conditioning and extinction. *Physiology & Behavior*, *122*, 208-215. doi: 10.1016/j.physbeh.2013.04.002

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11(3),* 501-518.

Green, D. M., & Swets, J. A. (1974). *Signal Detection Theory and Psychophysics*. Huntington, NY: Krieger.

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, 28,* 982-990.

Hansen, C. J., Stevens, L. C., & Coast, R. (2001). Exercise duration and mood state: How much is enough to feel better? *Health Psychology, 20(4),* 267-275. doi: 10.1037/0278-6133.20.4.267

Herring, M. P., Lindheimer, J. B., & O'Connor, P. J. (2013). The effects of exercise training on anxiety. *American Journal of Lifestyle Medicine*, *8*, 388-403. doi: 10.1177/1559827613508542

Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional pictures and words: effects of valence and arousal. *Cognitive, Affective, & Behavioral Neuroscience, 6(2),* 110-126.

Kessler, R. C., & Greenberg, P. E. (2002). The economic burden of anxiety and stress disorders. In K. L. Davis, D. Charney, J. T. Coyle & C. Nemeroff (Eds.), *Neuropsychopharmacology: The Fifth Generation of Progress*: American College of Neuropsychopharmacology.

Kessler, R. C., Petukhova, M., Sampson, N. A., Zaslavsky, A. M., & Wittchen, H. U. (2012). Twelve-month and lifetime prevalence and lifetime morbid risk of anxiety and mood disorders in the United States. *International Journal of Methods in Psychiatric Research, 21(3),* 169-184. doi: 10.1002/mpr.1359

Koster, E. H., 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. doi: 10.1016/j.brat.2003.08.001

Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research, 1341*, 12-24. doi: 10.1016/j.brainres.2010.03.091

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). International Affective Picture System (IAPS): Instruction manual and affective ratings. *Technical Report #A-6*. Gainsville, FL: University of Florida.

Loy, B. D., O'Connor, P. J., & Dishman, R. K. (2013). The effect of a single bout of exercise on energy and fatigue states: a systematic review and meta-analysis. *Fatigue: Biomedicine, Health & Behavior, 1*(4), 223-242.

MacLeod, C., & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *The Quarterly Journal of Experimental Psychology Section A, 40(4)*, 653-670. doi: 10.1080/14640748808402292

MacLeod, C., & McLaughlin, K. (1995). Implicit and explicit memory bias in anxiety: A conceptual replication. *Behaviour Research and Therapy, 33(1)*, 1-14.

McLaughlin, K. J., Baran, S. E., & Conrad, C. D. (2009). Chronic stress- and sex-specific neuromorphological and functional changes in limbic structures. *Molecular Neurobiology, 40(2)*, 166-182. doi: 10.1007/s12035-009-8079-7

McLean, C. P., Asnaani, A., Litz, B. T., & Hofmann, S. G. (2011). Gender differences in anxiety disorders: prevalence, course of illness, comorbidity and burden of illness. *Journal of Psychiatric Research, 45(8)*, 1027-1035. doi: 10.1016/j.jpsychires.2011.03.006

Mogoase, C., David, D., & Koster, E. H. W. (2014). Clinical efficacy of attentional bias modification procedures: An updated meta-analysis. *Journal of Clinical Psychology*, 1-25. doi: 10.1002/jclp.22081

Murdock, B. B. (1982). *Recognition Memory*. New York, NY: Academic Press.

Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kuitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11*(3), 143-182.

Roig, M., Nordbrandt, S., Geersten, S. S., & Nielsen, J. B. (2013). The effects of cardiovscular exercise on human memory: A review with meta-analysis. *Neuroscience and Biobehavioral Reviews, 37*, 1645-1666.

Sass, S. M., Heller, W., Stewart, J. L., Silton, R. L., Edgar, J. C., Fisher, J. E., & Miller, G. A. (2010). Time course of attentional bias in anxiety: emotion and gender specificity. *Psychophysiology, 47(2)*, 247-259. doi: 10.1111/j.1469-8986.2009.00926.x

Sibold, J. S., & Berg, K. M. (2010). Mood enhancement persists for up to 12 hours following aerobic exercise: A pilot study. *Perceptual and Motor Skills, 111(2)*, 333-342.

Spielberger, C. D. (1983). *State-trait inventory for adults*: Mind Garden, Inc.

Steel, Z., Marnane, C., Iranpour, C., Chey, T., Jackson, J. W., Patel, V., & Silove, D. (2014). The global prevalence of common mental disorders: A systematic review and meta-analysis 1980-2013. *International Journal of Epidemiology, 43(2)*, 476-493. doi: 10.1093/ije/dyu038

Tan, J., Ma, Z., Gao, X., Wu, Y., & Fang, F. (2011). Gender difference of unconscious attentional bias in high trait anxiety individuals. *PLoS One, 6*(5), e20305. doi: 10.1371/journal.pone.0020305

Tian, Q., & Smith, J. C. (2011). Attentional bias to emotional stimuli is altered during moderate- but not high-intensity exercise. *Emotion, 11(6)*, 1415-1424.

Tran, U. S., Lamplmayer, E., Pitzinger, N. M., & Pfabigan, D. M. (2013). Happy and angry faces: Subclinical levels of anxiety are differentially related to attentional biases in men and women. *Journal of Research in Personality, 47*, 390-397.

CHAPTER 5

DISCUSSION

Individuals with clinical and non-clinical anxiety exhibit difficulty performing executive function tasks when threat stimuli are present, leading to cognitive performance decrements and attentional bias (Bar-Haim et al., 2007; Eysenck, 2010; Eysenck et al., 2007). Cognitive performance decrements and attentional bias result from an imbalance between two attentional systems: stimulus-driven (bottom-up) and goal-oriented (top-down) (Eysenck et al. 2007). It is purported that the stimulus-driven attention system is overactive and the goal-oriented attention system is underactive in anxious individuals when threat stimuli are present (Eysenck et al., 2007). The imbalance between the attention systems can be alleviated through computer-based Attention Modification Training (ABM), which results in diminished attentional bias and decreased anxiety symptoms (Bar-Haim, 2010; Hakamata et al., 2010; Mogoase et al., 2014). Recent research has explored the potential for exercise to modify attentional bias because the anxiolytic effects of exercise are well documented and the relationship between anxiety and attentional bias has been described as bidirectional (Bockstaele et al., 2014; Herring et al., 2013; Petruzzello et al., 1991).

The anxiolytic effects of acute and chronic exercise are well known; however, the impact of exercise on attentional bias, the disproportional allocation of attention towards threat stimuli, is not well understood (Herring et al., 2013; Petruzzello et al., 1991). Two studies have reported exercise-induced changes in picture-based attentional bias (Barnes et al., 2010; Tian & Smith, 2011). A systematic replication performed by Cooper (2012) yielded results that were not consistent with the previous studies. The systematic replication (Cooper, 2012) utilized a word-based attention task rather than a picture-based attention task (Barnes et al., 2010; Tian & Smith, 2011). The difference in results suggests that the impact of exercise on attentional bias may vary by type of stimuli displayed during the attention task. The effects of ABM on attentional bias and anxiety symptoms vary based on type of stimuli utilized (i.e. word vs. picture) (Bar-Haim, 2010; Beard et al., 2012; Hakamata et al., 2010; Mogoase et al., 2014). It is purported that the efficacy of word-based ABM and picture-based ABM may depend on the type of anxiety disorder. For example, individuals with anxiety that is based on abstract threat items (e.g. Generalized Anxiety Disorder) may respond better to word-based ABM, whereas individuals with anxiety that is based on a specific phobia (e.g. arachnophobia) may have a better response to picture-based ABM (Bar-Haim, 2010).

The varying impact of ABM on attentional bias and anxiety symptoms based on type of stimuli presented could be dependent on processing differences between stimulus modalities. Evidence suggests that affective words and pictures are processed at different rates, with affective picture stimuli being processed quicker than affective word stimuli (De Houwers & Hermans, 1994). Additionally, fMRI research provides evidence that activation in the amygdala varies based on type of stimuli an individual is processing (i.e. word vs. picture) (Kensinger & Schacter, 2006). Observed differences in both exercise and ABM research for word-based and picture-based attentional bias, discrepancies in processing speed for word and picture stimuli, as well as differences in brain activation, led to the development of the present two studies that examined changes in word-based attentional bias and picture-based attentional bias pre- to post-exercise.

Comparing Study 1 to Study 2, the effect of exercise on word-based attentional bias was smaller than that of picture-based attentional bias. The two critical outcome measures for attentional bias were incongruent response times and bias scores. Exercise had a small effect on word-based incongruent response times from pre- to post-exercise, d = 0.25, as well as word-based bias scores, d = 0.23. In contrast, exercise had a small to moderate effect on picture-based incongruent response times pre- to post-exercise, d = 0.48, and picture-based bias scores, d = 0.45. These results suggest that individuals in the exercise condition were more effective at disengaging and shifting attention away from threatening picture stimuli post-exercise compared to the resting control condition, and this modification was greater in the picture-based attention task compared to the word-based attention task.

Individuals with heightened anxiety are purported to have difficulty disengaging and shifting their attention away from threatening stimuli; therefore, the results of the present studies suggest that exercise may attenuate attentional bias by improving disengagement and shifting of attention away from threatening stimuli (Koster, et al. 2004). The pre- to post-exercise changes in picture-based attentional bias followed the same pattern of change as the two previous studies examining exercise-induced changes in picture-based attentional bias (Barnes et al., 2010; Tian & Smith, 2011); however, the critical p-value in Study 2 was lower than those previously reported (incongruent trials pre- to pooled-post: p = .07, bias score: p = .09). Based on effect sizes, it seems that exercise has a more pronounced effect on picture-based attentional bias compared to word-based attentional bias. This difference may explain why the systematic replication performed by Cooper (2012) that utilized a word-based attentional bias paradigm failed to replicate the findings of previous studies utilizing picture-based attentional bias paradigms. This is the first series of experiments to explore the varying impacts of exercise on attentional bias measured by words and pictures. These preliminary results suggest that the effects of exercise on attentional bias may vary based on type of stimuli used for the attention task, with exercise having a stronger effect on picture-based attentional bias compared to word-based attentional bias. Further research is warranted to confirm these findings.

Memory performance for each condition was not uniform across the studies. In Study 1, individuals in the exercise condition performed the recognition memory task better than the resting control condition. This was expected based on previous research indicating enhanced memory performance after an acute bout of exercise (Chang et al., 2012; Lambourne & Tomporowski, 2010; Roig et al., 2013). Contrary to Study 1 and previous studies examining the impact of an acute bout of exercise on memory performance, Study 2 reported better memory performance for the resting control condition compared to the exercise condition. It should be noted that individuals in the exercise condition decreased their response times on incongruent trials in Study 2, meaning they were able to disengage their attention from the threat picture and shift attention to the dot-probe that replaced the neutral picture much quicker from pre- to post-exercise. Additionally, individuals in the exercise condition decreased their response times when two neutral pictures were displayed on the screen from pre- to post-exercise. The changes in response times and attention may have impacted the ability for individuals in the exercise condition to encode and store the information from the pictures, which could impact memory performance. Future research should explore the relationship between the exercise-induced changes in attention and memory in order to have a better understanding of the processes that are altered from pre- to post-exercise.

As expected, significant changes in mood were observed for Study 1 and Study 2. Specifically, changes in state anxiety, total mood disturbance, anger, confusion, vigor, and tension were observed. Future research may benefit from introducing a stress component to the research protocol to ensure that individuals with high trait anxiety experience high state anxiety when they completing testing sessions. Many individuals in the high trait anxiety group did not show signs of elevated state anxiety, which may have hindered the ability to find greater changes in attentional bias, as well as mood. It is important that research continues to examine the role of attentional bias, memory performance, and mood states to provide a better understanding of the potential therapeutic role exercise may play in alleviating anxiety, altering attentional bias linked to anxiety, and improving mood.

References

Bar-Haim, Y. (2010). Research review: Attention bias modification (ABM): A novel treatment for anxiety disorders. *The Journal of Child Psychology and Psychiatry, 51(8),* 859-870.

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. doi: 10.1037/0033-2909.133.1.1

Barnes, R. T., Coombes, S. A., Armstrong, N. B., Higgins, T. J., & Janelle, C. M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *Journal of Sports Sciences, 28(10),* 1065-1076.

Beard, C., Sawyer, A. T., & Hofmann, S. G. (2012). Efficacy of attention bias moidification using threat and appetitive sitmuli: A meta-analytic review. *Behavior Therapy, 43(4),* 724-740.

Bockstaele, B. V., Verschuere, B., Tibboe, 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.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Research, 1453,* 87-101. doi: 10.1016/j.brainres.2012.02.068

Cooper, S. L. (2012). Acute effects of aerobic exercise on positive and negative attentional bias. *Unpublished Manuscript*.

Eysenck, M. W. (2010). Attentional control theory of anxiety: Recent developments. In A. Gruszka (Ed.), *Handbook of Individual Differences in Cognition: Attention, Memory, and Executive Control.* (pp. 195-204): Springer Science+Business Media.

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

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, 28,* 982-990.

Herring, M. P., Lindheimer, J. B., & O'Connor, P. J. (2013). The effects of exercise training on anxiety. *American Journal of Lifestyle Medicine, 8,* 388-403. doi: 10.1177/1559827613508542

Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional pictures and words: effects of valence and arousal. *Cogn Affect Behav Neurosci, 6*(2), 110-126.

Koster, E. H., 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. doi: 10.1016/j.brat.2003.08.001

Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: a meta-regression analysis. *Brain Research, 1341,* 12-24. doi: 10.1016/j.brainres.2010.03.091

Mogoase, C., David, D., & Koster, E. H. W. (2014). Clinical efficacy of attentional bias modification procedures: An updated meta-analysis. *Journal of Clinical Psychology,* 1-25. doi: 10.1002/jclp.22081

Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kuitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11(3),* 143-182.

Roig, M., Nordbrandt, S., Geersten, S. S., & Nielsen, J. B. (2013). The effects of cardiovscular exercise on human memory: A review with meta-analysis. *Neuroscience and Biobehavioral Reviews, 37*, 1645-1666.

Tian, Q., & Smith, J. C. (2011). Attentional bias to emotional stimuli is altered during moderate- but not high-intensity exercise. *Emotion, 11(6),* 1415-1424.

APPENDIX A

NEUTRAL WORDS PRESENTED IN THE DOT-PROBE TASK[1]

actor	chimney	drill	green	lid	nursery	silent	tread
adjust	chocolate	duct	greyhound	linger	octopus	silk	tree
air	circle	dune	ground	litter	opera	skijump	trivia
album	class	echo	hairpin	lottery	ounce	sky	trunk
ancestor	cliffdiver	elbow	harp	loud	passage	slogan	turtle
antique	cloth	embattled	headlight	magazine	patent	smooth	usage
appliance	clue	engine	helium	manner	patient	sphere	van
arena	coach	erase	hen	mantel	pecan	sponge	vanity
arrow	coarse	erasure	herring	margin	penny	spray	vest
ash	column	extent	hill	material	permit	stairs	village
asphalt	contempt	eye	hire	melt	poet	statue	violin
auto	contents	fabric	history	memory	poster	steam	voyage
awaken	context	factory	hitch	merger	proper	stool	wagon
awning	cook	fawn	hotel	model	pulp	stop	week
banner	cord	fence	ice	modest	radiator	stow	window
barrel	cork	fig	icebox	moist	reef	street	windshield
basketball	corridor	film	immature	moment	render	swipe	wool
beet	creek	flight	industry	month	revere	teacher	wreath
bell	cupboard	flock	ingest	moon	revise	teeth	yolk
bicyclist	curtains	flower	intent	morsel	riddle	tendon	
black	curve	flute	irony	moth	rigor	terrace	
bland	custom	foot	jet	motorcycle	river	theory	
board	cute	forest	jungle	movie	rock	ticket	
bolt	dark	fragrance	kettle	myth	rope	tire	
boost	dawn	freezer	key	name	satellite	tissue	
brick	delude	furnace	label	napkin	saucer	ton	
brow	denote	future	ladder	nature	scene	tooth	
bulb	desert	gallon	lake	net	science	train	
bus	dew	giraffe	lamb	nine	scissors	tray	
calendar	dirt	glacier	lantern	nonsense	seagull		
campus	dishes	glance	leaves	noon	seat		
carpet	divert	glass	leisurely	nozzle	sentiment		
ceiling	dress	golf	lesson	nurse	ship		

[1]Words were selected from ANEW (Bradley& Lang, 2010)

APPENDIX B

THREAT WORDS PRESENTED IN THE DOT-PROBE TASK[1]

anxiety	failure	loss	shame
awkward	famine	lost	shark
beg	funeral	miserable	sick
cancer	grave	misery	starvation
castrate	grieve	missiles	stupid
choke	guilt	mourn	suffer
confusion	guilty	mutilation	suicide
corpse	gun	panic	surgery
coward	harassment	paralysis	terrified
criticism	helpless	perish	terror
dead	hostage	poison	terrorist
death	humiliate	poor	timid
defeated	idiot	punish	trauma
depressed	inferior	rape	tyrant
die	insecure	rejected	vanish
disease	isolation	rejection	victim
distress	kidnap	rob	virus
drown	loneliness	robbery	weep
embarrass	lonely	rot	welfare
evict	loser	scared	worry

[1]Words were selected from ANEW (Bradley& Lang, 2010)

APPENDIX C

NEUTRAL PICTURES PRESENTED IN THE DOT-PROBE TASK[2]

Lizard	1121	Reading	2377	Diving	2056
Lizard	1122	Secretary	2383	Farmer	2191
Pig	1350	Man W/Fish	2392	Neut Face	2210
Ferret	1410	Boat	2398	Neut Man	2214
Birds	1419	Girl	2411	Boy	2273
Seal	1440	Drying Hair	2442	Braces	2279
Polar Bears	1441	Feet	2445	ChildCamera	2302
Dog	1510	Boots	2446	Boy	2306
Hawk	1560	Amerindian	2484	Girl Makeup	2308
Horse	1590	Musician	2487	Girl Cow	2309
Pony	1595	Musician	2488	Cave	5661
Butterfly	1605	Musician	2489	Mountains	5700
Coyote	1640	NeutralMale	2499	Farmland	5720
Gorilla	1659	Woman	2511	Grain	5726
Gorilla	1660	Woman	2513	Plant	5740
Cow	1670	Cowboy	2635	Field	5764
Lion	1721	Shadow	2880	Nature	5780
Jaguars	1722	Smiling Girl	2900.2	Leaves	5800
Lion	1731	Beach Boys	4542	Mountain	5814
Owl	1740	Couple	4612	Mountains	5820
Elephants	1812	Flower	5020	Sunset	5829
Camels	1850	Venusflytrap	5040	Beach	5836
Jellyfish	1908	Harbor	5215	Flowers	5849
Turtles	1942	Nature	5220	Clouds	5870
Octopus	1947	Nature	5250	Bicyclist	5875
VeiledWoman	2018	Waterfall	5260	Clouds	5891
Adult	2020	Boat	5395	Desert	5900
Woman	2030	Astronaut	5470	Fireworks	5910
Cheerleaders	2034	Satellite	5471	Sky	5982
Woman	2037	Fireworks	5480	Sky	5990

[2] Pictures were selected from IAPS (Lang, Bradley, & Cuthbert, 2005)

Mushroom	5500	Screw	7018	Diver	8040	Light Bulb	7170
Mushroom	5520	Tools	7019	Diver	8041	Sailboat	8170
Mushrooms	5532	Fan	7020	Sailing	8080	Skydivers	8185
Still life	5535	Picnic Table	7026	Hockey	8117	Sky surfer	8186
Sky	5593	Iron	7030	Pole Vaulter	8130	Skier	8190
Mountains	5600	Shoes	7031	Hang Glider	8161	Ice Climber	8191
Sky Divers	5621	Shoes	7032	HotAirBalloon	8162	Skier	8193
Hang Glider	5626	Train	7033	Parachute	8163	Water Skier	8200
Hiker	5629	Shipyard	7036	Cheeseburger	7450	Waterskiing	8205
Mountains	5660	Ice Cream	7340	Hamburger	7451	Surfers	8206
Shoes	7038	Pizza	7351	French Fries	7460	Surfer	8208
Dust Pan	7040	Pizza	7352	French Fries	7461	Boat	8210
Drill	7043	Meat	7365	Pancakes	7470	Sailboat	8211
Pill	7046	Ice Cream	7390	Grapes	7472	Motorcycle	8251
Hair Dryer	7050	Candy	7400	Pasta	7480	Motorcyclist	8260
Candlestick	7053	Cupcakes	7405	Food	7481	Pilot	8300
Light bulb	7055	Candy	7410	Ferry	7489	Golfer	8311
Tool	7056	Candy	7430	Building	7491	Golf	8312
Dice	7058	Cookout	7440	Ferry	7492	Racecars	8325
Trash Can	7060	Rug	7179	Man	7493	Winner	8330
Puzzle	7061	Checkerboard	7183	Card Dealer	7503	Plane	8340
Sewing	7062	Abstract Art	7185	Stairs	7504	Tubing	8420
Bucket	7078	Abstract Art	7186	Cards	7505	Runner	8460
Luggage	7081	Abstract Art	7187	Painting	7507	Runner	8465
Headlight	7095	Abstract Art	7188	Ferris Wheel	7508	Runners	8467
Car	7096	Clock	7190	Skyscraper	7510	Gold	8500
Fire Hydrant	7100	Vase	7192	Chess	7512	Athletes	8540
Truck	7130	File Cabinets	7224	Crochet	7513	Mascot	8600
Bus	7140	Ironing Board	7234	Hospital	7521	Woman	8620
Umbrella	7150	Gym	7240	House	7530	Boy	9070
Sky	5991	Cracker	7255	Bridge	7546	Hands	9260
Outlet	6150	Ice Cream	7270	Bridge	7547	Dishes	9390
Rolling Pin	7000	Alcohol	7279	Office	7550	Dishes	9395
Buttons	7001	Wines	7280	Desert	7580	Building	9469
Disk	7003	Tomato	7287	Traffic	7590	Cigarettes	9832
Basket	7010	Agate	7830	Traffic	7595		
Gas Can	7011	Car Crash	7920	Jet	7620		
Rubberbands	7012	Basketball	8001	Agate	7820		
Light bulb	7013	Runner	8010	Fabric	7160		
Razor	7016	Skier	8021	Pole	7161		
Video	7017	Skier	8034	Bathroom	7165		

APPENDIX D

THREAT PICTURES PRESENTED IN THE DOT-PROBE TASK[2]

Snake	1040	Surgery	3212	RockClimber	8160
Snake	1050	Hospital	3220	Biker On Fire	8480
Snake	1051	Tumor	3261	Fire	8485
Snake	1052	SeveredHand	3400	Plane Crash	9050
Snake	1113	Attack	3530	StarvingChild	9075
Snake	1120	Plane Crash	3550.1	Oil Fire	9230
Spider	1201	Lightning	5950	Soldiers	9403
Spider	1205	Tornado	5961	Sliced Hand	9405
Roaches	1271	Tornado	5971	Hanging	9413
Pit Bull	1300	Tornado	5972	Execution	9414
Dog	1301	Tornado	5973	Assault	9425
Attack Dog	1304	Aimed Gun	6190	Dog	9570
Bear	1321	Terrorist	6213	Injection	9599
Attack Dog	1525	Aimed Gun	6230	Shipwreck	9620
Tiger	1726	Aimed Gun	6231	Jet	9622
Shark	1930	Aimed Gun	6250	Fire	9623
Shark	1931	Knife	6300	Bomb	9630
Shark	1932	Abduction	6312	Man On Fire	9635.1
Angry Face	2110	Beaten Fem	6315	Car Accident	9902
Angry Face	2120	Attack	6350	Car Accident	9908
Black Eye	2345.1	Attack	6370	Burning Car	9909
Police	2681	Attack	6520	Car Accident	9910
Bomb	2692	Attack	6540	Fire	9921
Gun	2811	Attack	6550	Explosion	9940
Mutilation	3000	Attack	6563		
HeadlessBody	3001	Suicide	6570.1		
Organs	3019	Tank	6940		
Mutilation	3068	Car Boot	7136		

[2] Pictures were selected from IAPS (Lang, Bradley, & Cuthbert, 2005)