EFFECTS OF AN ACUTE BOUT OF AEROBIC EXERCISE ON COGNITION AND ACADEMIC PERFORMANCE IN COLLEGE-AGED INDIVIDUALS WITH DIFFERING TRAIT ANXIETY LEVELS

BY

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THESIS

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ABSTRACT

Anxiety is a prevalent issue on college campuses, and is associated with impaired cognition. Finding an affordable behavioral therapy that could enhance cognitive performance in the academic setting would be valuable. Acute exercise has been associated with both reduced anxiety and improved cognition. **Purpose**: The purpose of this experiment was to investigate the effects of 30 minutes of aerobic exercise on state anxiety (SA), cognition, and academic performance in college-aged individuals. **Participants**: Thirty college students, with high- (*n*=9) or low-trait (*n*=21) anxiety, were solicited for this experiment. Fourteen were females and sixteen were males. **Methods**: Participation required three lab visits, lasting 1-2 hours each. Demographic questionnaires and baseline assessments of cognitive function, academic achievement, trait anxiety, and fitness were performed during visit one. The latter two visits were counterbalanced between experimental and control conditions. The control condition involved sitting quietly for 34 minutes on a treadmill, while the experimental condition involved 34 minutes of aerobic treadmill exercise, 20% below Ventilatory Threshold. Measures of state anxiety, academic achievement, and inhibition were assessed at multiple time points afterward. **Results**: Reductions in SA were seen in high-trait anxious individuals for both conditions. High-trait anxious individuals had decreased SA immediately post-condition, increased SA during the cognitive tests, and decreased SA at the end of the session. As hypothesized, SA of the high-trait anxious group decreased significantly more from baseline to immediately post-exercise than it did for the low-trait anxious group (as the low-trait group had a very slight increase). Low-trait anxious individuals had less profound fluctuations in SA over time than high-trait anxious individuals. Overall, accuracy was fairly high for all tasks except for the N2-back task. RT was slower for tasks that were more difficult (i.e., incongruent and nontarget trials). Findings revealed generally greater accuracy, faster RT, and greater response variability for high-trait

anxious individuals than low-trait anxious individuals on all tasks. However, these responses varied greatly depending on the condition and time of assessment. Exercise did seem to show a trend towards facilitating cognitive performance, but failed to reach significance on many accounts. However, this trend was not seen for N1-back and N2-back RT, because these were slower post-exercise for both groups. Thus, results are very inconclusive. Math SAT scores were higher after exercise than rest, for both groups. A similar trend was seen for Reading SAT scores.

DEDICATION

To Aunt Joan.

She was in my thoughts throughout this entire process.

Before losing her battle with cancer she told me that deciding to pursue my Ph.D. at Illinois was a “no-brainer”.

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CHAPTER 1

INTRODUCTION

Anxiety is a prevalent issue on college campuses, and is associated with, among other things, impaired cognition (National Institute of Mental Health, 2008). Finding a practical behavior that could enhance cognitive performance in the academic setting would be valuable to individuals distressed by anxiety. Acute bouts of exercise have been associated with a small 0.24 SD reduction in state anxiety (SA) levels (Petruzzello, Landers, Hatfield, Kubitz, & Salazar 1991). It is a major goal of this study to extend knowledge of benefits of acute aerobic exercise in the literature. Improvements in cognitive function (for a review see Tomporowski, 2003), and enhanced academic achievement (Hillman et al., 2009) may also result from participation in acute bouts of aerobic exercise. However, others have found that exercise does not elicit reductions in anxiety symptoms (DeMoor, Boomsma, Stubbe, Willemsen, & de Gues, 2008). It is important to gain a better understanding of the relationships between cognition, exercise, and emotion, specifically anxiety. Such knowledge will allow researchers to investigate the use of exercise to both enhance cognitive function and alleviate anxiety.

A large population, 15-35% of students, is affected by high-test anxiety, negatively affecting their academic performance (Driscoll, 2007). Anxiety-reduction has been correlated with academic performance enhancement "(r=0.49, df = 23, $p < .01$)" (Driscoll, 2007, p. 3). Although this correlation is between a specific "test anxiety" and academic performance, it is a moderate correlation and should be further investigated in terms of general state anxiety. This specific clinical population (i.e., test anxious) will not be addressed in the following research study, but it is the hope of the author that the acknowledgement of a possible treatment for individuals living with anxiety may spark future interest in this area.

RATIONALE

Anxiety is the most prevalent mental disorder in the United States, affecting over 18.1% of the population, and is often accompanied by cognitive impairment, with specific deficits in working memory and reasoning [Surgeon General, 2000; National Institute of Mental Health (NIMH), 2008]. This equates to 40 million Americans over 18 years of age (NIMH, 2008). Anxiety is also associated with increased mistakes and lower test scores. “Students with high anxiety perform around 12 percentile points below their low anxiety peers…” (http://www.amtaa.org/index.html). Test anxiety, in particular, distresses 15-35% of students, negatively affecting their academic performance, and possibly preventing them from pursuing higher education or careers (Driscoll, 2007; Ross & Driscoll, 2006). Since this type of research could not be found in previous literature, it was decided that instead of narrowing the study down to the specific test anxious population, a broader sample of high- versus low-trait anxious individuals would be solicited, in order to examine more general state anxiety changes first.

Students deal with daily academic pressures of homework, exams, quizzes, papers, and time management. On top of that, society places an important emphasis on academic achievement for means of superior job placement, scholarship, and acceptance to advanced degree programs. Lower educational attainment and socioeconomic status are associated with higher morbidity and mortality, and are major determinants of health disparities in this country (PAR-10-37, 2006). It is logical that students might want to participate in behaviors that facilitate academic performance; therefore, identification of ways to attenuate test anxiety and enhance cognition is of high importance. Exercise is one potential strategy.

HYPOTHESES

1) An acute bout of aerobic exercise will be associated with reductions in state anxiety levels in both high- and low-trait anxious individuals, with significantly greater reductions seen in the high-trait anxious group.
   a) This reduction will be greater than any reduction seen following the same amount of time spent in a control condition.
   b) State anxiety will begin to return to baseline sometime after the initial decrease (i.e., the effect will be transient).
2) An acute bout of aerobic exercise will be associated with enhanced cognitive performance, as compared to performance after rest, measured by a working memory paradigm and an inhibition paradigm.
   a) Accuracy will increase; reaction time and variability in response times will both decrease for both the flanker and n-back tasks. Such responses will be more pronounced for high-trait anxious individuals than low-trait anxious individuals, as compared to their baseline scores.
3) Changes in state anxiety will be inversely associated with academic performance. Those individuals with high-trait anxiety, who experience reductions in state anxiety levels following an acute bout of exercise, will see significant improvements in cognition, and subsequently perform better on an academic achievement exam.
   a) SAT math and reading scores will be better following the acute bout of exercise than following rest.
4) Better changes in cognitive function [increased accuracy, decreased reaction time (RT), and decreased variability in RT will be associated with better academic achievement scores.

DEFINITIONS

Academic Performance: For the purposes of this study, academic performance is considered to be the numeric score earned on a Scholastic Aptitude Test covering math and reading material deemed important by a national governing body, the College Board (2009).

Aerobic Exercise: Physical activity involving repetitive movement of large muscle groups for prolonged periods of time (Kennedy & Yoke, 2005, p. 123) requiring "processes in which energy (ATP) is supplied when oxygen is utilized" (Howley & Franks, 2003, p. 546).

Anxiety: The Merriam-Webster Dictionary defines this as "an abnormal and overwhelming sense of apprehension and fear often marked by physiological signs (as sweating, tension, and increased pulse), by doubt concerning the reality and nature of the threat and by self-doubt about one's capacity to cope with it" (anxiety, 2010). "Anxiety results when an individual doubts his or her ability to cope with the situation that causes him or her stress" (Hardy et al., 1996 as cited in Humara, 1999, p. 2).

Inhibition: Cognitive inhibition is defined as "the stopping or overriding of a mental process, in whole or in part, with or without intention" (Gorfein, & MacLeod, 2007, p. 5).

State anxiety (SA): SA is compared to trait anxiety as being "more situational in nature and is often associated with arousal of the autonomic nervous system"(Spielberger, 1996 as cited in Humara, 1999, p. 2).

Trait anxiety (TA): Trait anxiety is as "a characteristic of personality that endures over time and is manifest across a variety of situations" (Donner, 2009, p. 1).

Working Memory: Working memory is an aspect of cognition that "enables a human to retrieve stored information" and allows that information to be used and "manipulated" to "influence current behavior" (Goldman-Rakic, 1992).

CHAPTER 2

LITERATURE REVIEW

ACUTE AEROBIC EXERCISE & COGNITION

It is important to make the distinction between fitness effects and the effects of an acute bout of exercise on cognition. A study by Themanson and Hillman (2006) serves as an exemplary difference between these two effects. The purpose of this experiment was to determine effects of caridorespiratory fitness and acute aerobic exercise, separately, on cognitive functioning during the Eriksen flanker task (Eriksen & Eriksen, 1974, as cited in Davranche, Halll, & McMorris, 2009). Researchers measured event-related brain potentials (ERPs) and analyzed components related to action monitoring: error-related negativity (ERN), error-positivity (P_e), and N2. Response speed, accuracy, and response time following errors were also recorded. Kinesiology undergraduate students (*N*=28, 50% female) were split into two groups, high-fit (VO_{2max} above the ACSM 80th percentile) or low-fit (everyone else). Participants came to the lab two different days at the same time, with conditions counterbalanced. One day they rested or read quietly for 30 minutes (min), and the other day they exercised for 30 min on a treadmill, prior to performing five blocks of 144 trials of the incongruent and neutral conditions of the flanker task. Results indicated that high-fit had smaller ERN and larger P_e amplitudes than low-fit; they also exhibited more response slowing following errors compared with correct trials. This was interpreted as an increase in top-down attentional control abilities in higher fit individuals. There was no relationship between the acute bout of exercise and cognitive performance nor any of the neuroelectrical indices related to action monitoring. These findings indicate that fitness and acute bouts of exercise are associated with differential cognitive effects and should be considered separately.

Executive control has been examined as a dependent variable in acute exercise studies (Hillman, Snook, & Jerome, 2003). Executive control is an aspect of cognition "responsible for planning and controlling sequences of action to attain a specified goal" and is "associated with frontal lobe activity" (Colcombe & Kramer, 2003, as cited in Spirduso, 2009). The aim of the present study was to examine what effect acute cardiovascular exercise had on the P3 component of the ERP during an executive control task performed after exercise. A within subjects design was used to study 20, moderately to high fit undergraduate students. Subjects came to the lab twice. In one session, a graded exercise test was performed, and baseline ERP measurements and flanker test scores were obtained. The other session involved 30 min of self-paced, somewhat hard-to-hard treadmill exercise, followed by a rest period to bring HR back down within 10% of baseline. Subjects then completed the incompatible and neutral conditions of the letter/modified version of the Eriksen flanker task. Conditions were counterbalanced. Results indicated significantly increased P3 amplitudes for exercise compared to baseline, and longer P3 latency in the incompatible condition compared to the neutral condition in at baseline only. Increased P3 amplitude may suggest enhanced cognitive recruitment abilities in response to exercise (p. 312). There was no significant difference in P3 latency in the exercise condition between incompatible and neutral task conditions, but shorter P3 latency in the exercise conditions suggests that acute exercise has an effect on cognitive control at this neuroelectrical level (p. 313). This could possibly suggest increased attentional resource allocation and cognitive processing speeds following acute aerobic exercise. This is just another example of the cited impact of acute exercise on cognition.

Some evidence suggests that no improvement in cognitive function is seen following aerobic exercise (Audiffren, Tomporowski, & Zagrodnik, 2009). The purpose of this study was to examine performance on executive control, before, during, and after cycling at 90% of their ventilatory threshold (VT). Adults ages 18-25 (N=19) completed three sessions, with at least two days in between. The first session involved paperwork, practice on the Random Number Generation (RNG) task, and a graded exercise test. The exercise session involved a 5 min warm-up, then doing the RNG task before, during (multiple times), and after 35 min of exercise. The rest session involved sitting on a bike while performing an identical series of RNG tasks. Results found that participants' mental strategy to complete the RNG task changed to a less effortful one, during exercise. No significant effects were present immediately after exercise. This may support the idea that the human body is distracted by the physiological requirements of exercise to such an extent that cognitive ability is compromised during this activity.

There is evidence to suggest that working memory may be affected by aerobic exercise (Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009). Pontifex and colleagues attempted to expand the literature base, by examining both aerobic and resistance effects on an executive control process. The aim of this experiment was to examine what effects aerobic or resistance exercise, separately, have on working memory. Undergraduate students (N=21, 9 females) completed $VO_{2\ max}$ and 1- repetition max (1- RM) tests for seven exercises on day one. Days two, three and four were counterbalanced. Sessions involved completion of the Sternberg working memory task prior to, immediately following, and 30 min after taking part in one of the experimental conditions (aerobic exercise, resistance exercise, seated rest) (Pontifex et al., 2009, p. 930). Results indicated that for absolute reaction time (RT), the aerobic condition was associated with shorter RT latency during both post- assessments, relative to baseline. Further, there was a greater reduction in relative RT for aerobic exercise than resistance exercise. Evidence from this study suggests that there is a larger benefit of acute exercise on cognitive tasks requiring more executive control (p. 932). It appears that aerobic exercise was more facilitative for cognitive performance on a working memory task, when compared to resistance exercise.

Some have placed high importance on the search for a dose-response relationship between exercise and cognitive function. Chang and Etnier (2009) explored the presence of such a relationship in regards to resistance exercise intensity. Men and women with a mean age of 25.95 years (*N*=68) were randomly placed into: control (watched a lifting video), 40% 10-RM, 70% 10-RM, or 100% 10-RM conditions. After completing a day of baseline measures and demographic questionnaires, participants returned to the lab to sit quietly for 15 min prior to doing a pre-test for both the Stroop Color-Word Test (SCWT) and the Paced Auditory Serial Addition Task (PASAT). Next, they completed the resistance exercise session, consisting of two sets of 10 repetitions for six muscle groups. They completed SCWT and PASAT post-condition. Results found a significant linear relationship between exercise intensity and performance on SCT and a significant quadratic trend between intensity and SCWT. Exercise intensity significantly predicted performance on the PASAT for trials two, three, and four. Authors concluded that acute resistance exercise may have positive effects on processing speed and executive functioning. Future research should further explore this relationship in experienced lifters and different age groups. Results may appear promising, but many have documented the relationship as being an inverted-U shape, or possibly of different shapes specific to individual cognitive processes (Chang & Etnier, 2009, p. 641).

A meta-analysis performed by Etnier et al. (1997) analyzed moderator variables and calculated effect sizes for 134 studies involving physical fitness or exercise and cognitive function. Findings suggested that acute exercise has a small, insignificant mean effect (*M*=0.16) on cognition; however, this relationship is moderated by multiple variables within the designs. After further analysis, it was determined that random sampling, studying of intact groups, high experimental rigor, and increasing size of the exercise group all showed greater effect sizes. Further, studies that involved cognitive tests of perception, academic achievement, and motor skills appeared to have significant effect sizes in relation to acute exercise. However, caution must be taken when interpreting this last statement, as many of these effect sizes were derived from only a small total number of studies. By revealing many of the shortcomings of earlier research, this meta-analysis has hopefully prompted the development of better-designed studies of exercise and cognition in this field.

ACUTE AEROBIC EXERCISE & ACADEMIC PERFORMANCE

Academic achievement may be another realm where acute exercise exerts its apparent effects. In a study done by Hillman et al. (2009) children were studied to see if walking for a short period on a treadmill could influence changes in cognitive control or academic achievement. Children around 9.5 years old (*N*=20) were asked to complete the Brief Kaufman Intelligence Test (KBIT) to assess intelligence; RHR and VO_2 max were assessed, and guardians completed demographic questionnaires. All children participated in counterbalanced 20-min conditions of exercise at 60% MHR or rest. Following the condition, children were fitted with electrode caps and each completed a modified flanker task involving a row of five arrows, with incongruent and congruent conditions. The Wide Range Achievement Test 3rd edition (WRAT3) with spelling, reading, and math sections was completed after removal of the cap. Findings indicated only significantly higher scores on reading, following exercise; however, a time issue may have been in play as the testing did not occur until 55-60 min post-exercise. There was also an increase in response accuracy following exercise, in comparison to rest, for incongruent trials.

Neuroelectrical findings indicated increased P3 amplitude following acute exercise in comparison to after rest, with general effects over the central-parietal brain regions.

The following study represents a piece of observational literature that demonstrates the potential indirect effect of exercise on academic achievement. Mahar et al. (2006), observed how implementing a physical activity program during the school day might affect children's on-task behavior in class. Participants included students grades K-4 from 15 classrooms in North Carolina. All participated in a classroom-based Energizers program in which they were led by their teachers in one short, 10-min bout of physical activity during each day of school, for 12 weeks. Observers were trained to observe and quantify on-task behavior of the students 30 min before and after these Energizers. On-task behavior was convincingly manipulated as there was no difference between mean on-task time pre- or post-break during the baseline assessments, but there was a significant 8% mean increase in on-task behavior during the intervention period from pre- to post-Energizers. On-task behavior was improved by acute bouts of exercise. Improvements in on-task behavior could be the embodiment of obscure cognitive changes taking place in response to this exercise, i.e.: attention. It is plausible that even short 10-minute bouts of exercise could enhance academic achievement via this facilitated learning state.

ACUTE AEROBIC EXERCISE & EMOTION (ANXIETY)

Some exercise activities appear to be more susceptible to anxiety issues, which co-exist with cognitive impairment; therefore making them prime candidates for study. Scuba diving has been associated with panic-related fatalities, decreased memory and visual attention, and greater prevalence of abnormal brain images (Slosman et al., 2004). Koltyn and Morgan (1997) examined the influence of wet suit attire on anxiety, confronting the temperature hypothesis, which contributes reductions in anxiety after exercise to body temperature increases. This is one potential mechanism by which exercise may cause changes in mood state. However, they did not find this mechanism to be plausible as mood changes still occurred in the absence of body temperature change. Male divers (*N*=13) performed 20 min of moderate aerobic finning in a pool, in a bathing suit and a wet suit, on separate days. The State Trait Anxiety Inventory (STAI) and Body Awareness Scale were proctored on land, pre- and post-exercise, and underwater, pre- and post-exercise. Core temperature (T_c), subjective breathing and RPE were measured every 5 min. Perceptions of warmth, body awareness, T_c, and SA were significantly higher post-exercise, when a wet suit was worn. A significant decrease in SA was seen 15 min post-exercise in the bathing suit condition. Anxiety decreased, even when body temperature failed to increase, and increased in response to increased body temperature, refuting the temperature hypothesis. Other researchers have investigated the intensity of exercise as the variable source of anxiety reduction.

Raglin and Wilson (1996) examined the effects of varying intensities of cycling exercise on state anxiety levels. Male (*n*=10) and female (*n*=5) participants cycled for 20 min at 40%, 60%, and 70% $VO_{2\ peak}$ intensities, in a non-consecutive day, counterbalanced fashion. The STAI was administered prior to each exercise session, and 5 min, one hour, and two hours following exercise. Results indicated decreases in SA from pre- to post-exercise for all time points following 40% and 60% $VO_{2\ peak}$; state anxiety only decreased significantly from baseline one and two hours following exercise at 70% $VO_{2\ peak}$. These findings are very important for research involving acute aerobic exercise and anxiety, because the effects appear to endure for at least two hours.

Motl, O'Connor, and Dishman (2003) examined the effects of varying intensities of cycling exercise on SA levels in high- and low- trait anxious men, as well as the Hoffman (H)

Reflex reactions. This was done, because some have suggested that the H-Reflex is a physiological marker related to anxiety. Participants (*N*=40, half high trait-anxious) completed a health questionnaire, physical activity recall, and an exercise test to determine $VO_{2\ peak}$ on day one. SA was then assessed before and after electrical stimulation of soleus muscle and recording of the H-Reflex. Participants completed three counterbalanced sessions, separated by a couple days, which involved 20 min of quiet rest, and cycling at both 40% and 70% $VO_{2\ peak}$. SA and H-reflex scores were assessed before and after each condition. There were significant reductions in the H-Reflex following exercise sessions, and in SA, with larger reductions for high-trait anxious individuals, from pre- to post- for both exercise conditions and rest. The changes that occurred for anxiety and the H-Reflex did not appear to be related to each other. Results from this study implicate that the H-Reflex may not be an acceptable physiological indicator of self-reported SA changes as was once thought.

Temporal arrangement of a study is critical, and separates naïve designs from rigorous ones. Knowing when to perform psychological assessments in relation to exercise depends on what exactly is being measured, and how long the exercise effects seem to endure. One study demonstrates the lasting effects of changes in anxiety levels in response to an acute bout of exercise (Bahrke & Morgan, 1978). The aim of this study was to compare the anxiolytic effects of meditation to those of an acute bout of exercise. Active male participants (*N*=75) completed the state and trait versions of the STAI, and then were randomly assigned to a group: exercise, meditation, or control. The exercise group ran on a treadmill for 20 min at 70% MHR, the meditation group followed a tape recording relaxation protocol while seated, and the control group sat quietly. The STAI-state version was completed immediately after, and 10 min following the condition. Findings indicated significant decreases in state anxiety for all groups, regardless of trait anxiety levels, but those who had higher SA levels to begin with were more responsive to change. This demonstrates that exercise was as effective in reducing SA as the other two conditions, and that SA continued to decrease 30 min post-exercise.

In a meta-analysis of affect regulation strategies done by Augustine and Hemenover (2009), exercise is categorized an active/constructive distraction strategy, which appears to be effective in moderate, but not high, intensity situations. It also appears to work better in non-competitive sports and tends to give more energy to those people who do not exercise on a regular basis (Augustine & Hemenover, 2009, p. 1187). Exercise was further categorized as a behavioral avoidance strategy, as opposed to a cognitive avoidance strategy. Exercise had a moderate effect size of d=0.47, which ranks it in the top five affect regulation strategies in this meta-analysis (Augustine & Hemenover, 2009, p. 1202).

COGNTION & EMOTION (ANXIETY)

There appears to be a critical link between emotion and cognition that should not be dismissed as a mere separation between two distinct areas of research (Miller, 1995). This connection has been explored be a few researchers in attempt to close this gap and explain more thoroughly what it is that is going on in the human body. Whether cognitive impairment is a separate trait of the individual, a result of an emotional disorder, or the root of mental distress is unknown; however, research in this realm can help individuals who face both of these issues.

Moriya and Tanno (2009) investigated cognitive impairments in individuals experiencing anxiety and depression. They examined cognitive tasks void of emotion-provoking stimuli. Previously, when emotional tasks have been used, attention was impaired in these populations. The aim of the study was to determine whether or not impaired attention occurred similarly in non-emotional processing, and which parts of the attentional system are specifically affected.

Participants included 43 undergraduates (20 women); all completed self-reports of the STAI. Participants completed the attention network test (ANT) designed by Fan et al. 2002 (as cited in Moriya & Tanno, 2009). This test combines a flanking and a cue task (central, spatial, or no cue) and measures three parts of the attentional system: alerting, orienting, and executive attention (Fan, McCandliss, Sommer, Raz, & Posner, 2002 as cited in Moriya & Tanno, 2009). Subjects had a fixation cross to look at on the computer screen at which the target stimuli appeared. A total of 144 trials were completed in which they were to press the left or right button in response to a cue or target. RT was shorter and error rates were lower in congruent conditions than incongruent, as expected. RT was shortest for spatial cue trials, and longest for no-cue trials. Error rate in the spatial cue trials was lower than the other two conditions. Scores on the STAI were negatively correlated with orienting attention, representing impairment in this network in individuals with more negative affect. Further, this impairment was seen in non-emotional cognitive processing. Alerting and executive attentions appeared to be unaffected. Future research should explore the orienting attentional network to pinpoint specific deficits.

Dennis and Chen (2008) presented participants with threat-related and non-threat-related emotional faces during the ANT task. Their purpose was to measure N2 amplitudes of these individuals as they performed congruent and incongruent trials cued by these facial images. Subject varied in levels of trait anxiety, because the investigators wanted to see what kind of N2 responses would result during ANT task performance in higher trait anxious individuals, following such pictures. Adults (N=36) completed the STAI, and were split into high- and low-trait anxious groups. While wearing EEG electrodes, participants completed the ANT task as described above. Results indicated that N2 amplitudes were normally larger following incongruent trials, compared to congruent. However, N2 amplitudes at frontal sites were significantly increased during these trials, for high-trait anxious individuals, following threat-related faces. When N2 amplitude increased, it appeared that the alerting network of the attentional system was compromised. Authors declared themselves pioneers in research showing an ERP component to be influenced by the emotional reaction of an individual.

A recent review of cognitive impairments in young adults with depression and anxiety was done in effort to highlight the co-existence of these potentially detrimental issues (Castaneda, Tuulio-Henriksson, Marttunen, Suvisaari, & Lönnqvist, 2008). In all, 36 studies involving an array of different affective disorders were reviewed. As the focus of this paper is on anxiety-related affective states, it is most appropriate to only summarize findings from anxiety and cognition studies. In regards to cognition, obsessive-compulsive disorder (OCD) has been studied the most, to date, and virtually no studies have been done on specific phobias or generalized anxiety disorder. Researchers have associated impaired executive function, long- and short-term visual memory, attention, and processing speed with OCD (Castaneda et al., 2008, p. 23). Impaired divided attention, short- and long-term verbal memory, short-term verbal learning, visual memory, and visual learning have all been cited in adults with panic disorder. Social phobia has been associated with debilitated executive function, attention, visuo-spatial ability, and short-term verbal memory and learning (Castaneda et al., 2008, p. 22). Post-traumatic stress disorder has been linked to impaired attention, short- and long-term visual memory, and executive functioning (Castaneda et al., 2008, p. 23). One must keep in mind that medications and co-morbid diseases also play a role in which of the impairments are seen in specific studies, and these things must be accounted for in order to properly interpret the results of each study.

SUMMARY

Numerous research studies have investigated the relationship between acute bouts of exercise and cognition (for a review see Tomporowski, 2003). Combined aerobic and strength methods or yoga may also improve cognition; however, these studies are still new and do not have enough documented success in the literature (Kramer, Erickson, & Colcombe, 2006; Kyizom, Singh, Singh, Tandon, & Kumar, 2010). Therefore, aerobic exercise seemed to be the appropriate choice for the present study. In choosing which cognitive tasks to assess performance by, it was necessary to consider tasks that measured aspects of cognition also consistent with taking academic exams. The most commonly studied executive control process in the acute exercise literature is inhibition (Hillman, 2009). Since trait anxiety, specifically, has not been studied extensively in regards to its relationship with cognitive performance, studying inhibition as one of the dependent variables in this study should provide a solid measure to compare with other studies of acute exercise. Making working memory one of the other dependent variables was done to include another aspect of cognition closely related to academic performance.

The relationship between acute exercise and emotion has also been examined, and it is evident that there is some relationship between exercise and anxiety. Some have attempted to explain the association between cognition and emotion and others have looked at the relationship between fitness and academic achievement; however, a crucial piece of the puzzle appears to be missing. After review of the literature, it appears that the next step would be to investigate the potential role of aerobic exercise in regulating anxiety, cognition, and academic performance. Thus, it is the intention of this study to investigate effects of an acute bout of aerobic exercise on dependent variables of SA, academic-related cognition, and academic performance in individuals with high- and low-trait anxiety. It is necessary to approach this problem using current theoretical frameworks that already have strong foundation in this area to develop a new hypothetical model. Multi-dimensional Anxiety Theory (Post, 2003) and the Catastrophe Model (Fazey & Hardy, 1988, as cited in Humara, 1999) will be used to formulate this new model.

THEORETICAL FOUNDATIONS

Multi-dimensional Anxiety Theory

This theory splits anxiety into cognitive and somatic portions. The somatic portion relates to physiological symptoms of anxiety, noticed by the individual (Post, 2003). This can also be thought of as arousal, which draws ideas from the Inverted-U Hypothesis, which will be described in the next section. The cognitive anxiety portion relates to expected performance, inability to concentrate, and disrupted attention (Post, 2003). The more cognitive anxiety one has, the lower their subsequent performance will be (Post, 2003).

Catastrophe Model of Anxiety & Performance

The Catastrophe Model of Anxiety & Performance is originally from the sport psychology literature and has combined ideas from the Multi-dimensional Anxiety Theory, and the Inverted-U Hypothesis (Humara, 1999). The Inverted-U Hypothesis suggests that people cannot perform to their best abilities at extreme low or high arousal levels. However, for each individual there is some optimal arousal level that will elicit optimal performance (Williams, Landers, & Boutcher, 1993, as cited in Pellegrini, Hicks, & Lopez, 2008). The Catastrophe Model suggests that maybe there is a different type of relationship for those who have high-trait anxiety and subsequently deal with high levels of state anxiety all of the time (Humara, 1999).

The original article by Fazey and Hardy (1988) was inaccessible; however, the Catastrophe Model of Anxiety and Performance could potentially explain the discrepancies in athletic performance between high- and low-trait anxious individuals, through means of state anxiety levels (Humara, 1999). When low-trait anxious individuals have increased SA, it appears to positive influence their athletic performance, whereas when high-trait anxious individuals experience increased state anxiety, the result is diminished athletic performance (Humara, 1999).

It is posited that when cognitive anxiety is low, physiological changes in arousal do not tend to affect the individuals' performance as much, but when cognitive anxiety is high, low physiological arousal levels exert an effect (Hardy et al., 1996 as cited in Humara, 1999). Although this model is meant for athletic performance, it could relate to a cognitive testing situation. It is thus conjectured by this author that the catastrophe model of anxiety and performance can be applied to academic performance, as well. Cognitive behavioral interventions have been used previously to try and alleviate both cognitive and somatic anxiety states (Humara, 1999); this study was designed to test this same paradigm using exercise as an intervention.

Exercise Cognition Model

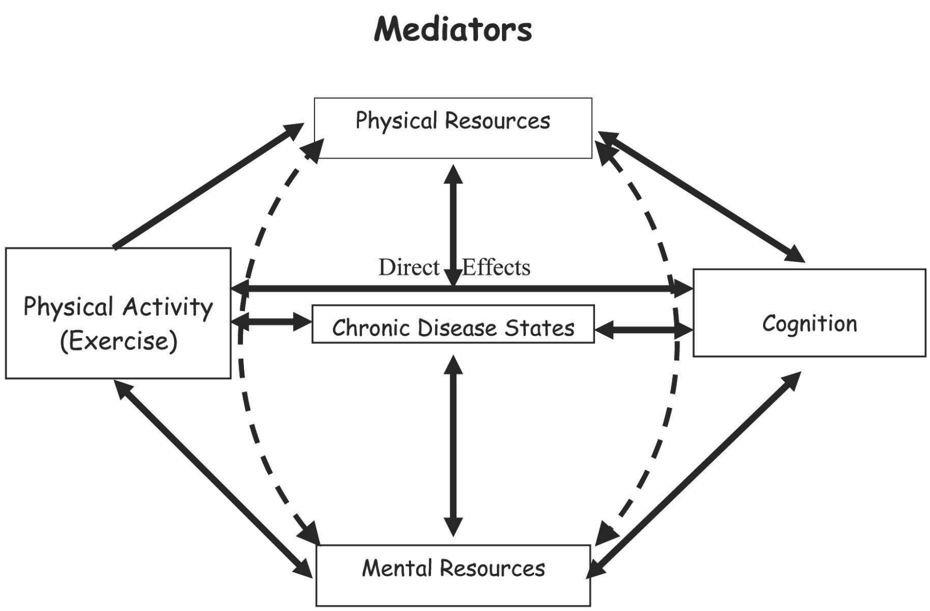

Figure 1: Exercise-cognition Model
Note: Figure 1 comes from (Spirduso, 2009, p. 196) which cites it as "Modified with permission" from: Spirduso, Poon, & Chodzko-Zajko, 2008, p. 4.

This model postulates that exercise has indirect effects on cognition as well as a direct effect. Exercise may enhance cognition indirectly through its preventative effects on chronic disease, and maintenance of the body's physical and mental resources (Spirduso, 2009). Exercise affects chronic disease status, which has its own influence on cognition. Spirduso notes that chronic respiratory disorders, such as Chronic Obstructive Pulmonary Disease (COPD), can severely impact cognition by creating a brain state lacking in oxygen (2009, p. 197). Anxiety disorders have been associated with greater risks for chronic diseases such as heart disease, gastrointestinal disorders, and chronic respiratory disorders, like COPD ("Anxiety linked…", 2008). Anxiety could find a place in this model as a cause for chronic disease. In this model, exercise also influences physical resources by means of promoting healthy blood flow and proper sleep, and reducing chronic pain and mental fatigue. Mental resources are influenced by exercise by means of improved neurotransmission and blood circulation in the brain.

Although this model represents the chronic relationship that habitual exercise has with these variables, it does provide some insight as to how acute exercise might influence cognition. By directly influencing state anxiety in the individual, the body's mental and physical resources may be enhanced, ultimately leading to improvements in cognitive function and performance. The authors state that mental resources mediate depression and stress levels, which may also contribute to the state of an individual's cognitive functioning (Spirduso, 2009, p. 197). Depressive symptoms can be improved acutely by exercise participation, just as anxiety symptoms can be. As anxiety is a mental disorder similar to depression, it is plausible that it could fit into this model in the same way. However, the current study and newly created hypothetical model below, attempt to specify emotion (anxiety level) as a moderator of the direct relationships between exercise and cognition and exercise and academic performance.

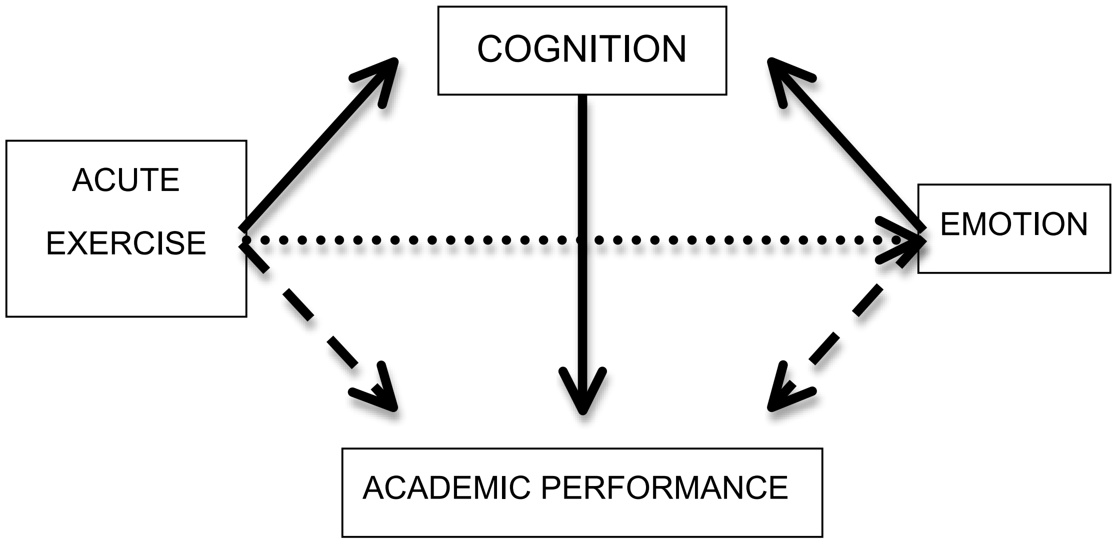

Figure 2: Hypothetical Model

Figure 2 demonstrates the hypothetical model for how exercise may directly, and indirectly, affect academic performance. The indirect pathway would be through human emotional states, namely anxiety. In this theory the solid arrows depict relationships that have previously been investigated and were discussed in the literature review above. The dotted arrow depicts a pathway through a moderator (anxiety). This cumulative hypothetical model brings together present theoretical frameworks and integrates indirect (dashed lines) relationships that need to be further explored. Exercise appears to be indirectly related to academic performance through cognitive enhancement (Hillman et al., 2009; Mahar et al., 2006). However, there may be an indirect effect of exercise on academic achievement through emotional pathways (mainly by alleviating state anxiety levels, specifically in those with high-trait anxiety). This relationship will be explored in the proposed experimental study. Hypothetical model conjectured by Tina Mattila.

CHAPTER 3

METHODS

The objectives of this research study were to collect data on state anxiety changes, cognitive abilities, and academic achievement following a 30-minute bout of aerobic exercise on a treadmill. Participation required three separate laboratory visits. Approximate total time commitment for the participants in this study was between four and six hours. All meetings were scheduled at the convenience of the participants, not to interefere with class time. Participants completed a baseline assessment, an exercise condition, and a control condition. The exercise and control conditions were completed in random order for all subjects, stratified by group (high-trait anxious or low-trait anxious). All research activities took place in laboratories within Louise Freer Hall on the University of Illinois at Urbana-Champaign campus. The Exercise Psychophysiology Laboratory and the Freer Teaching Laboratory were used for the test conditions and the graded exercise test, respectively. This study was conducted from January 2011 to May 2011. All subjects were given the option of receiving results from their participation in this study.

PURPOSE/RESEARCH QUESTIONS

The purpose of this experiment was to investigate the effects of 30 minutes of aerobic exercise on state anxiety (SA), cognition, and academic performance in college-aged individuals. Two groups of individuals were studied: those with high-trait anxiety and those with low-trait anxiety. The proposed study had four specific aims: (1) Determine if aerobic exercise can reduce SA in college-aged individuals, (2) Determine if SA reductions and/or aerobic exercise are associated with enhanced cognitive functioning, specifically inhibition and working memory, (3) Determine if SA reduction and/or aerobic exercise are associated with enhanced academic performance, and (4) Determine if post-condition changes in cognitive function are associated with similar changes in academic performance. Within these aims, the specific focus was to investigate the individual difference of trait anxiety. The overall goals were to create a better understanding of the relationship between cognition, exercise, and anxiety, and ultimately, to determine whether or not acute aerobic exercise can help alleviate anxiety and improve performance in academic testing situations.

PARTICIPANTS

Participant Selection

Sixty college-aged individuals (18-30 years, both male and female) from the Champaign-Urbana, Illinois area were anticipated to be included in this study. Information about the study was distributed about the Champaign-Urbana area and the University of Illinois campus. This was done by means of flyers (Appendix B), mass e-mails (Appendix C), and verbal communications with academic advisors in various campus departments and the Psychological Services Center in Champaign. The Psychological Services Center is located at 505 E. Green Street, 3rd floor, in Champaign, Illinois. They offer numerous psychological services to people in the community, provide outreach programs, serve as a clinical psychology program training site, and perform related research. E-mails and flyers were given to the Center to hang and pass out to potential participants. These messages explained the opportunity to participate in the study and provided information to contact the Exercise Psychophysiology Laboratory, at which time further determination of eligibility for testing could be determined. Scores from the Trait Anxiety Inventory (TAI; Spielberger, 1983) were used to determine eligibility for the study.

Those with TAI scores of 40 or above were considered high trait-anxious, and those with scores of 26(males)/27(females) or below were considered as low trait-anxious. The cut-off for the high-trait anxious groups was determined by using the Spielberger manual (1983) to choose the scores that fell 0.51 SD above the average for college-aged females (36.15 +/- 9.53) and 0.50 SD above the average for college-aged males (35.55 +/- 9.76). The cut-offs for the low-trait anxious groups were determined by choosing the scores that fell 1SD above and below the average for college-aged females and males. Participants meeting eligibility criteria were accepted continuously until numbers were fulfilled. The local Institutional Review Board approved the study (IRB#11156), and informed consent (Appendix A) was obtained from all potential participants.

As this study required working with human participants, attrition was anticipated. The following plan was developed on the assumption that individuals would inevitably drop out of the study: over-recruit individuals from each targeted enrollment stratification, turn no individuals meeting the study criteria away until numbers are fulfilled, contact participants by e-mail if they do not return for an unknown reason, and follow-up email contact by calling participants if they do not respond.

Participants were scheduled for testing sessions via e-mail. E-mails contained a list of all available 2-hour timeslots (although testing sessions did not always take this full amount of time). Participants were asked to choose which time slot(s) worked best for them to come into the lab. Sessions were not to interfere with participants' class schedules. E-mail reminders were sent either the night before, or early in the morning on the day of testing. If an individual was 15 minutes late or did not show up to their appointment, a member of the lab team called them at the phone number they had provided for contact purposes. If the individual answered the call, and was able to still come into the lab (time permitting), they were still tested that day. If the individual did not answer, a phone message was left and an e-mail was sent to schedule a make-up appointment. Such a series of events was only necessary for a handful of circumstances.

POTENTIAL RISKS AND BENEFITS

Risks

This study required that the participants engage in moderate-to-vigorous physical activity during the incremental exercise test to volitional exhaustion and the two subsequent exercise trials. Acute consequences associated with exercise are possible muscle soreness and fatigue. These symptoms usually dissipate within a few days (approximately 2-4 days). As with any kind of physical activity, there was a small possibility of heart attack and sudden death. Risks were minimized by the exclusion criteria being utilized (i.e., age limit of 30, any contraindications to exercise). Participants were screened for good health and potential for minimal risk prior to study participation via the Physical Activity Readiness-Questionnaire (PAR-Q) (Chisholm, Collis, Kulak, Davenport, Gruber, & Stewart, 1978) and Health and PA History form (modified from Health & PA History Form, Department of Kinesiology & Community Health, University of Illinois at Urbana-Champaign, 2010). The computerized testing sections were brief, and should not have caused any additional harm to participants' eyes than is regularly incurred during their own daily computer and television time. Laboratory staff was trained to watch for any signs that an individual may have been in danger of fainting and spoke with participants throughout study duration to confirm that they were feeling healthy and capable of completing the study.

Benefits

Participants benefited from learning their fitness level from the graded exercise test. Additionally, participants were provided with the opportunity to ask for a summary of what was found from the study. A handful of participants were eager to learn of the findings. The greatest benefit to science was the help that their participation provided in gaining a better understanding of how exercise may be associated with anxiety reduction and enhanced cognition. Participants in this study were part of a research project that could potentially provide insight to enhance cognitive functioning, especially in those individuals whose cognition may be compromised daily by their high trait anxiety levels. The benefits of exercise are well known and well documented. The findings of this study were hoped to provide evidence to support the potential benefit of using exercise to control anxiety and/or facilitate processing of cognitive information. Because participants were healthy individuals, and potential risks associated with the methods to be employed were minimal relative to the information to be gained, this research study seemed to outweigh the risks. Ultimately, this could have important implications for the prescription of exercise for individuals suffering from high anxiety levels and/or test anxiety.

DATA COLLECTION

The following will describe where, with what equipment, and how data from this experiment were collected. All data were collected and recorded using a subject ID not traceable to the subject's identity by the investigator involved.

Exercise Psychophysiology Laboratory (room 357 Freer Hall):

The ExPPL is primarily used for research, but also provides a venue for hands-on instruction. It is a 550 square foot laboratory located in Room 357 of Louise Freer Hall on the UIUC campus, a building dedicated to the Department of Kinesiology and Community Health. The ExPPL has a large conference space, surrounded by three smaller rooms equipped for distinct functions. The first room has walls covered with sound proofing foam, for noise reduction. The second room serves as a computer lab with three computers, printer, a shelving unit, and sink. The computers are loaded with SPSS 12.0 software for data organization, collection of self-report data, and statistical analysis. The third room is used for exercise interventions, containing a Quinton ClubTrack Treadmill and a computer. This computer is used for data storage and cognitive testing, as it has been loaded with STIM2 software. The STIM2 software contains the flanker task to be used to test participants' inhibition, and will also run an external file of the N-back working memory task that was shared by a cooperating lab in the department. All ExPPL computers are inter-connected through the Department of Kinesiology & Community Health Local Area Network (LAN), and thus have all data automatically backed up onto the secure network server monitored by the department staff and the faculty uploading the information, to ensure that data is protected. Files can always be recovered from the last time they were saved to the server. The computers are also connected to the Internet via fast Ethernet links. The lab has also recently acquired a metabolic system to be used for functional and instructional purposes. Desks, a bulletin board, and a wipe board are available to graduate and undergraduate students in the laboratory. Multiple outlets are located around the room for laptop computer plug-ins. The conference room has plenty of artificial and natural lighting, with two large single-paned, functional windows on the west wall. Designated members of the ExPPL, including the Primary Investigator, have 24-hour access to the facility. The laboratory is also stocked with Polar Heart Rate monitors and watches for use in tracking participant heart rate during exercise participation. Locked filing cabinets are used for written questionnaire data, coded only by participant ID, and not by name, ensuring that participants are not identifiable, nor is their personal information.

Freer Teaching Laboratory (room 19 Freer Hall):

Room 19 of Louise Freer Hall is an 850 square foot facility consisting of the Undergraduate Teaching Laboratory and Human Performance Lab. It is equipped with one

Ametek metabolic cart, two new Parvomedics metabolic cart systems (Parvomedics TrueOne 2400 Sandy, UT, USA), two Tissot tanks, a Quinton elevated motorized treadmill, a newer standard treadmill, EKG equipment, and two Monarch cycle ergometers. The protocol used for the incremental exercise test was programmed into the Parvomedics system.

Other Equipment

The treadmills (Quinton) used for the incremental exercise test were located in room 19 of Freer Hall. Standard plastic mouthpieces and nose clips were used in order to collect accurate values for the incremental exercise test. A disinfectant (Cidex©) was used along with soap and water to maintain proper sanitation of reusable equipment. Oxygen and carbon dioxide (inspired and expired) data from the incremental exercise test was collected and measured by a metabolic cart (Ametek) and corresponding computer software (Parvomedics metabolic cart system). The treadmill (Quinton ClubTrack) used for conditional testing had adjustable speed and grade capacity and was in the Exercise Psychophysiology Laboratory in room 357 Freer Hall. Heart rates were monitored by the Polar Electro© T31 transmitter and recorded on a wrist electrocardiogram (Polar Electro). Cognitive assessments of inhibition and working memory were performed using computer software (Stim2); results were exported into an Excel data file. Paper/pencil tests were administered for all other measures.

MEASURES

***PAR-Q (Appendix D)*:**

The Physical Activity Readiness Questionnaire (PAR-Q; Chisholm et al., 1978) was used to determine if it was physically safe for a participant to partake in this study, as it involved moderate aerobic exercise. The PAR-Q is made up of seven yes or no questions and was completed prior to any involvement in the study. If the answer to any of the seven questions was "yes" the participant was considered to be at too high of a risk for their own health to be included in the study, and were excluded.

***Health & PA History Inventory (Appendix E)*:**

This questionnaire (modified from Health & PA History Form, Department of Kinesiology & Community Health, University of Illinois at Urbana-Champaign, 2010) asks basic demographic and personal information questions (sex, age, year in school, height, weight, physical activity, and academic information.). SAT/ACT score and college cumulative GPA were also documented. Such information will be available for use as covariate items in analyses.

Incremental Exercise Test to Volitional Exhaustion

Aerobic Capacity ($VO_{2\ max}$) fitness will be determined by means of maximal aerobic capacity measured during the incremental exercise test to volitional exhaustion on the treadmill. After data collection $VO_{2\ peak}$ values were more accurate, and subsequently used for VT calculations. Computer software connected to the metabolic cart was used to determine the point at which the amount of oxygen inhaled no longer increased even when the participant continued to exercise at a higher grade or speed. The specific equipment used was described above, and the process of data collection is described more thoroughly in the “Procedures” section.

Ventilatory Threshold (VT):

Historically, percentage of $VO_{2\ max}$ has been used to achieve relative exercise intensities across subjects; however, 65% $VO_{2\ max}$ for one person could denote an entirely different absolute metabolic level for another. It appears VT may be a more efficient marker for obtaining the same relative aerobic exercise intensity across subjects, since VT is near the points at which metabolic crossover occurs and lactate threshold is reached (Ekkekakis, Hall, & Petruzzello, 2008). The VT was determined using the protocol from Ekkekakis, Hall, & Petruzzello (2008, p. 140) and software created for determining the intersection of expired VO and VCO. Participants exercising aerobically should be below this threshold. During instances in which this protocol did not work, the VT was determined automatically using the Parvomedics software. The computer printout provided a time at which VT was reached, VO_2 in L/min, and a heart rate (HR). With this information in hand, laboratory staff went through the breath-by-breath metabolic text report to find the noted time and VO_2. Next, the corresponding VO_2 mL/kg/min was determined. The VO_2 mL/kg/min value 20% below the one corresponding with VT was circled and the HR at this time point was used as the target HR for the exercise condition. If there were any discrepancies, values were charted to get an accurate visual extrapolation of the data.

***Feeling Scale (FS) (Appendix F)*:**

This is a scale developed by Hardy and Rejeski (1989) that measures how someone is feeling from +5 (very good) to -5 (very bad) (Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007). The FS was used during the incremental exercise test and both conditions to determine how an individual was feeling and was used during conditions, to serve as a comparison between how they were feeling during the condition versus during aerobic exercise portion of the incremental exercise test.

***Felt Arousal Scale (FAS) (Appendix G)*:**

This is a scale developed by Svebak and Murgatroyd in 1985 (Backhouse et al., 2007). This scale ranges from 1 to 6, and assesses from low to high arousal levels in participants. This was used during the incremental exercise test and during both conditions to check participant arousal levels. “Both the FS and FAS have been used in several previous exercise studies conducted by various laboratories around the world and have exhibited satisfactory convergent and discriminant validity” (Backhouse et al., 2007, p. 507).

Preference for and Tolerance of Exercise Intensity Questionnaire (PRETIE-Q) (Appendix H):

The PRETIE-Q is a 16-item Likert scale questionnaire that takes inventory of an individual's exercise habits by having them select whether they agree or disagree, on a continuum, with a statement about their exercise habits (Ekkekakis, Hall, & Petruzzello, 2005). Half of the questionnaires represent the idea of exercise preference, while the other half represents exercise tolerance.

***Rating of Perceived Exertion (RPE) Scale (Appendix I)*:**

This scale ranges from 6 to 20, with 6 being low exertion, and 20 being exhaustion (Borg, 1998). Participants pointed to numbers on this continuum during the incremental exercise test and each condition, in order to check their exertion levels in relation to heart rate measures.

State Anxiety Inventory (SAI) (Appendix J)

State anxiety (SA) is compared to trait anxiety as being "more situational in nature and is often associated with arousal of the autonomic nervous system" (Spielberger,1996, as cited in Humara, 1999, p. 2). SA was assessed using the 10-item State Anxiety Inventory (SAI). This survey contains 10 statements about how the individual is feeling at that moment in time. Participants chose the response that best fit how they felt at the time, using a 4-point Likert scale ranging from "Not at all" to "Very much so". The STAI has been questioned as a valid outcome measure, so SA results should be interpreted with caution. The scale does not appear capable of discriminating increased positive activation from anxiety, nor decreased positive activation from decreased anxiety, resulting in indefinite outcome scores (Ekkekakis, Hall, & Petruzzello, 1999). Yet, this measure is used often in the literature, and produces consistent results across similar studies. Participants completed the 10-item SAI (r=0.95 with full 20-item inventory) at four time points: immediately prior to condition, 0, 35, and 70 minutes post-condition.

***Trait Anxiety Inventory (TAI) (Appendix K)*:**

Individual trait anxiety levels were determined using the TAI (Spielberger, 1983). The TAI consists of 20 items that assess how that person feels in general, on average, or all of the time, and is taken in paper pencil format. Participants choose the response that best reflects how they feel. Based on norms for college-aged women and men, low-trait anxiety is reflected by scores <28 for females and <27 for males; high-trait anxiety is reflected by TAI scores >40 for females and >40 for males (Spielberger, 1983).

***Modified Flanker Task (Appendix L)*:**

This task involves inhibition of irrelevant stimuli surrounding the relevant stimulus. Specifically, the Flanker task targets selective response inhibition, a subset of executive control. For this experiment, the task involved a series of images with five congruent or four congruent and one incongruent stimuli presented on the screen. In general, such stimuli can be in the form of shapes, arrows, or letters. Arrows were used as stimuli for this study, and the participant was asked to choose the direction in which the middle arrow (either congruent or incongruent to the two arrows on each side of it) is pointing by pushing an assigned key on the computer (Eriksen & Eriksen, 1974, as cited in Davranche, Halll, & McMorris, 2009). Participants looked at a series of five symbols in a horizontal row (e.g., >>>>>, >><>>, <<<<<, <<><<), and pressed a specific key on the keyboard in relation to the orientation of the center symbol. The center symbol was similar (i.e., congruent) or dissimilar (i.e., incongruent) to the four (2 per side) symbols flanking it on both the right and left sides. Participants performed two blocks of 100 trials, with each trial lasting 80-100 milliseconds. The inter-trial interval was between 1000-1200 milliseconds. Reaction time and correctness of answers were assessed. On visit 1, one practice block of 64 was performed as an orientation to the task.

***N-back Task (Appendix M)*:**

In this task, the participant was asked to both recognize a non-verbal stimulus, and to determine whether or not the current stimulus was the same or different from a prior stimulus, N items back (Gevins & Cutillo, 1993, as cited in Owen, McMillan, Laird, & Bullmore, 2005). The individual was prompted visually as to when they should make this decision (as soon as they saw the shape). This task was meant to test working memory through behavioral performance. Working memory is an aspect of cognition that "enables a human to retrieve stored information" and allows that information to be used and "manipulated" to "influence current behavior" (Goldman-Rakic, 1992). This task involves three consecutive phases called the N0-back, the N1-back, and the N2-back. Each phase requires participants to discriminate between 5 different stimuli. The stimuli are shapes represented by a specific color (blue triangles, red circles, orange crosses, purple stars, and green squares). Each shape is presented, one at a time, in the center of a computer screen for duration of 2900ms with a 100ms inter-stimulus interval (ISI) and 80 trials of equally probable presentation of each stimulus (16 trials for each shape). Stimuli, ISI, total trials, and probability are the same in all three phases with the exception of shape presentation order. Participants were asked to compare the shape they previously saw, 0, 1, or 2 shapes back in the series, to that which appeared on the screen. The first phase, or N0-back, requires participants to only pay attention to the presentation of the cross shape. The participant makes a right hand response if the current stimulus shape is a cross, or makes a left hand response if the current stimulus shape is not a cross. The second phase, or N1-back, follows immediately after the N0-back and requires participants to remember the shape presented immediately before the current shape. The participant makes a right hand response if the current stimulus shape is the same as the previous shape, or makes a left hand response if the current stimulus shape is not the same as the previous shape. The N2-back phase follows immediately after the N1-back. This phase requires the participant to remember the shape presented two shapes back and make a right hand response if the current stimuli shape is the same as the second stimuli previous (i.e., Target stimulus), and a left hand response if the current stimuli shape is not the same shape as the second stimuli previous (i.e., Nontarget stimulus). Reaction time and correctness of answers were assessed. The total time to complete all three phases is about 12 minutes. [Description adopted from protocol belonging to the Neurocognitive Kinesiology Laboratory at the University of Illinois]

***Practice Reading Scholastic Aptitude Test (SAT) & Practice Math SAT (Appendices N, O)*:**

The SAT tests involved shortened forms of critical reading (12 questions) and math (10 questions) sections from January and May, year 2000 practice exams (Claman, 2003). These tests were used to assess academic achievement. Scores from these standardized tests have been used nationally and accepted as valid predictors of scholastic aptitude (College Board, 2009). Scores on the reading exam could range from 0 to 12, and scores on the math exam could range from 0 to 10. Scores were calculated using the formula provided in the testing book (Claman, 2003). SAT tests were hand-scored by two individuals, one undergraduate laboratory student and one graduate student. The number of incorrect answers was divided by four; this total was then subtracted from the number of correct answers. No test material was given to participants to take out of the laboratory, and test copies were only used within the bounds of this research study.

RESEARCH DESIGN

The study was partially cross-sectional in nature, as it investigated the individual differences of trait anxiety and aerobic fitness levels. The rest of the study followed a within-subjects experimental design, involving the performance of an acute bout of aerobic exercise (main independent variable) and a sitting at rest condition (control). The main dependent variables were state anxiety levels, inhibition, working memory, and academic achievement scores.

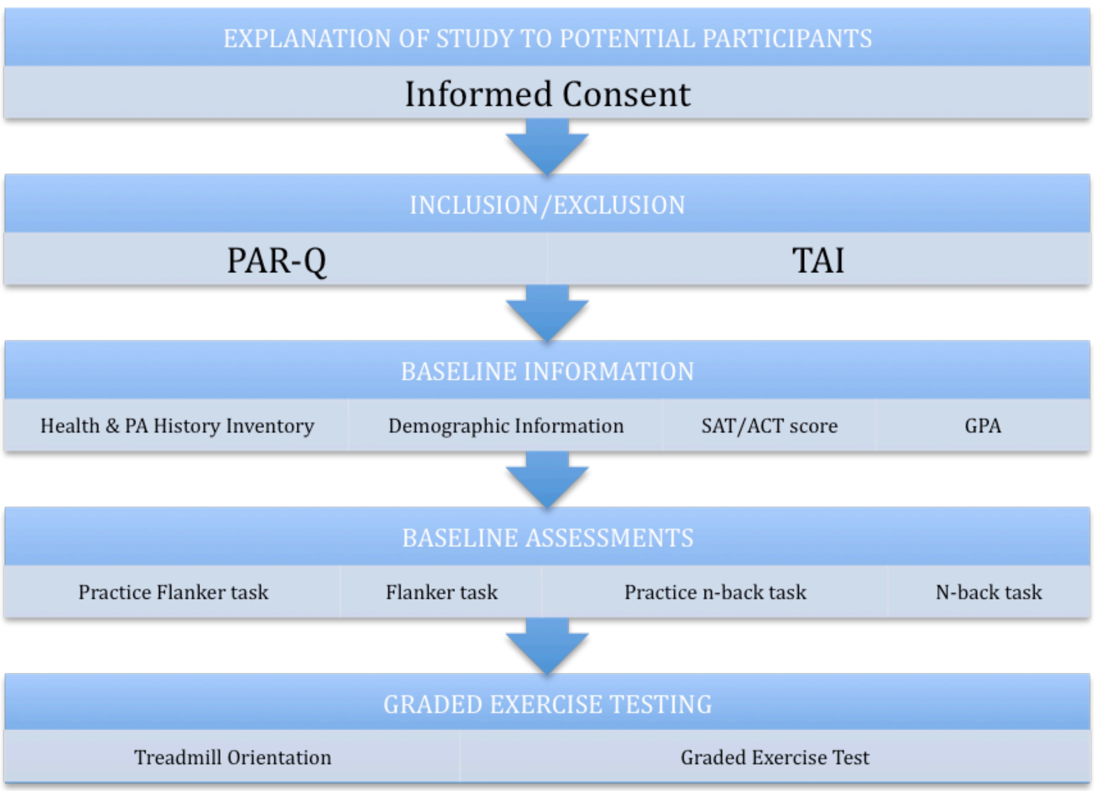

Figure 3: Visit 1: Baseline Assessments & Orientation

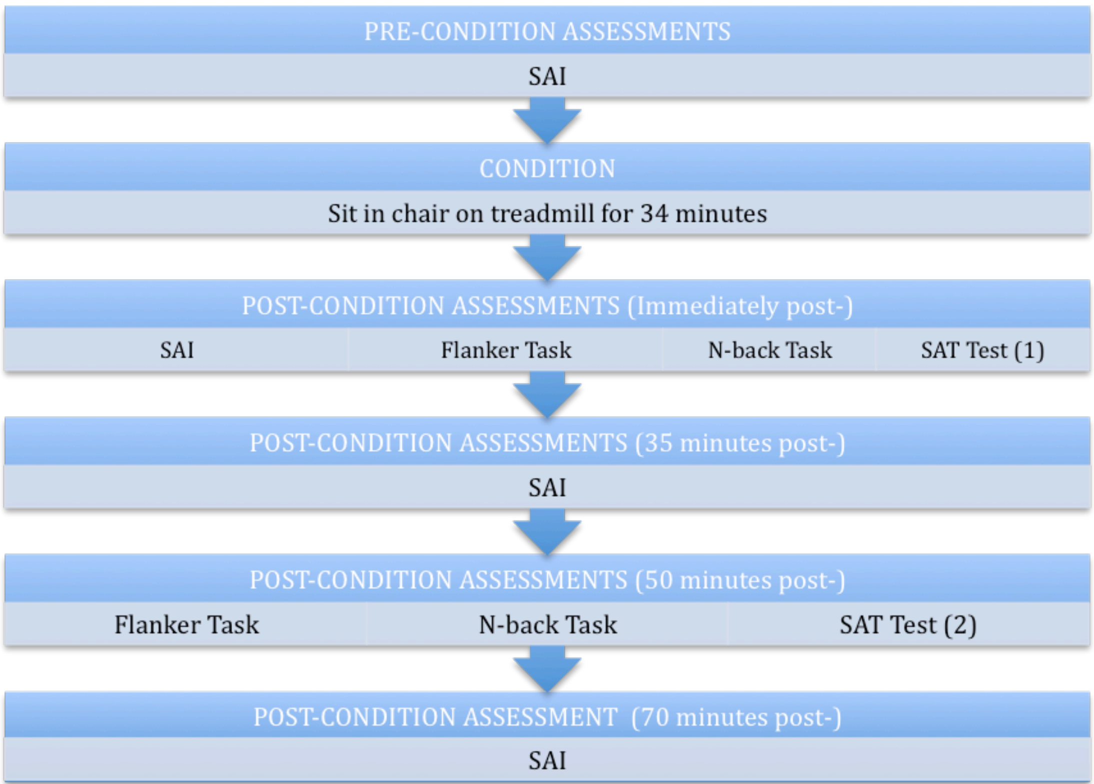

Figure 4: Control Condition-Rest (Visit 2 or 3)

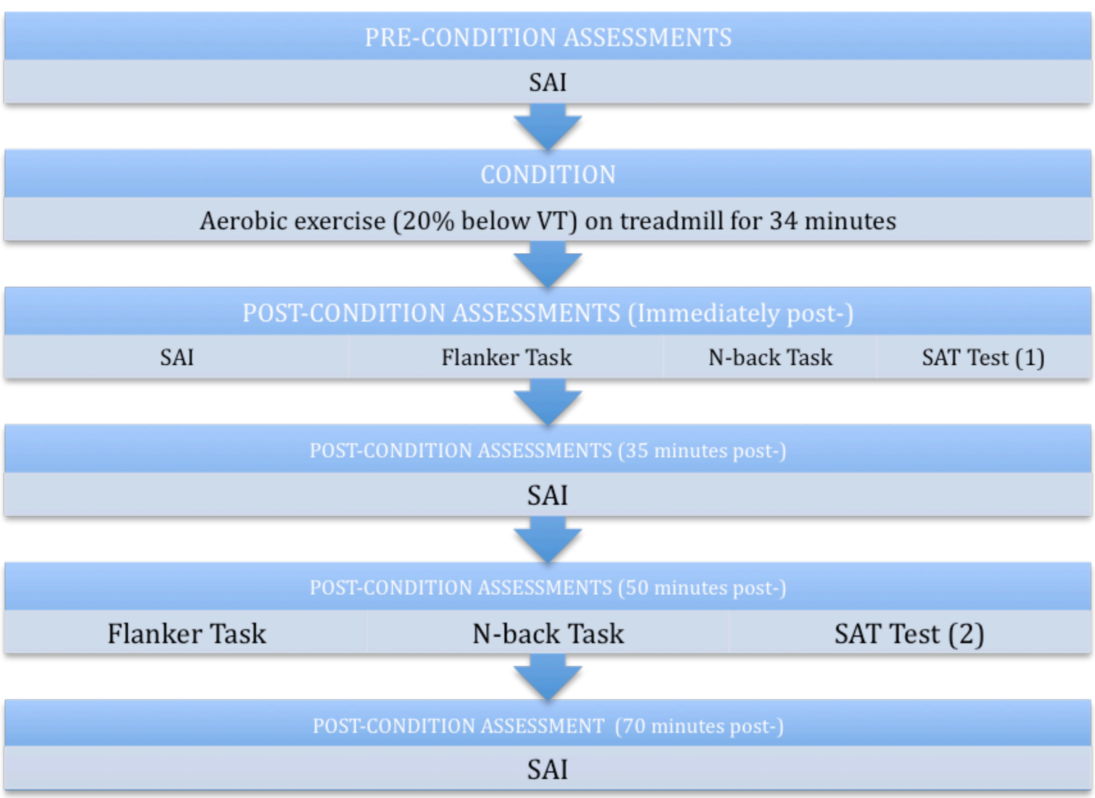

Figure 5: Experimental Condition (Visit 2 or 3)

PROCEDURES

Visit 1

Upon arrival to the Exercise Psychophysiology Laboratory (room 357 Freer) participants were greeted and asked to sit down to fill out paperwork. Prior to any baseline assessments, participants completed a PAR-Q and were given an informed consent form to read over and sign, if they chose to participate in the study. Additional paperwork included the Trait Anxiety Inventory (TAI), the Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q), and the Health & PA History Form (Spielberger, 1983; Ekkekakis, Hall, & Petruzzello, 2005; modified from Health & PA History Form, Department of Kinesiology & Community Health, University of Illinois at Urbana-Champaign). Individual characteristics of regular physical activity behavior, age, height, weight, gender, SES, education level, standardized college entrance test score, GPA (semester and cumulative), and medication use was also recorded at this time. The standardized test scores and GPA were chosen as measures of baseline academic achievement, because similar measures have been used in previous work in this field (Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Grissom, 2005).

Baseline cognitive assessments of working memory and inhibition were also completed on visit one. The N-back task and Flanker task were completed using a computer monitor and keyboard (Gevins & Cutillo, 1993, as cited in Owen, McMillan, Laird, & Bullmore, 2005; Eriksen & Eriksen, 1974, as cited in Davranche, Hall, & McMorris, 2009). There were 3 separate parts of versions A, B, and C of the N-back task, proctored in one of six random-balanced orders. These tasks were described in detail in the measures section. The Flanker task only had one part, and was proctored in one of two random versions, A or B. Each test was described to the participant (refer to Appendices M & L, respectively), and they were allowed to complete a practice version of each test prior to actual data collection. Lights were turned off for all computer tests to allow for easy viewing of the visual stimuli on the screen. A member of the research team remained in the room for the practice session to ensure that the participant understood the instructions for the task. After each practice session, the assessor asked if the participant felt comfortable, set up the actual test, and left the room.

Ventilatory threshold (VT) and fitness were also determined on this day. Fitness level was determined by means of peak aerobic capacity measured during a graded exercise test. Thus, following the computer tests, participants were asked to step on the treadmill in the Exercise Psychophysiology Laboratory. Participants were allowed to orient themselves with a treadmill, for as long as needed, prior to performing the graded exercise test. They were shown how to turn on and start the treadmill and then asked to increase the speed until they had reached a comfortable jogging pace. They were asked to choose a "jogging pace, that they felt comfortable maintaining for an extended period of time". They were also allowed to choose a warm-up speed at this time. These speeds were recorded for use during the graded exercise test. After this was ascertained, the treadmill was stopped and the participant was instructed to collect all of their belongings.

The rest of Visit 1 testing took place in the Freer Teaching Laboratory. The metabolic cart was calibrated and all equipment was set up earlier in the day. Upon arriving to the room, the participant was asked to set their things down and go to the fitting room to put on a Polar© HR monitor (Polar Electro). Next, the participant was asked to sit on a chair in the testing room. A member of the research team explained what all of the equipment was, what the graded exercise test would be like, and how to signal that they would like to stop. To signal exhaustion, participants were instructed to grab onto the side rails and jump their feet off of the belt. A foam board displaying the Feeling Scale (FS; Hardy & Rejeski, 1989 as cited in Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007) and Borg's Rating of Perceived Exertion (RPE; Borg, 1998) scale were used to assess how participants were feeling and how hard they were working, respectively, during the test. Both scales were explained to them prior to test start. Next, the research team member in charge of the computer input the participant's age, height, weight, sex, warm-up speed, and jogging speed. After asking the participant if they had any questions, the testing session began.

Participants began in a seated position in a wooden chair, placed on the treadmill belt. The researcher fitted the headgear to the individual's head, and then allowed them to place the mouthpiece in their mouth. While the researcher tightened the apparatus, participants were instructed to press firmly against the mouthpiece in order to ensure a proper seal. A demonstration was given on how to wear the nose clips, and participants were allowed to put these on themselves. After the researcher confirmed that no air was coming in or out of the nostrils, the start button was clicked on the computer screen. A baseline period of 3 minutes was spent at rest. At the end of the 3 minutes, a research team member asked the participant to stand and straddle the belt as they removed the chair from the treadmill. Once the belt started, participants were asked to step on and begin walking or jogging for their 2-min warm-up. Thirty seconds before the end of each 2-min stage of the graded exercise test, the research team placed the board with the Feeling Scale and RPE scale in front of the participant and asked them to point to a number indicating their current state. The participant was notified 10-15 seconds before the grade was to increase for the next stage. Once the participant had reached a point of volitional exhaustion they stopped and jumped off of the belt, while holding the railings. A gloved member of the research team stepped behind them and removed the headgear and mouthpiece so that they could breathe freely. Participants then stepped back on the treadmill and continued to walk for a cool-down. After the cool-down, participants were walked to a water fountain and back to the testing room to rest until their HR was 100 b•min^{-1} or less. Then, participants were allowed to go back to the changing room to remove their HR monitor. They were told that they would receive an e-mail about Day 2 testing and were walked to the front door of Freer Hall.

Visits 2 & 3

On the latter two visits, a control condition and an experimental condition were counter-balanced. Upon arrival, they were seated at a table in the lab and asked to fill out the 10-item State Anxiety Inventory (SAI) (Spielberger, 1983). Next, they were fitted with a Polar© HR monitor and the day's events were explained to them. Participants were also familiarized with the Feeling Scale (FS), RPE scale, and an additional Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985 as cited in Backhouse, Ekkekakis, Biddle, Foskett, & Williams, 2007) at this time. The control condition involved sitting quietly in a chair on a treadmill for 34 minutes. The experimental condition involved 30 minutes of aerobic exercise on a treadmill, with a 2-minute warm-up and a 2-minute cool-down. Aerobic exercise was performed and monitored at 20% below each individual's Ventilatory Threshold (VT) (according to their target HR range calculated from the results of their graded exercise test), in order to guarantee that the individual did not begin using anaerobic systems to complete the bout. In a meta-analysis done by Petruzzello et al. (1991), the mode, intensity, and duration of exercise associated with the most significant improvements in anxiety was aerobic exercise, of moderate to high intensity, lasting 21-30 min. Colcombe and Kramer (2003) did a meta-analysis involving older individuals, showing that 31-45 min was most effective for improving cognitive performance. Though the participants in this study were not old, the aim was to improve cognitive function. Therefore, in this study, 30 min of aerobic treadmill exercise was chosen as the exercise manipulation.

Following the warm-up, testing began and the participant was asked about their current state (using the FS, RPE, and FAS scales) every four minutes until 25:30. From 25:30 to the end of the cool-down, the participant was asked about their state every two minutes, in addition to one final time when the treadmill was stopped. Grade and speed were adjusted throughout the test by the research team. This was necessary in order to maintain the participant's exercise target HR. Participants were given the option to share their preference of more grade or speed with the researcher, and sincere efforts were made to acknowledge their wishes when possible. Immediately after the treadmill stopped, participants were asked to complete another 10-item SAI. They were then instructed to remove their HR monitor, drink desired water, and wipe away any sweat. After this short period (no more than 5 minutes, usually fewer) cognitive testing began. Computer tests (Flanker, N-back) were completed first, in random order. Each portion was explained to them as it was on Visit 1, and they were offered an opportunity to practice. Once they felt comfortable, the researcher left the room. Lights were turned off for both practice and actual tests. The participant alerted the researcher at the end of each test by stating "I'm done".

After the participant completed all four computer tests, they were given a Scholastic Aptitude Test (SAT) practice test. The SAT Critical Reading and Math sections of practice tests were used to assess academic achievement (Claman, 2003). Participants were instructed to complete Part 1 (reading or math) depending which of the two versions they were given that day. There were two separate versions of the SAT exam. One had a reading portion first and math second, and the other was a completely different version with reading and math parts in the reverse order. Participants were instructed to read the instructions and to try to complete the test to the best of their abilities. They were told that they would have a maximum of 15 minutes to complete the test, but if they finished early they could say, "I'm done". The researcher then closed the door and set the timer for 15 minutes. Following completion of Part 1, participants were asked to complete a third 10-item SAI. Next, they were given similar instructions to complete Part 2 of the SAT exam. Once they had finished the exam, or time had run out, they were asked to take the four computerized cognitive tasks one more time. The session ended with the participant completing one final 10-item SAI. State anxiety was assessed pre-condition, immediately post-condition, 35 minutes post-condition, and 70 post-condition. Previous work had shown that the effects of acute exercise on state anxiety appear to last up to 30, 60, or 120 minutes (Bahrke & Morgan, 1978; Cox, Thomas, & Davis, 2000; Raglin & Wilson, 1996). The entire testing period, including the experimental condition, lasted less than 120 minutes. They were either told that they would receive an e-mail about Visit 3 or thanked for their time and asked if they would like to be added to the list of individuals interested in seeing general results of the study.

DATA ANALYSIS

The Statistical Package for the Social Sciences (SPSS) 12.0, was used for all data analysis. Data was input into an SPSS spreadsheet with proper variable coding. A 2 (Group) x 2 (Condition) x 4 (Time) Repeated Measures Analysis of Variance (RM-ANOVA) was used to examine Condition x Time (within-subjects factors) and Trait Anxiety (as a between subjects "Group" variable). If interactions existed, post-hoc analyses were performed. When the sphericity assumption was violated the Huynh-Feldt (H-F) ε was used to adjust the degrees of freedom. Univariate analyses were performed to calculate descriptive statistics of all participants.

Independent samples *t*-tests were run on individual differences of sex, age, height, weight, trait anxiety, years of education, GPA, ACT Score, VO_{2peak}, and Ventilatory Threshold (VT) to determine any group differences for the beginning sample, the final sample, and between those who dropped out and those who completed the study. Change scores were computed for SA, SAT score, accuracy, RT, and StdRT for all Flanker and N-back trials.

To determine whether an acute bout of aerobic exercise was associated with reductions in state anxiety levels in both high- and low-trait anxious individuals, with significantly greater reductions seen in the high-trait anxious group (Hypothesis 1), RM-ANOVA was performed on state anxiety levels in relation to Group, Condition, and Time. State anxiety changes between four time points (pre-condition, immediately post-condition, 35 min post-condition, and 70 min post-condition) were analyzed to determine if a significant decrease was seen after exercise (Hypothesis 1). These change scores were compared with change scores from the cognitive measures, using the Pearson product moment correlation. This was done to determine whether or not state anxiety seemed to be moderating this relationship. To determine if state anxiety would begin to return to baseline sometime after any initial decrease (Hypothesis 1), RM-ANOVA was performed to look at mean state anxiety over time.

To determine if an acute bout of aerobic exercise was associated with enhanced cognitive performance, as compared to performance after rest (Hypothesis 2), RM-ANOVA was performed on all measures of performance for both Flanker and N-back tasks. Flanker analyses were separated by responses to congruent and incongruent stimuli. RM-ANOVA was performed for accuracy, reaction time (RT), and standard deviations of RT (StdRT) for Congruent, Incongruent, and Overall Flanker trials. N-back analyses were separated by responses to nontarget, versus target stimuli. RM-ANOVA was performed for accuracy, reaction time (RT), and StdRT for Target, Nontarget, and Overall and N-back (0, 1, and 2) trials. Baseline and post-condition scores on N-back and Flanker tasks were examined to determine if an acute bout of aerobic exercise was associated with enhanced cognitive performance, as compared to performance after rest (Hypothesis 2). RM-ANOVA was also used to investigate whether or not enhanced cognitive performance was significantly greater in high-trait anxious, relative to low-trait anxious (Hypothesis 2), whether or not accuracy would increase, and whether or not RT and variability in response times would decrease for both the Flanker and N-back tasks. This also helped in the determining whether such responses were more pronounced for high-trait anxious individuals than low-trait anxious individuals, compared to their baseline scores (Hypothesis 2).

To determine whether or not changes in state anxiety were inversely associated with academic performance (Hypothesis 3), RM-ANOVA was performed to determine whether or not individuals performed better on academic achievement exams after exercise, more so than after rest (Hypothesis 3). Pearson product moment correlations between the changes in state anxiety on the exercise day and changes on SAT reading and math scores from the resting day to the exercise day were determined. The differences in performance between high-trait anxious and low-trait anxious individuals were also investigated (Hypothesis 3).

To determine whether or not improvements in cognitive function (increased accuracy, decreased RT, and decreased StdRT) were associated with better academic achievement scores, Pearson product moment correlations were investigated to see if reductions in state anxiety and/or improvements in cognition were significantly correlated with improvements in academic achievement (Hypothesis 3).

Some participants had incomplete data due to unintentional losses that occurred throughout the data collection process. For each relationship investigated, only participants with full data sets were included, and this is noted under each table. Therefore, if an individual who dropped out still had complete data for one of the variables, their information was still included in analysis. All tests of significance were performed at an alpha level=.05. Bar graphs were used instead of line graphs, as it is unknown how variables may or may not have fluctuated in between the time points at which they were assessed.

CHAPTER 4

RESULTS

The purpose of this experiment was to investigate the effects of 30 minutes of aerobic exercise on SA, cognition, and academic performance in college-aged individuals with high-trait anxiety or low-trait anxiety. The first aim was to determine if aerobic exercise could reduce SA in college-aged individuals. The second aim was to determine if SA reductions and/or aerobic exercise were associated with enhanced cognitive functioning. The third aim was to determine if SA reduction and/or aerobic exercise were associated with enhanced academic performance. The fourth aim was to determine if post-condition changes in cognitive function were associated with similar changes in academic performance. Within these aims, the specific focus was to investigate the individual cognitive responses that individuals with differing levels of trait anxiety had following exercise versus rest.

PARTICIPANTS

Participants were recruited from Champaign-Urbana, IL and the surrounding areas, and were accepted continuously in hopes that desired numbers would eventually be fulfilled, and no individuals were turned away. All participants were offered the experience and given the opportunity to volunteer with full right to decline. They were given an informed consent form to read and to determine whether or not they would like to participate. Those who met study criteria were randomized to a condition order and stratified into high- and low-trait anxious groups. If at anytime the participant felt uncomfortable with the research or no longer wanted to participate, they were informed that they could ask to stop, with no penalty or negative judgements towards them. Data collection lasted for a period five months.

Table 1. Preliminary sample descriptive statistics of participants.

Participant Characteristics	Males (*n*=17)		Females (*n*=18)		Total Sample (*N*=35)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Trait Anxiety Inventory (TAI) score	27.88	10.61	31.32	11.19	30.14	11.08
Age (years)	21.00	1.73	21.28	2.49	21.14	2.13
Height (inches)	70.85	2.13	65.11	2.14	67.90	3.59
Weight (pounds)	169.19	16.96	133.94	18.20	150.53	24.90
Education (years)	15.07	1.39	15.11	1.18	15.09	1.26
ACT Score	27.56	1.75	27.88	2.98	27.88	2.98
GPA (4.0 scale)	3.32	0.48	3.57	0.38	3.45	0.44
$VO_{2\ peak}$ ($mL•kg^{-1}•min^{-1}$)	56.15	7.20	44.59	7.52	50.21	9.33
Ventilatory Threshold (VO L• min^{-1})	3.38	0.86	2.01	0.47	2.70	0.97

Note: The information above includes all participants who attended at least one of the three laboratory visits. Two individuals took the SAT instead of the ACT, and were excluded from the average ACT score calculation. One of these individuals dropped out of the study prior to completion.

Thirty-five college-aged individuals, 9 high-trait anxious, and 26 low-trait anxious, were solicited for this experimental study (17 males, 18 females). Characteristics of these individuals are described in Table 1 above. Numbers were unequal due to continuous inclusion of volunteers, fewer being high-trait anxious.

Table 2. Preliminary sample descriptive statistics by group.

Participant Characteristics	Low-trait (*n*=26) 14 Male, 12 Female		High-trait (*n*=9) 3 Male, 6 Female	
	M	***SD***	***M***	***SD***
Trait Anxiety Inventory (TAI) score	23.42	1.89	47.67	4.80
Age (years)	20.73	1.69	22.33	2.87
Height (inches)	68.56	3.38	66.00	3.71
Weight (pounds)	152.52	22.96	145.00	30.49
Education (years)	14.78	1.17	15.56	1.01
ACT Score	27.65	2.82	28.44	3.47
GPA (4.0 scale)	3.49	0.30	3.35	0.57
$VO_{2\ peak}$ ($mL•kg^{-1}•min^{-1}$)	52.33	8.53	44.06	9.23
Ventilatory Threshold (VO L• min^{-1})	2.90	1.00	2.18	0.72

Note: The information above includes all participants who attended at least one of the three laboratory visits. Two individuals took the SAT instead of the ACT, and were excluded from the average ACT score calculation. One of these individuals dropped out of the study prior to completion.

Characteristics of the individuals who participated long enough to be placed into a group are described in Table 2 above. An independent samples *t*-test showed significant group differences in Trait Anxiety ($p < .001$), VO_{2peak} ($p = .034$), and VT ($p = .033$), when equality of variances was not assumed.

An independent samples *t*-test showed significant group differences between those individuals who did not complete the study (*n*=5) and those who did (*n*=30). Average Trait Anxiety was significantly lower ($p = .002$) in those who did not complete the study (*M*=23.60, *SE*=0.51) than those who did (*M*=30.87, *SE*=2.12), when equality of variance was not assumed. Average VO_{2peak} was significantly lower ($p = .036$) in those who did not complete the study (*M*=45.08, *SE*=1.85) than those who did (*M*=51.06, *SE*=1.77).

Table 3. Final sample descriptive statistics by group.

Participant Characteristics	Low-trait (*n*=21)		High-trait (*n*=9)	
Male	13		3	
Female	8		6	
	M	***SD***	***M***	***SD***
Trait Anxiety Inventory (TAI) score	23.67	2.13	47.67	4.80
Age (years)	20.95	1.66	22.33	2.87
Height (inches)	68.93	3.32	66.00	3.71
Weight (pounds)	154.10	23.04	145.00	30.49
Education (years)	14.84	1.17	15.56	1.01
ACT Score	27.68	2.94	28.44	3.47
GPA (4.0 scale)	3.49	0.39	3.35	0.57
$VO_{2\ peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	54.06	8.44	44.06	9.23
Ventilatory Threshold (VO L• min^{-1})	2.97	1.00	2.18	0.72

Note: This table includes averages for all participants who attended all three laboratory visits. One low-trait anxious individual took the SAT instead of the ACT, and was excluded from the average ACT score calculation.

This left the final sample size at 30 individuals (9 high-trait anxious, 21 low-trait anxious; 16 males, 14 females). Participant characteristics for the final sample of individuals who completed the study in its entirety are described in Table 3 above. An independent samples *t*-test showed significant group differences in Trait Anxiety ($p < .001$), VO_{2peak} ($p = .014$), and VT ($p = .023$), when equal variance was not assumed. As designed, the high-trait anxious group had higher Trait Anxiety than the low-trait anxious group. The high-trait anxious group had a lower average VO_{2peak} and a lower average VT than the low-trait anxious group.

STATE ANXIETY

Table 4. State anxiety.

CONDITION	GROUP	TIME	*M*	*SD*
REST	Low-trait	Baseline	13.38	3.67
	High-trait		19.11	6.55
	Low-trait	Immediately Post-Rest	10.81	1.03
	High-trait		16.11	5.80
	Low-trait	35 minutes Post-Rest	13.29	4.38
	High-trait		18.22	5.61
	Low-trait	70 minutes Post-rest	13.57	4.03
	High-trait		17.22	3.99
EXERCISE	Low-trait	Baseline	12.52	2.36
	High-trait		20.44	6.75
	Low-trait	Immediately Post-Exercise	13.38	2.94
	High-trait		14.44	2.74
	Low-trait	35 minutes Post-Exercise	14.00	4.09
	High-trait		19.22	4.84
	Low-trait	70 minutes Post-Exercise	12.67	3.12
	High-trait		16.44	4.80

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9)

Average state anxiety over time for both groups is displayed in Table 4 above. Average state anxiety for the high-trait anxious group (*M*=17.65, *SE*=0.87) was higher than the low-trait anxious group (*M*=12.95, *SE*=0.57). Tests of within-subjects effects showed a significant main effect of Time [H-F ε=0.97, $F(2.92,81.85)=10.40$, $p< .001$, partial $\eta^2=.27$] and significant Time x Group [H-F ε=0.97, $F(2.92,81.85)=4.47$, $p= .006$, partial $\eta^2=.14$] and Condition x Time x Group interactions [H-F ε=0.82, $F(2.47,69.03)=3.22$, $p= .036$, partial $\eta^2=.10$]. An independent samples *t*-test (2-tailed sig.) showed that the reduction in SA from baseline to immediately post-exercise was significantly greater in high-trait anxious individuals than low-trait anxious individuals (Mean difference=-6.86, *SE*=2.13, $t(10.17)=-3.21$, $p= .009$, when equality of variance was not assumed). This *t*-test also showed that the reduction in SA from 35 minutes post-exercise to 70 minutes post-exercise was also significantly greater in high-trait anxious individuals (Mean difference=-4.14, *SE*=1.81, $t(9.32)=-2.29$, $p= .047$, when equality of variances was not assumed). No such relationships existed for changes in SA following the rest condition.

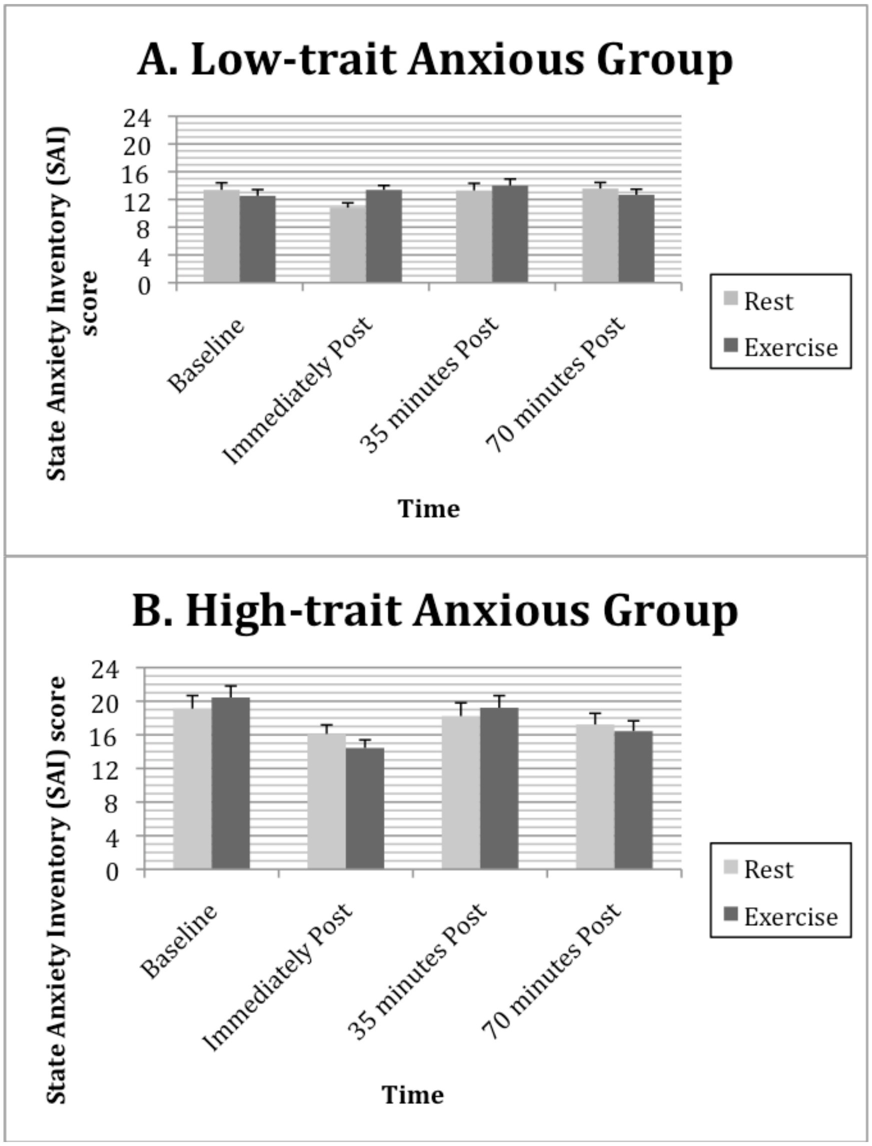

Figure 6: State Anxiety Change Over Time Across Condition

FLANKER RESULTS

FLANKER ACCURACY

Table 5. Flanker accuracy on congruent trials.

CONDITION	GROUP	TIME	*M*	*SD*
EXERCISE	Low-trait	Baseline	97.20	3.37
	High-trait		97.67	2.65
	Low-trait	Immediately Post-Exercise	97.60	4.68
	High-trait		97.56	3.68
	Low-trait	50 minutes Post-Exercise	96.90	4.89
	High-trait		97.00	3.04
REST	Low-trait	Baseline	97.20	3.37
	High-trait		97.67	2.65
	Low-trait	Immediately Post-Rest	96.60	4.65
	High-trait		97.56	4.10
	Low-trait	50 minutes Post-Rest	95.10	5.55
	High-trait		97.89	2.26

Note: (Low-trait anxious n=20, High-trait anxious n=9)

Average accuracy for congruent trials are displayed in Table 5 above. Average accuracy for congruent trials for the high-trait anxious group (M=97.56, SE=1.13) was greater than the low-trait anxious group (M=96.77, SE=0.76), but this difference was not statistically significant. Tests of within-subjects effects showed a significant Group x Condition interaction [H-F ε=1.00 $F(1,27)$=5.21, p= .31, partial η^2=.16. The high-trait group had increased accuracy from 0 to 50 minutes post-rest (mean change= +0.33%), while the low trait group became less accurate between 0 and 50 minutes post-rest (mean change= -1.5%), but this difference was not statistically significant.

Table 6. Flanker accuracy on incongruent trials.

CONDITION	GROUP	TIME	M	SD
	Low-trait	Baseline	87.15	8.85
	High-trait		89.89	7.56
EXERCISE	Low-trait	Immediately Post-Exercise	87.15	13.32
	High-trait		88.89	7.94
	Low-trait	50 minutes Post-Exercise	87.70	11.94
	High-trait		90.22	6.74
	Low-trait	Baseline	87.15	8.85
	High-trait		89.89	7.56
REST	Low-trait	Immediately Post-Rest	86.00	11.76
	High-trait		87.11	6.72
	Low-trait	50 minutes Post-Rest	85.90	13.29
	High-trait		87.11	8.87

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9)

Average accuracy on incongruent trials is displayed in Table 6 above. Average accuracy for incongruent trials for the high-trait anxious group (*M*=88.85, *SE*=3.27) was greater than the low-trait anxious group (*M*=86.84, *SE*=2.19), but this difference was not statistically significant. No significant effects or interactions were found for accuracy on incongruent trials. Overall, average accuracy for the high-trait anxious group was greater (*M*=88.85, *SE*=3.27) than the low-trait anxious group (*M*=86.84, *SE*=2.19, but this difference was not statistically significant. Post-hoc analysis revealed that the accuracy on incongruent trials was greater for exercise (*M*=88.50, *SE*=2.01) than rest; this relationship approached significance (*M*=87.19, *SE*=1.98, *p*= .065). The high-trait anxious group had greater post-exercise accuracy on incongruent trials 50 minutes post-exercise (*M*=90.22, *SD*=6.74) than baseline (*M*=89.89, *SD*=7.56), but this difference was not statistically significant. The low-trait anxious group had no change in accuracy on incongruent trials from baseline (*M*=87.15, *SD*=8.85) to immediately post-exercise (*M*=87.15, *SD*=13.32).

Table 7. Flanker accuracy on all trials.

CONDITION	GROUP	TIME	*M*	*SD*
EXERCISE	Low-trait	Baseline	92.18	5.20
	High-trait		93.78	4.87
	Low-trait	Immediately Post-Exercise	92.38	8.38
	High-trait		93.22	5.69
	Low-trait	50 minutes Post-Exercise	92.30	8.00
	High-trait		93.61	4.62
REST	Low-trait	Baseline	92.18	5.20
	High-trait		93.78	4.87
	Low-trait	Immediately Post-Rest	91.30	7.69
	High-trait		92.33	5.14
	Low-trait	50 minutes Post-Rest	90.50	8.99
	High-trait		92.50	5.07

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9)

Average Accuracy for all trials are displayed in Table 7 above. Average accuracy for all Flanker trials for the high-trait anxious group (*M*=93.20, *SE*=2.09) was greater than the low-trait anxious group (*M*=91.80, *SE*=1.40), but this difference was not statistically significant. No significant effects or interactions were found for accuracy on all trials. Post-exercise accuracy for the high-trait anxious group (*M*=93.22, *SE*=2.56) was greater than post-rest (*M*=92.33, *SE*=2.34) and than post-exercise and post-rest accuracies for the low-trait anxious group (*M*=92.38, *SE*=1.72; *M*=91.30, *SE*=1.57), but these differences were not statistically significant.

FLANKER REACTION TIME

Table 8. Flanker reaction time on congruent trials.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	386.55	61.42
	High-trait		388.67	36.12
	Low-trait	Immediately Post-Exercise	374.87	49.07
	High-trait		367.22	19.15
	Low-trait	50 minutes Post-Exercise	371.94	44.66
	High-trait		360.17	17.46
REST	Low-trait	Baseline	386.55	61.42
	High-trait		388.67	36.12
	Low-trait	Immediately Post-Rest	376.49	47.50
	High-trait		374.50	31.70
	Low-trait	50 minutes Post-Rest	363.68	41.19
	High-trait		369.23	29.01

Note: (Low-trait anxious n=20, High-trait anxious n=9); (ms)=milliseconds

Average RT for congruent trials are displayed in Table 8 above. Average RT for congruent trials for the high-trait anxious group (M=374.74, SE=14.19) was faster than the low-trait anxious group (M=376.68, SE=9.52), but this difference was not statistically significant. Tests of within-subjects effects showed a significant main effect of Time for RT on congruent trials [H-F ε=0.62, $F(1.24,33.58)$=10.19, p= .002, partial η^2=.27], but there were no main effects of Condition or Group. There were no interaction effects. Average RT for congruent trials was significantly faster than baseline (M=387.61, SE= 11.07) at both post-condition time points, immediately post- (M=373.27, SE=8.15, p= .008) and 50 minutes post-condition (M=366.25, SE=7.30, p= .002), respectively. Average RT for congruent trials was significantly faster immediately post-condition than 50 minutes post-condition (p= .006). RT for congruent trials post-exercise in the high-trait anxious group (M=367.22, SE=14.15) was smaller than post-rest (M=374.50, SE=14.48) and than post-exercise and post-rest RT for congruent trials in the low-trait anxious group (M=374.87, SE=9.50; M=376.49, SE=9.71), but these differences were not statistically significant.

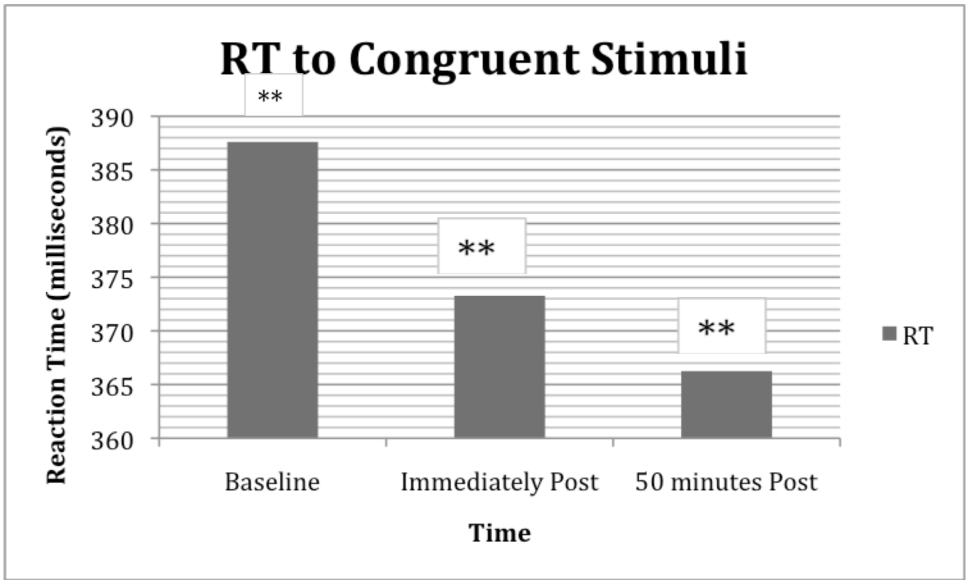

Figure 7: RT to Congruent Trials in the Flanker Task Over Time
Note: ** denotes significant differences from RT at all other time points

Table 9. Flanker reaction time on incongruent trials.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	441.28	60.65
	High-trait		438.64	40.34
	Low-trait	Immediately Post-Exercise	419.10	55.47
	High-trait		411.56	22.73
	Low-trait	50 minutes Post-Exercise	415.32	48.09
	High-trait		403.29	24.87
REST	Low-trait	Baseline	441.28	60.65
	High-trait		438.64	40.34
	Low-trait	Immediately Post-Rest	424.88	54.28
	High-trait		427.90	40.00
	Low-trait	50 minutes Post-Rest	406.95	46.30
	High-trait		408.88	34.56

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for incongruent trials are displayed in Table 9 above. Average RT for incongruent trials for the high-trait anxious group (*M*=421.49, *SE*=15.30) was faster than the low-trait anxious group (*M*=424.80, *SE*=10.26), but this difference was not statistically significant. Tests of within-subjects effects showed a significant main effect of Time for RT on incongruent trials [H-F ε=0.64, $F(1.28,34.67)=20.14$, $p< .001$, partial $\eta^2=.43$], and a Condition x Time interaction effect [H-F ε=0.96, $F(1.91,51.65)=3.22$, $p= .050$, partial $\eta^2=.11$]. Overall, average RT for incongruent trials in the high-trait anxious group was faster (*M*=421.49, *SE*=15.30) than in the low-trait anxious group (*M*=424.80, *SE*=10.26), but this difference was not statistically significant. RT for incongruent trials decreased significantly more from baseline (*M*=439.96, *SE*=11.12) immediately post-exercise (*M*=415.33, *SE*=9.66) than immediately post-rest (*M*=426.39, *SE*=10.13). Post-hoc analysis revealed RT on incongruent trials to be significantly different from each other at all time points ($p < .001$).

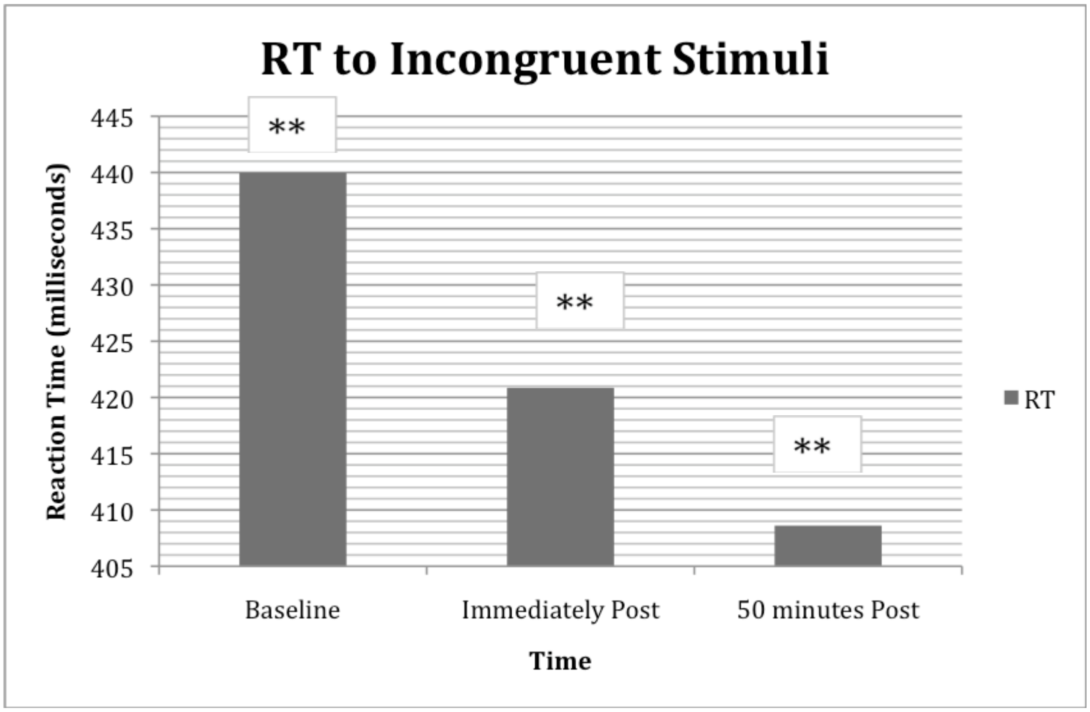

Figure 8: RT to Incongruent Trials in the Flanker Task Over Time
Note: ** denotes significant differences from RT at all other time points

Table 10. Flanker reaction time on all trials.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	412.24	60.63
	High-trait		412.69	38.15
	Low-trait	Immediately Post-Exercise	395.76	52.12
	High-trait		388.36	19.47
	Low-trait	50 minutes Post-Exercise	392.49	46.39
	High-trait		380.96	20.42
REST	Low-trait	Baseline	412.24	60.63
	High-trait		412.69	38.15
	Low-trait	Immediately Post-Rest	399.22	50.58
	High-trait		399.66	35.45
	Low-trait	50 minutes Post-Rest	384.21	43.42
	High-trait		387.98	31.87

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for all Flanker trials are displayed in Table 10 above. Average overall RT for Flanker trials for the high-trait anxious group (*M*=397.05, *SE*=14.69) was faster than the low-trait anxious group (*M*=399.36, *SE*=9.86), but this difference was not statistically significant. Tests of within-subjects effects showed a significant main effect of Time for RT for all Flanker trials [H-F ε=0.61, F (1.23,33.11)=15.46, $p < .001$, partial η^2=.36]. Post-hoc analysis revealed that RT was faster immediately post-condition (*M*=395.75, *SE*=8.72, $p = .001$) and 50 minutes post-condition (*M*=386.41, *SE*=7.73, $p < .001$) than at baseline (*M*=412.46, *SE*=11.03). After exercise, high-trait anxious individuals' RT continuously decreased over time, while low-trait individuals' RT began returning to baseline 50 minutes post-condition, but this difference was not statistically significant. Overall, the high-trait anxious group had faster average RT (*M*=397.05, *SE*=14.69) than in the low-trait anxious group (*M*=399.36, *SE*=9.86), but this difference was not statistically significant.

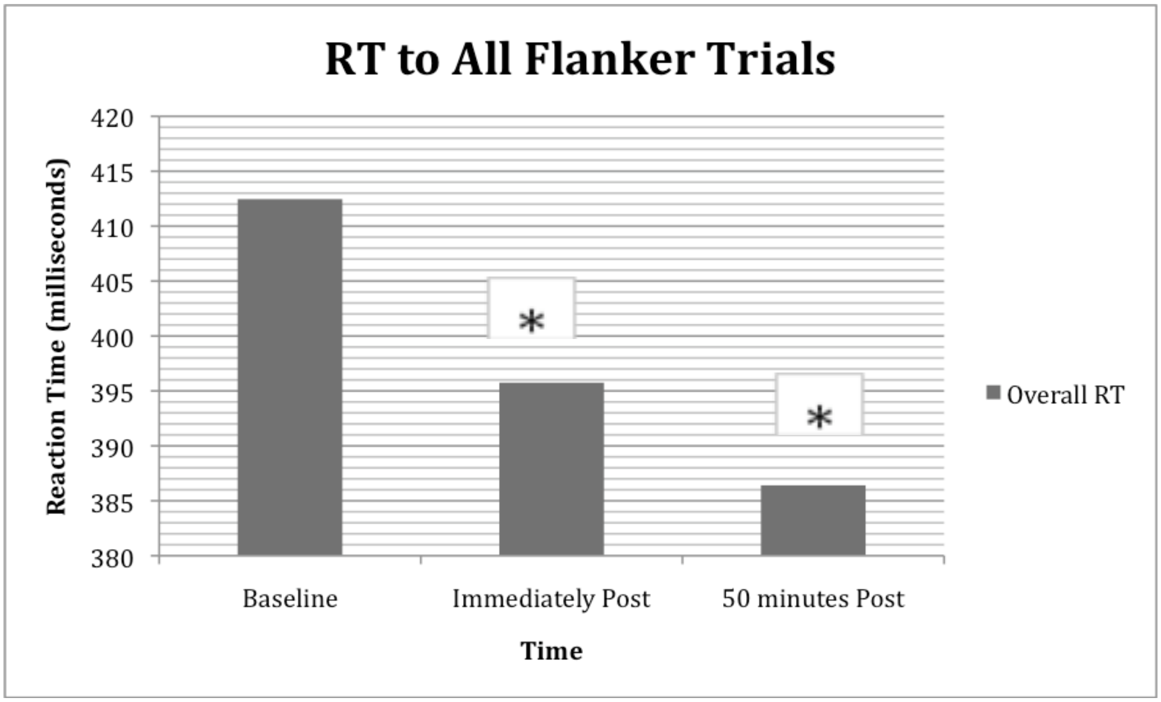

Figure 9: Reaction Time to All Flanker Trials
Note: * denotes significant difference from baseline

FLANKER STANDARD DEVIATION OF REACTION TIME (StdRT)

Table 11. Flanker standard deviation of RT on congruent trials.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
	Low-trait	Baseline	56.70	20.95
	High-trait		68.01	24.76
EXERCISE	Low-trait	Immediately Post-Exercise	50.82	17.28
	High-trait		54.02	10.30
	Low-trait	50 minutes Post-Exercise	51.50	19.30
	High-trait		50.27	11.41
	Low-trait	Baseline	56.70	20.95
	High-trait		68.01	24.76
REST	Low-trait	Immediately Post-Rest	52.48	18.81
	High-trait		61.42	20.73
	Low-trait	50 minutes Post-Rest	54.71	23.95
	High-trait		60.62	21.14

Note: (Low-trait anxious n=20, High-trait anxious n=9); (ms)=milliseconds

Average StdRT for congruent Flanker trials are displayed in Table 11 above. Average StdRT for congruent trials for the high-trait anxious group (M=60.39, SE=5.68) was greater than the low-trait anxious group (M=53.82, SE=3.81), but this difference was not statistically significant. Tests of within-subjects effects showed a significant main effect of Time for standard deviation of RT on congruent trials [H-F ε=0.86, F (1.72, 46.34)=5.12, p= .013, partial η^2=.16]. A Condition main effect approached significance [H-F ε=1.00, F (1, 27)=4.14, p= .052, partial η^2=.13], but there were no group effects. Standard deviation of RT on congruent trials was significantly smaller than baseline (*M*=62.35, *SE*=4.45), both immediately post-condition (*M*=54.69, *SE*=3.27, *p*= .008) and 50 minutes post-condition (*M*=54.28, *SE*=3.56, *p*= .028). Both groups had reduced StdRT following exercise. The high-trait anxious group had a greater reduction in StdRT immediately following exercise (~8 ms more) and control (~3 ms more) than the low-trait anxious group; however these differences were not statistically significant.

Table 12. Flanker standard deviation of RT on incongruent trials.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	61.63	17.56
	High-trait		67.70	13.09
	Low-trait	Immediately Post-Exercise	55.44	14.84
	High-trait		59.54	12.35
	Low-trait	50 minutes Post-Exercise	53.65	13.07
	High-trait		54.81	6.97
REST	Low-trait	Baseline	61.63	17.56
	High-trait		67.70	13.09
	Low-trait	Immediately Post-Rest	58.45	12.21
	High-trait		70.87	17.91
	Low-trait	50 minutes Post-Rest	61.43	11.88
	High-trait		68.14	22.39

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average StdRT for incongruent Flanker trials are displayed in Table 12 above. Average StdRT for incongruent trials for the high-trait anxious group (*M*=64.79, *SE*=4.10) was larger than the low-trait anxious group (*M*=58.70, *SE*=2.75), but this difference was not statistically significant. Tests of within-subjects effects showed a significant main effect of Condition for StdRT on incongruent trials [H-F ε=1.00, F (1, 27)=15.50, p= .001, partial η^2=.37] and Condition x Time interaction [H-F ε=1.00, F (2, 54)=7.18, p= .002, partial η^2=.21]. A Time main effect approached significance [H-F ε=0.96, F (1.93, 52.03)=3.07, p= .057, partial η^2=.10], and there were no group effects. Post-hoc analysis revealed that the StdRT on incongruent trials was significantly smaller for exercise (*M*=58.80, *SE*=2.55) than rest (*M*=64.70, *SE*=2.62, *p*=.001). The high-trait anxious group had a slight increase in StdRT immediately following rest (~3 ms) while the low-trait anxious group had a slight decrease (~3 ms); however, this difference was not statistically significant.

Table 13. Flanker standard deviation of RT on all trials.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	66.53	16.45
	High-trait		72.90	17.32
	Low-trait	Immediately Post-Exercise	58.54	13.44
	High-trait		61.53	8.69
	Low-trait	50 minutes Post-Exercise	57.73	13.91
	High-trait		57.42	7.12
REST	Low-trait	Baseline	66.53	16.45
	High-trait		72.90	17.32
	Low-trait	Immediately Post-Rest	61.48	13.54
	High-trait		71.93	16.66
	Low-trait	50 minutes Post-Rest	63.12	15.70
	High-trait		68.41	17.06

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average StdRT for all Flanker trials is displayed in Table 13 above. Average overall StdRT for Flanker trials for the high-trait anxious group (*M*=67.52, *SE*=4.24) was larger than the low-trait anxious group (*M*=62.32, *SE*=2.84), but this difference was not statistically significant. Tests of within-subjects effects showed significant main effects of Condition [H-F ε=1.00, *F* (1, 27)=12.61, *p*= .001, partial η^2=.318] and Time [H-F ε=0.87, *F* (1.73, 46.8)=8.32, *p*= .001, partial η^2=.24] and a significant Condition x Time interaction [H-F ε=1.00, *F* (2, 54)=6.36, *p*= .003, partial η^2=.19] for StdRT across all Flanker trials. Post-hoc analysis revealed that StdRT was significantly lower following exercise (*M*=62.44, *SE*=2.49) than rest (*M*=67.39, *SE*=2.79, *p*= .001). Overall StdRT at baseline (*M*=69.71, *SE*=3.36) was significantly greater than StdRT immediately post-condition (*M*=63.37, *SE*=2.42, *p*= .003) and StdRT 50 minutes post-condition (*M*=61.67, *SE*=2.59, *p*= .004).

N-BACK RESULTS

N-BACK ACCURACY

Table 14. N0-back accuracy on target stimuli.

CONDITION	GROUP	TIME	*M*	*SD*
EXERCISE	Low-trait	Baseline	94.39	5.70
	High-trait		89.60	7.68
	Low-trait	Immediately Post-Exercise	93.14	8.58
	High-trait		95.86	4.41
	Low-trait	50 minutes Post-Exercise	91.26	13.66
	High-trait		90.28	7.09
REST	Low-trait	Baseline	94.39	5.70
	High-trait		89.60	7.68
	Low-trait	Immediately Post-Rest	94.08	8.23
	High-trait		90.30	7.75
	Low-trait	50 minutes Post-Rest	90.33	12.42
	High-trait		89.58	12.89

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9)

Average accuracy for all Target trials of the N0-back task are displayed in Table 14 above. Average accuracy for Target trials on the N0-back task for the high-trait anxious group (*M*=90.87, *SE*=2.45) was lower than the low-trait anxious group (*M*=92.93, *SE*=1.64), but this difference was not statistically significant. No significant main effects or interactions were revealed for accuracy on Target Stimuli on the N0-back task. Overall, accuracy on Target trials of the N0-back task increased from baseline (*M*=92.00, *SE*=1.28) to immediately post-condition (*M*=93.34, *SE*=1.41) and decreased below baseline at 50 minutes post-condition (*M*=90.36, *SE*=2.30), but after sphericity was adjusted for, this difference was not significant. Accuracy scores on the N0-back task to Target Stimuli immediately post-exercise seem to demonstrate that high-trait individuals had improved performance following exercise, more so than the immediately post-rest and low-trait individuals (refer to Table 14 for means). However, this difference was not statistically significant.

Table 15. N0-back accuracy on nontarget stimuli.

CONDITION	GROUP	TIME	*M*	*SD*
EXERCISE	Low-trait	Baseline	99.77	0.76
	High-trait		99.66	1.03
	Low-trait	Immediately Post-Exercise	99.84	0.49
	High-trait		99.47	0.80
	Low-trait	50 minutes Post-Exercise	99.22	1.56
	High-trait		99.30	1.59
REST	Low-trait	Baseline	99.77	0.76
	High-trait		99.66	1.03
	Low-trait	Immediately Post-Rest	99.92	0.36
	High-trait		99.64	0.71
	Low-trait	50 minutes Post-Rest	99.69	0.82
	High-trait		99.12	1.14

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9)

Average accuracy for all nontarget trials of the N0-back task are displayed in Table 15 above. Average accuracy for nontarget trials on the N0-back task for the high-trait anxious group (*M*=99.47, *SE*=0.16) was lower than the low-trait anxious group (*M*=99.70, *SE*=0.11), but this difference was not statistically significant. (*p*= .257). No significant main effects or interactions were revealed for accuracy on Nontarget Stimuli on the N0-back task.

Table 16. N1-back accuracy on target stimuli.

CONDITION	GROUP	TIME	*M*	*SD*
EXERCISE	Low-trait	Baseline	93.81	4.15
	High-trait		91.11	4.86
	Low-trait	Immediately Post-Exercise	92.86	4.35
	High-trait		92.22	8.70
	Low-trait	50 minutes Post-Exercise	83.33	23.84
	High-trait		91.11	9.28
REST	Low-trait	Baseline	93.81	4.15
	High-trait		91.11	4.86
	Low-trait	Immediately Post-Rest	93.81	4.15
	High-trait		86.67	9.35
	Low-trait	50 minutes Post-Rest	89.76	7.33
	High-trait		88.33	10.31

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9)

Average accuracy for all Target trials of the N1-back task are displayed in Table 16 above. Average accuracy for Target trials on the N1-back task for the high-trait anxious group (*M*=90.09, *SE*=1.79) was lower than the low-trait anxious group (*M*=91.23, *SE*=1.17), but this difference was not statistically significant (p= .598). No significant main effects or interactions were revealed for accuracy on Target Stimuli on the N1-back task. A Condition x Group interaction approached significance [H-F ε=1.00, $F(1, 28)$=3.33, p= .079, partial η^2=.11]. Post-hoc analysis showed that high-trait anxious individuals had lesser accuracy after rest (M=88.70, SE=1.61) than exercise (M=91.48, SE=2.58), while low-trait anxious individuals had greater accuracy after rest (M=92.46, SE=1.05) than exercise (M=90.00, SE=1.69).

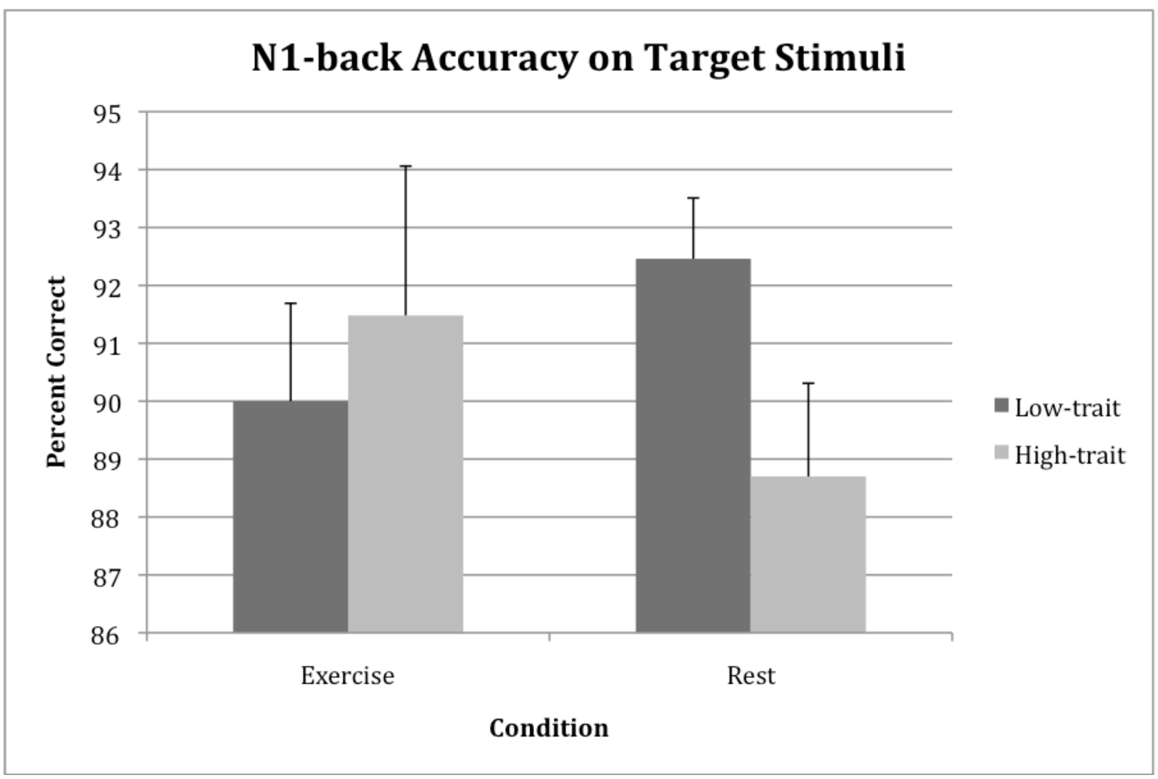

Figure 10: N1-back Accuracy on Target Stimuli
Note: High- and low-trait individuals appeared to have inverse responses to exercise and rest. Average scores for high-trait individuals were higher after exercise and lower after rest. Average scores for low-trait individuals were lower after exercise and higher after rest. However, no significant group effects were found.

Table 17. N1-back accuracy on nontarget stimuli.

CONDITION	GROUP	TIME	*M*	*SD*
EXERCISE	Low-trait	Baseline	99.19	1.16
	High-trait		99.06	0.90
	Low-trait	Immediately Post-Exercise	98.79	1.87
	High-trait		97.92	1.86
	Low-trait	50 minutes Post-Exercise	93.21	18.16
	High-trait		98.87	1.70
REST	Low-trait	Baseline	99.19	1.16
	High-trait		99.06	0.90
	Low-trait	Immediately Post-Rest	98.95	1.37
	High-trait		98.11	2.16
	Low-trait	50 minutes Post-Rest	98.79	1.53
	High-trait		97.73	1.90

Note: (Low-trait anxious n=21, High-trait anxious n=9)

Average accuracy for all nontarget trials of the N1-back task are displayed in Table 17 above. Average accuracy for nontarget trials on the N1-back task for the high-trait anxious group (M=98.46, SE=0.89) was the same as the low-trait anxious group (M=98.02, SE=0.59). No significant main effects or interactions were revealed for accuracy on Nontarget Stimuli on the N1-back task. In general, accuracy on Nontarget Stimuli on the N1-back task decreased over time. Accuracy at baseline (M=99.12, SE=0.22) was greater than accuracy immediately post-condition (M=98.44, SE=0.30), which was greater than accuracy 50 minutes post-condition (M=97.15, SE=1.57).

Table 18. N2-back accuracy on target stimuli.

CONDITION	GROUP	TIME	*M*	*SD*
EXERCISE	Low-trait	Baseline	91.90	9.42
	High-trait		92.22	7.55
	Low-trait	Immediately Post-Exercise	87.86	15.78
	High-trait		91.11	6.97
	Low-trait	50 minutes Post-Exercise	88.81	15.64
	High-trait		87.22	9.05
REST	Low-trait	Baseline	91.90	9.42
	High-trait		92.22	7.55
	Low-trait	Immediately Post-Rest	93.81	6.10
	High-trait		93.89	4.17
	Low-trait	50 minutes Post-Rest	91.43	8.82
	High-trait		89.44	10.74

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9)

Average accuracy for all Target trials of the N2-back task are displayed in Table 18 above. Average accuracy on Target Stimuli on the N2-back task for the high-trait anxious group (*M*=91.02, *SE*=2.29) was higher than the low-trait anxious group (*M*=90.95, *SE*=1.50), but this difference was not statistically significant (*p*=.981). No significant main effects or interactions were revealed for accuracy on Target Stimuli on the N2-back task. In general, accuracy on Target Stimuli on the N2-back task decreased over time. Accuracy at baseline (*M*=92.06, *SE*=1.78) was greater than accuracy immediately post-condition (*M*=91.67, *SE*=1.54), which was greater than accuracy 50 minutes post-condition (*M*=89.23, *SE*=1.82). On average, accuracy was higher after rest (*M*=92.12, *SE*=1.08) than after exercise (*M*=89.85, *SE*=2.01).

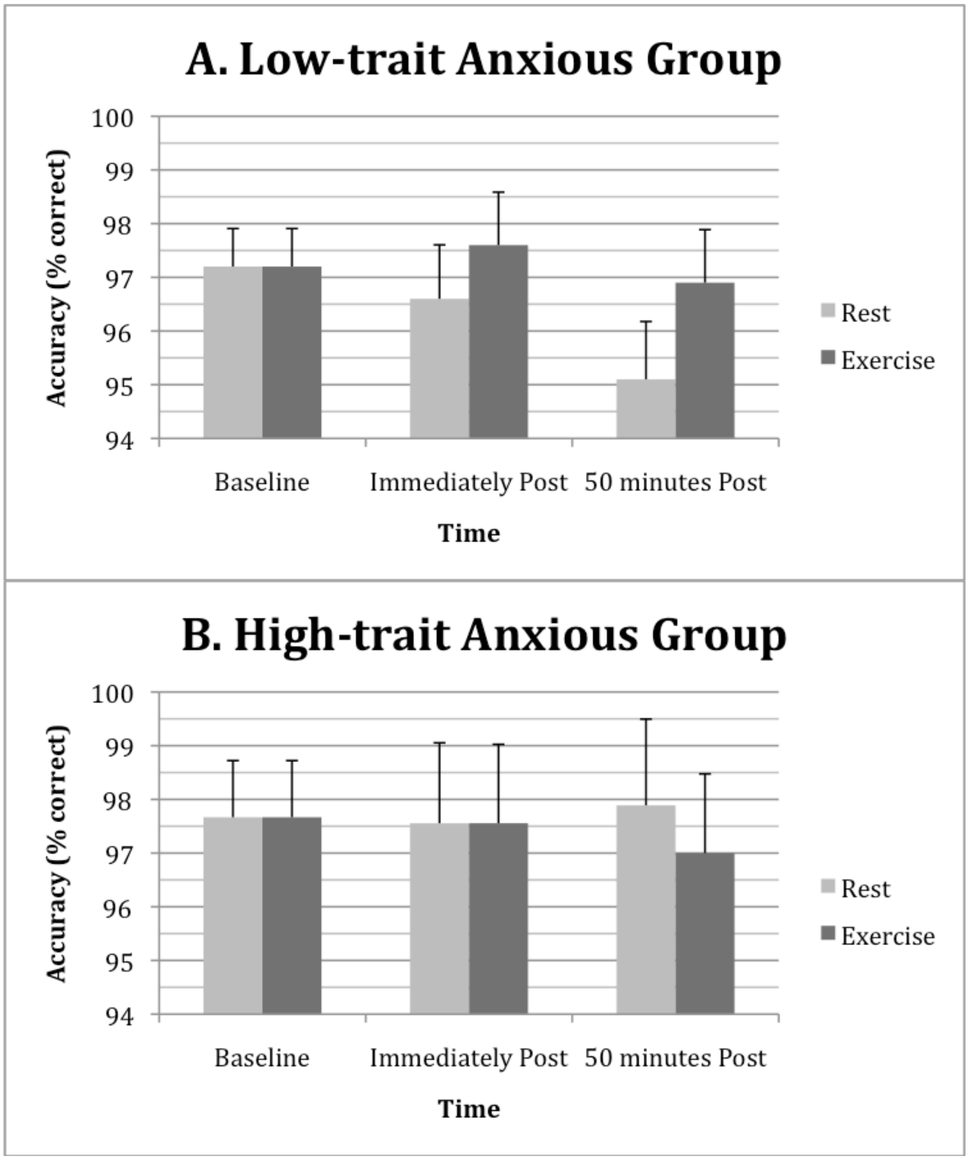

Figure 11: Accuracy on Flanker Task Over Time

Table 19. N2-back accuracy on nontarget stimuli.

CONDITION	GROUP	TIME	M	SD
EXERCISE	Low-trait	Baseline	96.16	3.74
	High-trait		94.08	4.73
	Low-trait	Immediately Post-Exercise	94.59	14.53
	High-trait		96.56	4.24
	Low-trait	50 minutes Post-Exercise	94.84	15.56
	High-trait		97.70	2.74
REST	Low-trait	Baseline	96.16	3.74
	High-trait		94.08	4.73
	Low-trait	Immediately Post-Rest	98.29	1.63
	High-trait		97.33	1.95
	Low-trait	50 minutes Post-Rest	98.20	2.14
	High-trait		97.52	2.31

Note: (Low-trait anxious n=20, High-trait anxious n=9)

Average accuracy for all nontarget trials of the N2-back task are displayed in Table 19 above. Average accuracy on Nontarget Stimuli on the N2-back task for the high-trait anxious group (M=96.21 SE=1.63) was the same as the low-trait anxious group (M=96.37, SE=1.07). No significant main effects or interactions were revealed for accuracy on Nontarget Stimuli on the N2-back task. In general, accuracy on Nontarget Stimuli on the N2-back task increased over time. Accuracy at baseline (M=95.11, SE=0.81) was lower than accuracy immediately post-condition (M=96.69, SE=1.26), which was lower than accuracy 50 minutes post-condition (M=97.07, SE=1.37). On average, accuracy was higher after rest (M=96.93, SE=0.37) than after exercise (M=95.65, SE=1.78). High-trait anxious individuals became more accurate over time, for both conditions, and low-trait anxious individuals performed better post-rest than post-exercise.

N-BACK REACTION TIME (RT)

Table 20. N0-back RT to target stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	436.35	54.26
	High-trait		416.12	33.05
	Low-trait	Immediately Post-Exercise	451.19	64.45
	High-trait		439.00	43.48
	Low-trait	50 minutes Post-Exercise	462.97	82.59
	High-trait		472.07	76.40
REST	Low-trait	Baseline	436.35	54.26
	High-trait		416.12	33.05
	Low-trait	Immediately Post-Rest	462.82	90.17
	High-trait		455.07	39.45
	Low-trait	50 minutes Post-Rest	475.99	76.51
	High-trait		461.17	79.68

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for all Target trials of the N0-back task are displayed in Table 20 above. On average, high trait individuals (*M*=443.26, *SE*=19.40) had faster RT to Target Stimuli on the N0-back task than low-trait individuals (*M*=454.28, *SE*=13.01), but the difference was not statistically significant (p= .641). Test of within-subjects effects showed a main effect of Time for RT on Target Stimuli on the N0-back task [H-F ε=0.93, F (1.87, 50.39)=12.92, p< .001, partial η^2=.32]. In general, RT on Target Stimuli on the N0-back task slowed over time. Post-hoc analysis showed that RT at baseline (*M*=426.24, *SE*=9.82) was significantly faster than immediately post-condition (*M*=452.02, *SE*=12.70, p= .003) and 50 minutes post-condition (*M*=468.05, *SE*=14.85, p< .001), and both post-condition reaction times were significantly different from each other (p= .030). On average, RT was slower after rest (*M*=451.25, *SE*=12.61) than after exercise (*M*=446.28, *SE*=11.30).

Table 21. N0-back reaction time to nontarget stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	416.79	52.48
	High-trait		392.03	44.64
	Low-trait	Immediately Post-Exercise	418.68	75.23
	High-trait		395.98	31.60
	Low-trait	50 minutes Post-Exercise	411.74	81.97
	High-trait		377.97	34.16
REST	Low-trait	Baseline	416.79	52.48
	High-trait		392.03	44.64
	Low-trait	Immediately Post-Rest	425.61	82.67
	High-trait		388.06	40.12
	Low-trait	50 minutes Post-Rest	412.79	78.77
	High-trait		396.14	67.67

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for all nontarget trials of the N0-back task are displayed in Table 21 above. Average RT to Nontarget Stimuli on the N0-back task for the high-trait anxious group (*M*=390.37, *SE*=19.52) was faster the low-trait anxious group (*M*=417.07, *SE*=13.10), but the difference was not statistically significant (*p*= .266). No significant main effects or interactions were revealed for RT to Nontarget Stimuli on the N0-back task. RT to Nontarget Stimuli on the N0-back task remained relatively the same (~400 ms) over time. On average, RT was slower after rest (*M*=405.24, *SE*=12.42) than after exercise (*M*=402.20, *SE*=11.64).

Table 22. N1-back reaction time to target stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	528.47	100.18
	High-trait		493.02	73.15
	Low-trait	Immediately Post-Exercise	517.35	133.67
	High-trait		494.27	115.99
	Low-trait	50 minutes Post-Exercise	516.89	166.81
	High-trait		481.13	72.59
REST	Low-trait	Baseline	528.47	100.18
	High-trait		493.02	73.15
	Low-trait	Immediately Post-Rest	528.23	119.09
	High-trait		505.78	83.78
	Low-trait	50 minutes Post-Rest	475.60	97.81
	High-trait		478.50	101.63

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for all Target trials of the N1-back task are displayed in Table 22 above. On average, high trait individuals (*M*=490.95, *SE*=32.98) had faster RT to Target Stimuli on the N1-back task than low-trait individuals (*M*=515.83, *SE*=21.59), but the difference was not statistically significant (*p*= .533). No significant main effects or interactions were revealed for RT to Target Stimuli on the N1-back task. Average RT to Target Stimuli on the N1-back task decreased over time. RT at baseline (*M*=559.35, *SE*=23.51) was slower than RT immediately post-condition (*M*=530.48, *SE*=27.43), which was slower than RT 50 minutes post-condition (*M*=472.76, *SE*=23.86). Unexpectedly, average RT to Target Stimuli on the N1-back task was slower after exercise (*M*=523.29, *SE*=27.89) than after rest (*M*=518.44, *SE*=21.34), but this difference was not statistically significant (*p*= .720).

Table 23. N1-back reaction time to nontarget stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	572.11	121.64
	High-trait		546.59	108.43
	Low-trait	Immediately Post-Exercise	582.30	175.31
	High-trait		477.72	93.01
	Low-trait	35 minutes Post-Exercise	540.30	197.09
	High-trait		420.72	57.73
REST	Low-trait	Baseline	572.11	121.64
	High-trait		546.59	108.43
	Low-trait	Immediately Post-Rest	553.89	146.08
	High-trait		508.02	92.21
	Low-trait	35 minutes Post-Rest	485.64	102.65
	High-trait		444.36	81.05

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for all nontarget trials of the N1-back task are displayed in Table 23 above. On average, high trait individuals (*M*=490.67, *SE*=40.02) had faster RT to Nontarget Stimuli on the N1-back task than low-trait individuals (*M*=551.06, *SE*=26.20), but the difference was not statistically significant (p= .217). Test of within-subjects effects showed a main effect of Time for RT to Nontarget Stimuli on the N1-back task [H-F ε=0.98, $F(1.95, 54.61)=24.50$, $p< .001$, partial η^2=.47]. An interaction effect was revealed for Time x Group [H-F ε=0.98, $F(1.95, 54.61)=2.90$, p= .07, partial η^2=.09] that approached significance. In general, RT to Nontarget Stimuli on the N1-back task decreased over time. Post-hoc analysis showed that RT at baseline (*M*=559.35, *SE*=23.51) was significantly faster than immediately post-condition (*M*=530.48, *SE*=27.43, p= .048) and 50 minutes post-condition (*M*=472.76, *SE*=23.86, $p< .001$), and RT immediately post-condition was significantly faster than 50-minutes post-condition ($p< .001$). Again, average RT was faster after rest (*M*=518.44, *SE*=21.34) than after exercise (*M*=523.29, *SE*=27.89).

Table 24. N2-back reaction time to target stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	831.04	288.98
	High-trait		739.54	212.52
	Low-trait	Immediately Post-Exercise	687.64	220.28
	High-trait		599.31	170.14
	Low-trait	35 minutes Post-Exercise	631.64	224.84
	High-trait		545.33	114.05
REST	Low-trait	Baseline	831.04	288.98
	High-trait		739.54	212.52
	Low-trait	Immediately Post-Rest	649.90	200.19
	High-trait		598.02	176.82
	Low-trait	35 minutes Post-Rest	610.87	213.24
	High-trait		556.52	180.69

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for all Target trials of the N2-back task are displayed in Table 24 above. On average, high trait individuals (*M*=629.71, *SE*=66.702) had faster RT to Target Stimuli on the N2-back task than low-trait individuals (*M*=707.02, *SE*=43.67), but the difference was not statistically significant (p= .340). Tests of within-subjects effects showed a significant main effect of Time for RT to Target Stimuli on the N2-back task [H-F ε=0.63, $F(1.26, 35.31)=24.62$, $p< .001$, partial η^2=.47]. In general, RT decreased over time. RT at baseline (*M*=785.29, *SE*=53.66) was significantly slower than immediately post-condition (*M*=633.72, *SE*=37.31, $p<$ .001) and 50 minutes post-condition (*M*=586.09, *SE*=37.08, $p< .001$), and RT immediately post-condition was significantly slower than 50-minutes post-condition (p= .001). Average RT was faster after rest (*M*=664.32, *SE*=39.84) than after exercise (*M*=672.42, *SE*=41.90).

Table 25. N2-back reaction time to nontarget stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	1025.83	343.30
	High-trait		902.96	256.62
	Low-trait	Immediately Post-Exercise	771.06	264.59
	High-trait		695.64	207.13
	Low-trait	35 minutes Post-Exercise	717.58	235.78
	High-trait		576.87	124.20
REST	Low-trait	Baseline	1025.83	343.30
	High-trait		902.96	256.62
	Low-trait	Immediately Post-Rest	769.81	278.91
	High-trait		659.43	175.90
	Low-trait	35 minutes Post-Rest	684.00	256.55
	High-trait		571.23	192.43

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9); (ms)=milliseconds

Average RT for all nontarget trials of the N2-back task are displayed in Table 25 above. On average, high trait individuals (*M*=718.18, *SE*=79.10) had much faster RT to Target Stimuli on the N2-back task than low-trait individuals (*M*=832.35, *SE*=51.79), but the difference was not statistically significant (*p*= .237). Tests of within-subjects effects revealed a significant main effect of Time for RT to Non-target Stimuli on the N2-back task [H-F ε=0.59, *F*(1.18, 32.95)=43.00, *p*< .001, partial η^2=.61]. RT at baseline (*M*=964.39, *SE*=63.93) was significantly slower than immediately post-condition (*M*=723.99, *SE*=46.69, *p*< .001) and 50 minutes post-condition (*M*=637.42, *SE*=42.09, *p*< .001). RT immediately post-condition was significantly slower than 50-minutes post-condition (*p*< .001). Average RT was faster after rest (*M*=768.88, *SE*=48.90) than after exercise (*M*=781.66, *SE*=47.94).

N-BACK STANDARD DEVIATION OF REACTION TIME (StdRT)

Table 26. N0-back standard deviation of RT to target stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	63.37	17.34
	High-trait		76.32	52.09
	Low-trait	Immediately Post-Exercise	74.62	39.59
	High-trait		62.41	17.96
	Low-trait	50 minutes Post-Exercise	73.47	41.77
	High-trait		88.58	62.97
REST	Low-trait	Baseline	63.37	17.34
	High-trait		76.32	52.09
	Low-trait	Immediately Post-Rest	88.54	52.89
	High-trait		92.14	47.85
	Low-trait	50 minutes Post-Rest	96.61	60.18
	High-trait		75.99	43.04

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average StdRT for all Target trials of the N0-back task are displayed in Table 26 above. On average, high trait individuals (*M*=78.63, *SE*=8.64) had greater StdRT to Target Stimuli on the N0-back task than low-trait individuals (*M*=76.66, *SE*=5.80), but the difference was not statistically significant (*p*= .852). No significant main effects or interactions were revealed for StdRT to Target Stimuli on the N0-back task. A condition main effect approached significance [H-F ε=1.00, *F*(1, 27)=3.61, *p*= .068, partial η^2=.12]. Average StdRT to Target Stimuli on the N0-back task increased over time. StdRT at baseline (*M*=69.85, *SE*=6.40) was smaller than StdRT immediately post-condition (*M*=79.43, *SE*=7.20), which was smaller than StdRT 50 minutes post-condition (*M*=83.66, *SE*=8.46). Average StdRT to Target Stimuli on the N0-back task was smaller after exercise (*M*=73.13, *SE*=5.22) than after rest (*M*=82.16, *SE*=6.18), but this difference was not statistically significant (*p*=.068). High-trait and low-trait anxious individuals had different StdRT responses to the different conditions; see Figure 12 below.

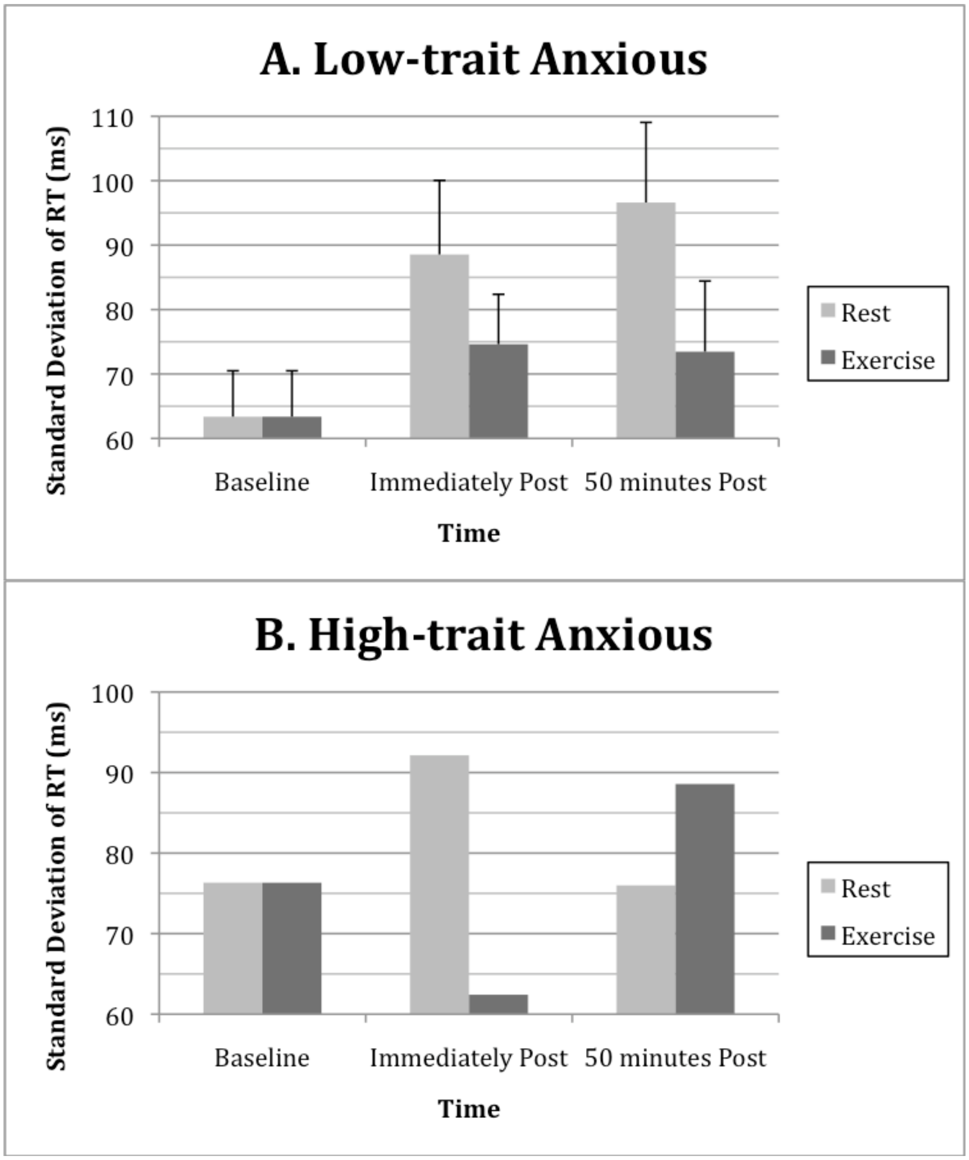

Figure 12: N0-back Standard Deviation of RT to Target Stimuli

Table 27. N0-back standard deviation of RT to nontarget stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	71.17	24.89
	High-trait		75.48	31.23
	Low-trait	Immediately Post-Exercise	77.74	31.20
	High-trait		84.46	35.86
	Low-trait	35 minutes Post-Exercise	117.75	88.84
	High-trait		102.86	61.39
REST	Low-trait	Baseline	71.17	24.89
	High-trait		75.48	31.23
	Low-trait	Immediately Post-Rest	99.82	50.19
	High-trait		79.41	20.51
	Low-trait	35 minutes Post-Rest	101.23	62.40
	High-trait		122.33	99.60

Note: (Low-trait anxious *n*=20, High-trait anxious *n*=9); (ms)=milliseconds

Average StdRT for all nontarget trials of the N0-back task are displayed in Table 27 above. On average, high trait individuals (*M*=90.00, *SE*=12.43) had about the same StdRT to Nontarget Stimuli on the N0-back task as low-trait individuals (*M*=89.811, *SE*=8.34, *p*= .990). Tests of within-subjects effects showed a significant main effect of Time for StdRT to Nontarget Stimuli on the N0-back task [H-F ε=0.69, *F*(1.38, 37.14)=6.59, *p*= .008, partial η^2=.20]. In general, StdRT increased over time. StdRT at baseline (*M*=73.32, *SE*=5.40) was significantly smaller than immediately post-condition (*M*=85.36, *SE*=6.84, *p*=.034) and 50 minutes post-condition (*M*=11.04, *SE*=14.30, *p*= .005), and StdRT immediately post-condition was significantly smaller than 50-minutes post-condition (*p*= .047).

Table 28. N1-back standard deviation of RT to target stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	124.47	44.41
	High-trait		109.89	47.28
	Low-trait	Immediately Post-Exercise	132.17	98.72
	High-trait		138.29	116.15
	Low-trait	50 minutes Post-Exercise	114.49	104.37
	High-trait		132.08	70.14
REST	Low-trait	Baseline	124.47	44.41
	High-trait		109.89	47.28
	Low-trait	Immediately Post-Rest	127.56	61.87
	High-trait		144.08	77.87
	Low-trait	50 minutes Post-Rest	114.02	61.65
	High-trait		107.80	52.30

Note: (Low-trait anxious n=21, High-trait anxious n=9); (ms)=milliseconds

Average StdRT for all Target trials of the N1-back task are displayed in Table 28 above. On average, high trait individuals (M=123.67, SE=16.50) had similar StdRT to Target Stimuli on the N1-back task to low-trait individuals (M=122.86, SE=10.80, p= .968). No significant main effects or interactions were revealed for StdRT to Target Stimuli on the N1-back task. A Condition x Group interaction approached significance [H-F ε=1.00, $F(1, 28)$=0.07, p= .079, partial η^2=.003]. Average StdRT to Target Stimuli on the N1-back task increased then decreased over time. StdRT at baseline (M=117.18, SE=9.01) increased to StdRT immediately post-condition (M=135.52, SE=14.23), and then returned to baseline StdRT 50 minutes post-condition (M=117.10, SE=14.48). Average StdRT to Target Stimuli on the N1-back task was greater after exercise (M=125.23, SE=12.65) than after rest (M=121.30, SE=8.28), but this difference was not statistically significant (p= .638).

Table 29. N1-back standard deviation of RT to nontarget stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	157.40	72.51
	High-trait		150.22	62.59
	Low-trait	Immediately Post-Exercise	192.16	108.19
	High-trait		160.20	70.25
	Low-trait	35 minutes Post-Exercise	172.38	131.49
	High-trait		103.64	32.09
REST	Low-trait	Baseline	157.40	72.51
	High-trait		150.22	62.59
	Low-trait	Immediately Post-Rest	172.93	86.31
	High-trait		181.12	104.92
	Low-trait	35 minutes Post-Rest	153.58	65.04
	High-trait		138.42	59.77

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9); (ms)=milliseconds

Average StdRT for all nontarget trials of the N1-back task are displayed in Table 29 above. On average, high trait individuals (*M*=78.63, *SE*=8.64) had slighter larger StdRT to Nontarget Stimuli on the N1-back task than low-trait individuals (*M*=76.66, *SE*=5.80 *p*= .852). No significant main effects or interactions were revealed for StdRT to Nontarget Stimuli on the N1-back task. Tests of within-subjects effects revealed a main effect of Condition for StdRT to Nontarget Stimuli on the N1-back task that approached significance [H-F ε=1.00, $F(1, 27)=3.61$ $p= .068$, partial $\eta^2=.12$]. Average StdRT to Nontarget Stimuli on the N1-back task increased over time. StdRT at baseline (*M*=69.85, *SE*=6.40) was smaller than StdRT immediately post-condition (*M*=79.43, *SE*=7.20, *p*= .267), which was smaller than StdRT 50 minutes post-condition (*M*=83.66, *SE*=8.46, *p*= .628). Average StdRT to Nontarget Stimuli on the N1-back task was smaller after exercise (*M*=73.13, *SE*=5.22) than after rest (*M*=82.16, *SE*=6.18), but this difference only approached significance (*p*= .068).

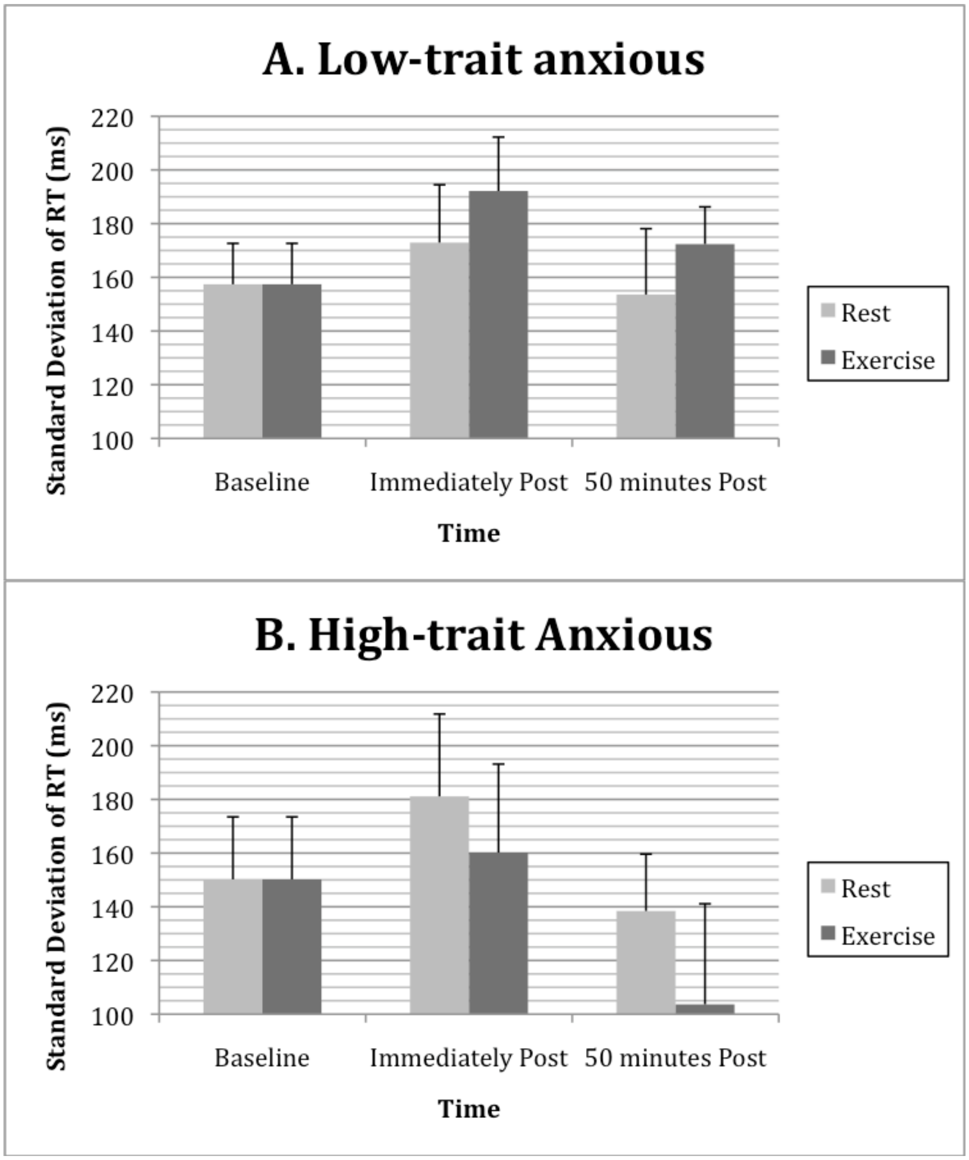

Figure 13: N1-back Standard Deviation of Reaction Time to Nontarget Stimuli

Table 30. N2-back standard deviation of RT to target stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	337.00	189.69
	High-trait		236.50	125.49
	Low-trait	Immediately Post-Exercise	268.29	152.09
	High-trait		179.27	90.81
	Low-trait	35 minutes Post-Exercise	222.54	126.11
	High-trait		163.84	35.13
REST	Low-trait	Baseline	3367.00	189.69
	High-trait		236.50	125.49
	Low-trait	Immediately Post-Rest	229.54	129.11
	High-trait		166.34	77.53
	Low-trait	35 minutes Post-Rest	264.39	159.64
	High-trait		171.10	86.02

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9); (ms)=milliseconds

Average StdRT for all Target trials of the N2-back task are displayed in Table 30 above. On average, high trait individuals (*M*=276.46, *SE*=25.66) had larger StdRT to Target Stimuli on the N2-back task than low-trait individuals (*M*=192.26, *SE*=39.20), but this difference only approached significance (*p*= .083). Tests of within-subjects effects showed a significant main effect of Time for StdRT to Target Stimuli on the N2-back task [H-F ε=0.74, *F*(1.48, 41.36)=8.30, *p*= .002, partial η^2=.23]. Post-hoc analysis revealed that StdRT at baseline (*M*=286.75, *SE*=34.62) was significantly larger than immediately post-condition (*M*=210.86, *SE*=21.17, *p*= .005) and 50 minutes post-condition (*M*=205.47, *SE*=22.29, *p*= .005). Average StdRT to Target Stimuli on the N2-back task was the same after exercise (*M*=234.57, *SE*=24.34) as after rest (*M*=234.15, *SE*=24.19, *p*= .973).

Table 31. N2-back standard deviation of RT to nontarget stimuli.

CONDITION	GROUP	TIME	*M* (ms)	*SD*
EXERCISE	Low-trait	Baseline	369.96	157.33
	High-trait		318.13	82.15
	Low-trait	Immediately Post-Exercise	286.03	137.60
	High-trait		224.59	88.67
	Low-trait	35 minutes Post-Exercise	271.08	125.60
	High-trait		221.11	70.52
REST	Low-trait	Baseline	369.96	157.33
	High-trait		318.13	82.15
	Low-trait	Immediately Post-Rest	284.23	138.06
	High-trait		213.79	82.81
	Low-trait	35 minutes Post-Rest	260.68	106.53
	High-trait		189.58	98.98

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9); (ms)=milliseconds

Average StdRT for all nontarget trials of the N2-back task are displayed in Table 31 above. On average, high-trait individuals (*M*=306.99, *SE*=23.16) had larger StdRT to Nontarget Stimuli on the N2-back task than low-trait individuals (*M*=247.56, *SE*=35.37, *p*= .171). Tests of within-subjects effects revealed a significant main effect of Time for StdRT to Nontarget Stimuli on the N2-back task [H-F ε=0.83, *F*(1.66, 46.37)=22.62 *p*< .001, partial η^2=.45]. Average StdRT to Nontarget Stimuli on the N2-back task decreased over time. StdRT at baseline (*M*=344.05, *SE*=27.90) was significantly larger than immediately post-condition (*M*=252.16, *SE*=22.18, *p*< .001) and 50 minutes post-condition (*M*=235.61, *SE*=19.29, *p*< .001). Average StdRT to Nontarget Stimuli on the N1-back task was slightly larger after exercise (*M*=281.82, *SE*=22.30) than after rest (*M*=272.73, *SE*=21.45, *p*= .429).

SCHOLASTIC APTITUDE TEST (SAT)

Table 32. Post-condition math SAT scores.

CONDITION	GROUP	M	SD
Exercise	Low-trait	6.98	2.32
	High-trait	6.53	2.23
Rest	Low-trait	6.47	2.13
	High-trait	5.42	1.98

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9)

Average math SAT scores for each condition are displayed in Table 32 above. On average, high-trait individuals (*M*=5.97, *SE*=0.67) had lower math scores than low-trait individuals (*M*=6.76, *SE*=0.44), but this difference was not statistically significant (*p*= .337). Tests of within-subjects effects revealed a significant main effect of Condition [H-F ε=1.00, *F*(1, 28)=4.73, *p*= .038, partial η^2=.14]. Average math scores following rest (*M*=5.98, *SE*=0.42) were lower than after exercise (*M*=6.75, *SE*=0.46, *p*= .038). An independent samples *t*-test showed that the change in Math SAT score from rest to exercise for high-trait individuals (mean difference=1.11) was greater than the change seen for low-trait individuals (mean difference=0.44), but this was not statistically significant [*t*(9.57)=-0.72, *p*= .491].

Table 33.Post-condition reading SAT scores.

CONDITION	GROUP	*M*	*SD*
Exercise	Low-trait	7.30	3.08
	High-trait	9.22	1.95
Rest	Low-trait	7.42	2.51
	High-trait	8.67	2.58

Note: (Low-trait anxious *n*=21, High-trait anxious *n*=9)

Average reading SAT scores for each condition are displayed in Table 33 above. On average, high-trait individuals (*M*=8.94, *SE*=0.77) had higher reading scores than low-trait individuals (*M*=7.36, *SE*=0.50), but this difference only approached significance (*p*= .094). Tests of within-subjects effects revealed a no significant main effects or interactions. An independent samples *t*-test showed that the change in Reading SAT score from rest to exercise for high-trait individuals (mean difference=0.56) was greater than the change seen for low-trait individuals (mean difference=-0.12), but this was not statistically significant [$t(13.34)=-0.59$, $p= .567$].

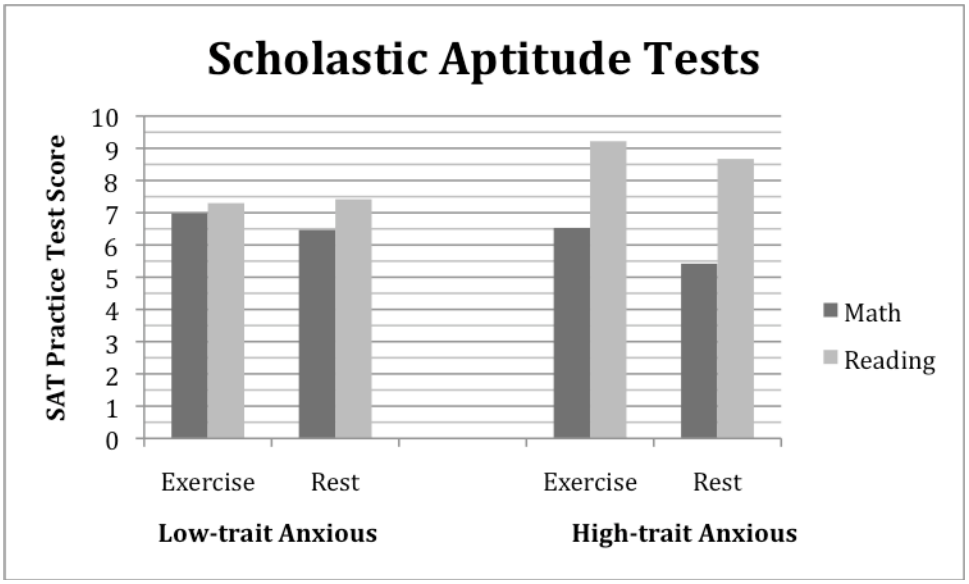

Figure 14: Math and Reading SAT Scores Across Conditions

CORRELATIONS

Correlational analysis was run on changes in SA in relation to changes in accuracy, RT, and StdRT, on all cognitive tasks. Correlational analysis was also run on post-exercise changes in SA post-exercise in relation to differences in reading and math SAT scores from the rest to the exercise condition. Correlational analysis was run on changes in all post-exercise cognitive behavioral measures of accuracy, RT, and StdRT in relation to changes in reading and math SAT scores from the rest to the exercise condition.

Please keep the following in mind while viewing the tables in this section:

For Changes in SA: Time 1=Baseline to Immediately Post, Time 2=Immediately Post to 35 minutes Post, Time 3=35 minutes Post to 70 minutes Post

For Changes in Cognitive Variables: Time 1=Baseline to Immediately Post, Time 2=Immediately Post to 50 minutes Post

RELATIONSHIPS BETWEEN CHANGES IN STATE ANXIETY (SA) & ACCURACY

Table 34. Changes in state anxiety and accuracy on Flanker task after rest.

		CONGRUENT ACCURACY		INCONGRUENT ACCURACY	
CHANGE SCORES		**Time 1**	**Time 2**	**Time 1**	**Time 2**
STATE ANXIETY Time 1	Pearson Correlation	-.135	-.060	-.260	-.171
	p-value	(.469)	(.748)	(.158)	(.357)
STATE ANXIETY Time 2	Pearson Correlation	-.237	-.253	-.118	-.215
	p-value	(.200)	(.169)	(.526)	(.246)
STATE ANXIETY Time 3	Pearson Correlation	-.058	-.181	-.065	-.137
	p-value	(.757)	(.330)	(.730)	(.461)

Note: N=31; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in Accuracy on the Flanker Task after rest, for congruent or incongruent stimuli.

Table 35. Changes in state anxiety and accuracy on Flanker task after exercise.

		CONGRUENT ACCURACY		INCONGRUENT ACCURACY	
CHANGE SCORES		**Time 1**	**Time 2**	**Time 1**	**Time 2**
STATE ANXIETY Time 1	Pearson Correlation	.167	.264	.253	.192
	p-value	(.378)	(.167)	(.177)	(.317)
STATE ANXIETY Time 2	Pearson Correlation	.169	-.016	.070	-.105
	p-value	(.371)	(.935)	(.712)	(.586)
STATE ANXIETY Time 3	Pearson Correlation	.106	.098	.173	.037
	p-value	(.579)	(.612)	(.362)	(.848)

Note: N=30 (Accuracy Time 1), N=29 (Accuracy Time 2); *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in Accuracy on the Flanker Task after exercise, for congruent or incongruent stimuli.

Table 36. Changes in state anxiety and accuracy on N0-back task after rest.

CHANGE SCORES		NONTARGET ACCURACY Time 1	NONTARGET ACCURACY Time 2	TARGET ACCURACY Time 1	TARGET ACCURACY Time 2
STATE ANXIETY Time 1	Pearson Correlation	.028	.005	-.088	-.230
	p-value	(.883)	(.978)	(.639)	(.221)
STATE ANXIETY Time 2	Pearson Correlation	.367	.265	-.032	-.058
	p-value	(**.042**)	(.156)	(.865)	(.762)
STATE ANXIETY Time 3	Pearson Correlation	.318	.257	-.033	-.124
	p-value	(.081)	(.171)	(.861)	(.513)

Note: N=31 (Accuracy Time 1), N=30 (Accuracy Time 2); *p*-values are 2-tailed tests

After rest, a significant low positive correlation was found between change in SA at Time 2 and change in N0-back nontarget accuracy at Time 1 (r= .37, p= .042). Thus, greater increases in SA from immediately post-rest to 35 minutes post-exercise were associated with greater increases in N0-back accuracy on nontarget stimuli from immediately post-rest to 50 minutes post-exercise. In other words, accuracy on nontarget trials of the N0-back task, during the first round of cognitive testing, was greater when SA increased from immediately post-rest to 35 minutes post-rest.

Table 37. Changes in state anxiety and accuracy on N0-back task after exercise.

CHANGE SCORES		NONTARGET ACCURACY Time 1	NONTARGET ACCURACY Time 2	TARGET ACCURACY Time 1	TARGET ACCURACY Time 2
STATE ANXIETY Time 1	Pearson Correlation	.358	.123	-.378	-.184
	p-value	(.052)	(.518)	(**.039**)	(.329)
STATE ANXIETY Time 2	Pearson Correlation	.273	-.091	-.199	.076
	p-value	(.144)	(.631)	(.293)	(.688)
STATE ANXIETY Time 3	Pearson Correlation	.286	-.065	-.351	-.025
	p-value	(.126)	(.733)	(.057)	(.895)

Note: N=30; *p*-values are 2-tailed tests

After exercise, a significant low negative correlation was found between change in SA at Time 1 and change in N0-back Target Accuracy at Time 1 (r= -.38, p= .039). Thus, greater decreases in SA from baseline to immediately post-exercise were associated with greater increases in N0-back accuracy on target stimuli from immediately post-exercise to 50 minutes post-exercise. In other words, accuracy on target trials of the N0-back task, during the first round of cognitive testing, was greater when SA decreased from baseline to immediately post-exercise.

Table 38. Changes in state anxiety and accuracy on N1-back task after rest.

CHANGE SCORES		NONTARGET ACCURACY Time 1	NONTARGET ACCURACY Time 2	TARGET ACCURACY Time 1	TARGET ACCURACY Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.247	.206	-.191	.001
	p-value	(.180)	(.267)	(.305)	(.996)
STATE ANXIETY Time 2	Pearson Correlation	-.077	.161	-.099	.234
	p-value	(.682)	(.387)	(.595)	(.206)
STATE ANXIETY Time 3	Pearson Correlation	.108	.521	.113	.403
	p-value	(.565)	(**.003**)	(.547)	(**.024**)

Note: N=31; *p*-values are 2-tailed tests

After rest, significant moderate positive correlations were found between change in SA at Time 3 and changes in N1-back Nontarget Accuracy (r= .52, p= .003) and N1-back Target Accuracy (r= .40 p= .024) at Time 2. Thus, greater increases in SA from 35 minutes post-rest to 70 minutes post-rest were associated with greater increases in N1-back accuracy on nontarget and target stimuli from immediately post-rest to 50 minutes post-rest. In other words, accuracy on target and nontarget trials of the N1-back task, during the second round of cognitive testing, was greater when SA increased from 35 minutes post-exercise to 70 minutes post-rest.

Table 39. Changes in state anxiety and accuracy on N1-back task after exercise.

CHANGE SCORES		NONTARGET ACCURACY Time 1	NONTARGET ACCURACY Time 2	TARGET ACCURACY Time 1	TARGET ACCURACY Time 2
STATE ANXIETY Time 1	Pearson Correlation	.064	-.190	.017	-.124
	p-value	(.737)	(.314)	(.929)	(.514)
STATE ANXIETY Time 2	Pearson Correlation	-.036	-.150	-.161	-.288
	p-value	(.849)	(.430)	(.396)	(.122)
STATE ANXIETY Time 3	Pearson Correlation	.116	-.142	-.124	-.224
	p-value	(.542)	(.455)	(.514)	(.234)

Note: N=30; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in Accuracy on the N1-back Task after exercise, for Target or Nontarget stimuli.

Table 40. Changes in state anxiety and accuracy on N2-back task after rest.

CHANGE SCORES		NONTARGET ACCURACY Time 1	NONTARGET ACCURACY Time 2	TARGET ACCURACY Time 1	TARGET ACCURACY Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.018	-.039	-.121	-.369
	p-value	(.925)	(.834)	(.516)	(**.041**)
STATE ANXIETY Time 2	Pearson Correlation	.260	.259	-.066	-.020
	p-value	(.157)	(.159)	(.724)	(.915)
STATE ANXIETY Time 3	Pearson Correlation	.057	.093	-.063	-.069
	p-value	(.762)	(.619)	(.737)	(.713)

Note: N=31; *p*-values are 2-tailed tests

After rest, a significant low negative correlation was found between change in SA at Time 1 and change in N2-back Target Accuracy at Time 2 (r= -.37, p= .041). Thus, greater decreases in SA from baseline to immediately post-rest were associated with greater increases in N2-back accuracy on target stimuli from baseline to immediately post-rest. In other words, accuracy on the N2-back task, during the second round of cognitive testing, was better when SA decreased from baseline to immediately post-rest.

Table 41. Changes in state anxiety and accuracy on N2-back task after exercise.

CHANGE SCORES		NONTARGET ACCURACY Time 1	NONTARGET ACCURACY Time 2	TARGET ACCURACY Time 1	TARGET ACCURACY Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.254	-.247	-.219	-.170
	p-value	(.175)	(.188)	(.244)	(.368)
STATE ANXIETY Time 2	Pearson Correlation	-.108	-.075	-.039	-.242
	p-value	(.571)	(.693)	(.839)	(.198)
STATE ANXIETY Time 3	Pearson Correlation	-.113	-.124	-.177	-.267
	p-value	(.553)	(.514)	(.349)	(.154)

Note: N=30; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in Accuracy on the N2-back Task after exercise, for Target or Nontarget stimuli.

RELATIONSHIPS BETWEEN CHANGES IN SA & REACTION TIME (RT)

Table 42. Changes in state anxiety and RT on Flanker task after rest.

CHANGE SCORES		CONGRUENT RT Time 1	CONGRUENT RT Time 2	INCONGRUENT RT Time 1	INCONGRUENT RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	.186	.114	.131	.166
	p-value	(.316)	(.541)	(.481)	(.371)
STATE ANXIETY Time 2	Pearson Correlation	.125	.020	.129	.069
	p-value	(.503)	(.914)	(.490)	(.714)
STATE ANXIETY Time 3	Pearson Correlation	.045	-.046	.006	-.016
	p-value	(.808)	(.807)	(.975)	(.932)

Note: N=31; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in RT on the Flanker Task after rest, for Congruent or Incongruent stimuli.

Table 43. Changes in state anxiety and RT on Flanker task after exercise.

CHANGE SCORES		CONGRUENT RT Time 1	CONGRUENT RT Time 2	INCONGRUENT RT Time 1	INCONGRUENT RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	.296	.338	.323	.398
	p-value	(.113)	(.073)	(.081)	(**.032**)
STATE ANXIETY Time 2	Pearson Correlation	.269	.249	.330	.308
	p-value	(.150)	(.193)	(.075)	(.104)
STATE ANXIETY Time 3	Pearson Correlation	.127	.188	.202	.252
	p-value	(.505)	(.328)	(.284)	(.187)

Note: N=30 (Accuracy Time 1), N=29 (Accuracy Time 2); *p*-values are 2-tailed tests

After exercise, a significant moderate positive correlation was found between change in SA at Time 1 and change in Flanker RT to Incongruent trials at Time 1 (r= .40, p= .032). Thus, greater increases in SA from baseline to immediately post-exercise were associated with greater increases in Flanker RT to incongruent stimuli from baseline to immediately post-exercise. In other words, RT on the incongruent trials of the Flanker task, during the second round of cognitive testing, was faster when SA decreased from baseline to immediately post-exercise.

Table 44. Changes in state anxiety and RT on N0-back task after rest.

CHANGE SCORES		NONTARGET RT Time 1	NONTARGET RT Time 2	TARGET RT Time 1	TARGET RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.082	-.096	-.101	.035
	p-value	(.661)	(.613)	(.587)	(.853)
STATE ANXIETY Time 2	Pearson Correlation	-.064	-.131	-.211	.059
	p-value	(.732)	(.489)	(.255)	(.755)
STATE ANXIETY Time 3	Pearson Correlation	-.079	-.278	-.202	-.094
	p-value	(.672)	(.137)	(.276)	(.620)

Note: N=31 (Accuracy Time 1), N=30 (Accuracy Time 2); *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in RT on the N0-back Task after rest, for Target or Nontarget stimuli.

Table 45. Changes in state anxiety and RT on N0-back task after exercise.

CHANGE SCORES		NONTARGET RT Time 1	NONTARGET RT Time 2	TARGET RT Time 1	TARGET RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.116	.162	-.189	-.310
	p-value	(.540)	(.393)	(.318)	(.096)
STATE ANXIETY Time 2	Pearson Correlation	.198	.384	.089	-.273
	p-value	(.294)	(**.036**)	(.642)	(.144)
STATE ANXIETY Time 3	Pearson Correlation	.051	.261	.033	-.289
	p-value	(.788)	(.164)	(.863)	(.122)

Note: N=30; *p*-values are 2-tailed tests

After exercise, a significant low positive correlation was found between change in SA at Time 2 and change in N0-back RT to Nontarget stimuli at Time 2 (r= .38, p= .036). Thus, greater increases in SA from immediately post-exercise to 35 minutes post-exercise were associated with greater increases in N0-back RT to Nontarget stimuli from immediately post-exercise to 50 minutes post-exercise. In other words, RT on the N0-Back task during the second round of cognitive testing was faster when SA decreased following exercise.

Table 46. Changes in state anxiety and RT on N1-back task after rest.

CHANGE SCORES		NONTARGET RT Time 1	NONTARGET RT Time 2	TARGET RT Time 1	TARGET RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.067	.025	.120	.178
	p-value	(.722)	(.896)	(.520)	(.337)
STATE ANXIETY Time 2	Pearson Correlation	.113	.094	.197	.223
	p-value	(.543)	(.613)	(.288)	(.229)
STATE ANXIETY Time 3	Pearson Correlation	.058	.030	.046	.058
	p-value	(.756)	(.875)	(.807)	(.758)

Note: N=31; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in RT on the N1-back Task after rest, for Target or Nontarget stimuli.

Table 47. Changes in state anxiety and RT on N1-back task after exercise.

CHANGE SCORES		NONTARGET RT Time 1	NONTARGET RT Time 2	TARGET RT Time 1	TARGET RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	.534	.504	.170	.205
	p-value	(**.002**)	(**.005**)	(.369)	(.278)
STATE ANXIETY Time 2	Pearson Correlation	.629	.346	.230	-.003
	p-value	(**.000**)	(.061)	(.221)	(.989)
STATE ANXIETY Time 3	Pearson Correlation	.545	.379	.063	.000
	p-value	(**.002**)	(**.039**)	(.741)	(1.00)

Note: N=30; *p*-values are 2-tailed tests

After exercise, significant moderate positive correlations were found between changes in SA at Times 1 and 3 and change in N1-back Nontarget RT at Time 1 (r= .53, p= .002; r= .55, p= .002). A significant moderately high positive correlation was found between changes in SA at Time 2 and change in N1-back Nontarget RT at Time 1 (r= .63, p< .001). A significant moderate positive correlation was also found between change in SA at Time 1 and change in N1-back Nontarget RT at Time 2 (r= .50, p= .005). A significant low positive correlation was found between change in SA at Time 3 and change in N1-back Nontarget RT at Time 2 (r= .38, p= .039). Thus, greater increases in SA at each time point were associated with greater increases in N1-back RT to Nontarget stimuli post-exercise between most time points. In other words, RT on the N1-Back task, during both rounds of cognitive testing, was faster when SA decreased following exercise.

Table 48. Changes in state anxiety and RT on N2-back task after rest.

CHANGE SCORES		NONTARGET RT Time 1	NONTARGET RT Time 2	TARGET RT Time 1	TARGET RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.199	-.229	-.148	-.181
	p-value	(.282)	(.216)	(.428)	(.330)
STATE ANXIETY Time 2	Pearson Correlation	-.243	-.291	-.164	-.145
	p-value	(.187)	(.112)	(.379)	(.438)
STATE ANXIETY Time 3	Pearson Correlation	-.190	-.174	-.162	-.109
	p-value	(.305)	(.349)	(.383)	(.560)

Note: N=31; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in RT on the N2-back Task after rest, for Target or Nontarget stimuli.

Table 49. Changes in state anxiety and RT on N2-back task after exercise.

CHANGE SCORES		NONTARGET RT Time 1	NONTARGET RT Time 2	TARGET RT Time 1	TARGET RT Time 2
STATE ANXIETY Time 1	Pearson Correlation	.021	.215	.199	.098
	p-value	(.912)	(.254)	(.291)	(.605)
STATE ANXIETY Time 2	Pearson Correlation	.242	.315	.297	.354
	p-value	(.197)	(.090)	(.111)	(.055)
STATE ANXIETY Time 3	Pearson Correlation	.230	.371	.300	.341
	p-value	(.222)	(**.043**)	(.107)	(.065)

Note: N=30; *p*-values are 2-tailed tests

After exercise, a significant low positive correlation was found between change in SA at Time 3 and change in N2-back RT to Nontarget stimuli at Time 2 (r= .37, p= .043). Thus, greater increases in SA from 35 minutes post-exercise to 70 minutes post-exercise were associated with greater increases in N2-back RT to Nontarget stimuli from immediately post-exercise to 50 minutes post-exercise. In other words, RT was faster when SA decreased following exercise, during the second round of cognitive testing.

RELATIONSHIPS BETWEEN CHANGES IN SA & STANDARD DEVIATION OF RT

Table 50. Changes in state anxiety and StdRT on Flanker task after rest.

CHANGE SCORES		CONGRUENT StdRT		INCONGRUENT StdRT	
		Time 1	Time 2	Time 1	Time 2
STATE ANXIETY Time 1	Pearson Correlation	.049	.021	.181	.256
	p-value	(.795)	(.909)	(.329)	(.165)
STATE ANXIETY Time 2	Pearson Correlation	-.065	-.011	.031	.160
	p-value	(.730)	(.952)	(.867)	(.389)
STATE ANXIETY Time 3	Pearson Correlation	-.089	-.061	.113	.215
	p-value	(.636)	(.744)	(.546)	(.246)

Note: N=31; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in StdRT on the Flanker Task after rest, for Congruent or Incongruent stimuli.

Table 51. Changes in state anxiety and StdRT on Flanker task after exercise.

CHANGE SCORES		CONGRUENT StdRT		INCONGRUENT StdRT	
		Time 1	Time 2	Time 1	Time 2
STATE ANXIETY Time 1	Pearson Correlation	.164	.275	-.092	.155
	p-value	(.386)	(.149)	(.628)	(.423)
STATE ANXIETY Time 2	Pearson Correlation	.351	.309	.023	.037
	p-value	(.057)	(.103)	(.902)	(.848)
STATE ANXIETY Time 3	Pearson Correlation	.167	.229	-.063	.055
	p-value	(.379)	(.233)	(.739)	(.778)

Note: N=30 (Accuracy Time 1), N=29 (Accuracy Time 2); *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in StdRT on the Flanker Task after exercise, for Congruent or Incongruent stimuli.

Table 52. Changes in state anxiety and StdRT on N0-back task after rest.

CHANGE SCORES		NONTARGET StdRT Time 1	NONTARGET StdRT Time 2	TARGET StdRT Time 1	TARGET StdRT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.162	-.102	-.080	.137
	p-value	(.384)	(.593)	(.669)	(.471)
STATE ANXIETY Time 2	Pearson Correlation	-.151	-.163	-.070	.205
	p-value	(.418)	(.390)	(.707)	(.276)
STATE ANXIETY Time 3	Pearson Correlation	-.080	-.331	-.287	-.053
	p-value	(.668)	(.074)	(.117)	(.781)

Note: N=31 (Accuracy Time 1), N=30 (Accuracy Time 2); *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in StdRT on the N0-back Task after rest, for Target or Nontarget stimuli.

Table 53. Changes in state anxiety and StdRT on N0-back task after exercise.

CHANGE SCORES		NONTARGET StdRT Time 1	NONTARGET StdRT Time 2	TARGET StdRT Time 1	TARGET StdRT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.281	.271	.044	-.158
	p-value	(.133)	(.148)	(.817)	(.404)
STATE ANXIETY Time 2	Pearson Correlation	.173	.293	.230	-.057
	p-value	(.362)	(.116)	(.222)	(.764)
STATE ANXIETY Time 3	Pearson Correlation	.031	.150	.075	-.051
	p-value	(.870)	(.427)	(.692)	(.788)

Note: N=30; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in StdRT on the N0-back Task after exercise, for Target or Nontarget stimuli.

Table 54. Changes in state anxiety and StdRT on N1-back task after rest.

CHANGE SCORES		NONTARGET StdRT Time 1	NONTARGET StdRT Time 2	TARGET StdRT Time 1	TARGET StdRT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.311	-.197	-.014	.163
	p-value	(.088)	(.287)	(.939)	(.381)
STATE ANXIETY Time 2	Pearson Correlation	-.062	-.175	.182	.033
	p-value	(.741)	(.346)	(.328)	(.860)
STATE ANXIETY Time 3	Pearson Correlation	-.134	-.168	-.112	-.046
	p-value	(.474)	(.365)	(.548)	(.808)

Note: N=31; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in StdRT on the N1-back Task after rest, for Target or Nontarget stimuli.

Table 55. Changes in state anxiety and StdRT on N1-back task after exercise.

CHANGE SCORES		NONTARGET StdRT Time 1	NONTARGET StdRT Time 2	TARGET StdRT Time 1	TARGET StdRT Time 2
STATE ANXIETY Time 1	Pearson Correlation	.377	.321	.190	.108
	p-value	(**.040**)	(.084)	(.315)	(.571)
STATE ANXIETY Time 2	Pearson Correlation	.431	.153	.390	.173
	p-value	(**.017**)	(.420)	(**.033**)	(.361)
STATE ANXIETY Time 3	Pearson Correlation	.276	.168	.197	.135
	p-value	(.140)	(.375)	(.297)	(.477)

Note: N=30; *p*-values are 2-tailed tests

After exercise, a significant low positive correlation was found between change in SA at Time 1 and change in N1-back StdRT to Nontarget stimuli at Time 1 (r= .38, p= .040). After exercise, significant moderate positive and low positive correlations were also found between the change in SA at Time 2 and changes in N1-back StdRT to Nontarget stimuli at Time 1 (r= .43, p= .017) and N1-back StdRT to Target stimuli at Time 2 (r= .39, p= .033), respectively. Thus, greater increases in SA from baseline to immediately post-exercise or immediately post-exercise to 35 minutes post-exercise were associated with greater increases in N1-back StdRT to Nontarget stimuli from baseline to immediately post-exercise. Greater increases in SA from immediately post-exercise to 35 minutes post-exercise were associated with greater increases in N1-back StdRT to Target stimuli from baseline to immediately post-exercise. In other words, response time variability on the N1-Back task during the first round of cognitive testing was smaller when SA decreased following exercise.

Table 56. Changes in state anxiety and StdRT on N2-back task after rest.

CHANGE SCORES		NONTARGET StdRT Time 1	NONTARGET StdRT Time 2	TARGET StdRT Time 1	TARGET StdRT Time 2
STATE ANXIETY Time 1	Pearson Correlation	-.175	-.253	-.175	-.215
	p-value	(.348)	(.170)	(.345)	(.245)
STATE ANXIETY Time 2	Pearson Correlation	-.092	-.340	-.041	-.102
	p-value	(.624)	(.061)	(.827)	(.586)
STATE ANXIETY Time 3	Pearson Correlation	.118	-.112	-.081	-.089
	p-value	(.528)	(.548)	(.666)	(.634)

Note: N=31; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in StdRT on the N2-back Task after rest, for Target or Nontarget stimuli.

Table 57. Changes in state anxiety and StdRT on N2-back task after exercise.

CHANGE SCORES		NONTARGET StdRT Time 1	NONTARGET StdRT Time 2	TARGET StdRT Time 1	TARGET StdRT Time 2
STATE ANXIETY Time 1	Pearson Correlation	.010	.072	.196	.031
	p-value	(.958)	(.704)	(.299)	(.872)
STATE ANXIETY Time 2	Pearson Correlation	-.031	.236	.215	.315
	p-value	(.870)	(.210)	(.254)	(.090)
STATE ANXIETY Time 3	Pearson Correlation	-.011	.189	.173	.255
	p-value	(.955)	(.318)	(.361)	(.173)

Note: N=30; *p*-values are 2-tailed tests

No significant correlations were found between changes in SA and changes in StdRT on the N2-back Task after exercise, for Target or Nontarget stimuli.

RELATIONSHIPS BETWEEN CHANGES IN SA & SCHOLASTIC APTITUDE TEST

Table 58. Changes in state anxiety post-exercise and SAT scores from rest to exercise.

CHANGE SCORES		READING	MATH
STATE ANXIETY Time 1	Pearson Correlation	.019	.348
	p-value	(.919)	(.059)
STATE ANXIETY Time 2	Pearson Correlation	.100	.386
	p-value	(.599)	(**.035**)
STATE ANXIETY Time 3	Pearson Correlation	.212	.425
	p-value	(.260)	(**.019**)

Note: N=30; *p*-values are 2-tailed tests

After exercise, significant low positive correlation was found between change in SA at Time 2 and change in Math SAT score from the resting day to the exercise day (r= .39, p= .035). A significant moderate positive correlation was found between change in SA at Time 3 and change in Math SAT score from the resting day to the exercise day (r= .43, p= .019). Thus, greater increases in SA from immediately post-exercise to 35 minutes post-exercise and 35 minutes post-exercise to 70 minutes post-exercise were associated with greater increases in SAT Math scores from rest to exercise days. In other words, Math SAT scores were greater when SA increased from immediately post-exercise to 35 minutes post-exercise and 35 minutes post-exercise to 70 minutes post-exercise.

Table 59. Cognitive behavioral changes for Flanker task after exercise and SAT scores.

CHANGE SCORES			READING	MATH
CONGRUENT ACCURACY	Time 1	Pearson Correlation	.325	-.009
		p-value	(.079)	(.964)
	Time 2	Pearson Correlation	.183	.009
		p-value	(.342)	(.964)
INCONGRUENT ACCURACY	Time 1	Pearson Correlation	.308	.133
		p-value	(.098)	(.482)
	Time 2	Pearson Correlation	.236	.075
		p-value	(.217)	(.698)
CONGRUENT StdRT	Time 1	Pearson Correlation	-.296	.294
		p-value	(.113)	(.115)
	Time 2	Pearson Correlation	-.215	.262
		p-value	(.263)	(.169)
INCONGRUENT RT	Time 1	Pearson Correlation	-.334	-.019
		p-value	(.071)	(.920)
	Time 2	Pearson Correlation	-.556	.092
		p-value	(**.002**)	(.634)
CONGRUENT RT	Time 1	Pearson Correlation	-.349	.071
		p-value	(.059)	(.710)
	Time 2	Pearson Correlation	-.331	.109
		p-value	(.080)	(.575)
INCONGRUENT RT	Time 1	Pearson Correlation	-.317	-.066
		p-value	(.088)	(.728)
	Time 2	Pearson Correlation	-.361	.067
		p-value	(.054)	(.730)

Note: N=29 for Time 1, N=30 for Time 2; *p*-values are 2-tailed tests

After exercise, a significant moderate negative correlation was found between change in StdRT to Incongruent stimuli on the Flanker Task at Time 2 and change in Reading SAT score (r= -.56, p= .002). No significant correlations were found between changes in any of the cognitive behavioral measures for the Flanker task in relation to the Math SAT score.

Table 60. Cognitive behavioral changes for N0-back task after exercise and SAT scores.

CHANGE SCORES			READING	MATH
NONTARGET ACCURACY	Time 1	Pearson Correlation	-.014	.029
		p-value	(.943)	(.879)
	Time 2	Pearson Correlation	.345	-.002
		p-value	(.062)	(.990)
TARGET ACCURACY	Time 1	Pearson Correlation	-.020	-.035
		p-value	(.915)	(.853)
	Time 2	Pearson Correlation	.096	.150
		p-value	(.615)	(.429)
NONTARGET StdRT	Time 1	Pearson Correlation	.091	-.054
		p-value	(.632)	(.775)
	Time 2	Pearson Correlation	.238	.303
		p-value	(.205)	(.103)
TARGET StdRT	Time 1	Pearson Correlation	-.001	.067
		p-value	(.995)	(.726)
	Time 2	Pearson Correlation	.404	-.103
		p-value	(**.027**)	(.589)
NONTARGET RT	Time 1	Pearson Correlation	.237	-.106
		p-value	(.207)	(.578)
	Time 2	Pearson Correlation	.394	.216
		p-value	(**.031**)	(.252)
TARGET RT	Time 1	Pearson Correlation	.263	.097
		p-value	(.161)	(.609)
	Time 2	Pearson Correlation	.363	-.084
		p-value	(**.049**)	(.658)

Note: N=30; *p*-values are 2-tailed tests

After exercise, a significant moderate positive correlation was found between change in N0-back StdRT to Target stimuli at Time 2 and change in Reading SAT score (r= .40, p= .027). Significant low positive correlations were found between change in N0-back RT to Target stimuli at Time 2 and change in Reading SAT score (r= .39, p= .031) and change in N0-back RT to Nontarget RT at Time 2 and change in Reading SAT score (r= .36, p= .049). No significant correlations were found between changes in accuracy for the N0-back task in relation to the Math SAT score.

Table 61. Cognitive behavioral changes for N1-back task after exercise and SAT scores.

CHANGE SCORES			READING	MATH
NONTARGET ACCURACY	Time 1	Pearson Correlation	-.070	-.156
		p-value	(.714)	(.412)
	Time 2	Pearson Correlation	-.227	.028
		p-value	(.227)	(.884)
TARGET ACCURACY	Time 1	Pearson Correlation	-.073	-.091
		p-value	(.700)	(.633)
	Time 2	Pearson Correlation	-.269	-.020
		p-value	(.150)	(.915)
NONTARGET StdRT	Time 1	Pearson Correlation	.210	.140
		p-value	(.266)	(.460)
	Time 2	Pearson Correlation	.150	-.046
		p-value	(.428)	(.808)
TARGET StdRT	Time 1	Pearson Correlation	.217	.175
		p-value	(.249)	(.354)
	Time 2	Pearson Correlation	.244	.143
		p-value	(.194)	(.452)
NONTARGET RT	Time 1	Pearson Correlation	.305	.358
		p-value	(.101)	(.052)
	Time 2	Pearson Correlation	.274	.131
		p-value	(.143)	(.491)
TARGET RT	Time 1	Pearson Correlation	.356	.171
		p-value	(.053)	(.366)
	Time 2	Pearson Correlation	.474	-.035
		p-value	(**.008**)	(.855)

Note: N=30; *p*-values are 2-tailed tests

After exercise, a significant moderate positive correlation was found between change in N1-back RT to Target stimuli at Time 2 and change in Reading SAT score (r= .47, p= .008). No significant correlations were found between changes in any of the cognitive behavioral measures for the N1-back task in relation to the Math SAT score.

Table 62. Cognitive behavioral changes for N2-back task post-exercise and SAT scores.

CHANGE SCORES			READING	MATH
NONTARGET ACCURACY	Time 1	Pearson Correlation	-.142	-.041
		p-value	(.454)	(.831)
	Time 2	Pearson Correlation	-.153	-.044
		p-value	(.420)	(.819)
TARGET ACCURACY	Time 1	Pearson Correlation	.007	-.120
		p-value	(.969)	(.527)
	Time 2	Pearson Correlation	-.178	.013
		p-value	(.347)	(.945)
NONTARGET StdRT	Time 1	Pearson Correlation	.253	-.233
		p-value	(.177)	(.216)
	Time 2	Pearson Correlation	.117	-.041
		p-value	(.537)	(.828)
TARGET StdRT	Time 1	Pearson Correlation	.252	.155
		p-value	(.179)	(.413)
	Time 2	Pearson Correlation	-.024	.213
		p-value	(.901)	(.258)
NONTARGET RT	Time 1	Pearson Correlation	.255	.182
		p-value	(.174)	(.335)
	Time 2	Pearson Correlation	.210	.286
		p-value	(.265)	(.125)
TARGET RT	Time 1	Pearson Correlation	.306	.192
		p-value	(.100)	(.309)
	Time 2	Pearson Correlation	.230	.320
		p-value	(.221)	(.085)

Note: N=30; *p*-values are 2-tailed tests

No significant correlations were found between changes in any of the cognitive behavioral measures for the N2-back task in relation to either Reading or Math SAT scores.

CHAPTER 5

DISCUSSION

The broad goals of this study were to create a better understanding of the relationship between cognition, exercise, and anxiety, expand the literature base, and benefit the general public. The study was specifically designed to investigate whether or not aerobic exercise has the ability to reduce anxiety levels associated with testing situations, and whether or not such reductions are associated with acute enhancements in cognitive functioning. Results from this experiment can hopefully provide knowledge necessary for establishing behavioral strategies for students with anxiety to help them perform to their greatest academic abilities.

PARTICIPANTS

Originally, 35 individuals wanted to participate in the study. Unfortunately, five dropped out of the study before completing all three visits (all were low-trait anxious). These five had significantly lower fitness levels [VO2peak was significantly lower (p=0.036) in those who did not complete the study (Mean=45.08, SE=1.85) than those who did (Mean=51.06, SE=1.77)]. Thus, it is possible that these individuals may have left the study due to negative feelings towards exercise following the incremental exercise test to volitional exhaustion. It is also suspected that high-trait individuals both did not drop out and did not join as often, because of their personalities. Mathews and Mackintosh described anxious individuals as ones who have a greater likelihood of reaching a pessimistic interpretation of ambiguous events (1998). Although fewer high-trait anxious individuals decided to partake in the study at all, it is possible that those who did felt personal motivations to complete something that they had dedicated themselves to, more so than low-trait anxious individuals. High-trait anxious individuals have also been described as people who are able to perform well when they know what is expected of them in an academic setting (Peterson, 1977). The uneven sample sizes for the two groups, high- and low-trait anxious individuals, were not desirable; however, it was not unexpected. An inverse relationship was found between trait anxiety scores and willingness to participate in phase I clinical trials (Almeida et al., 2008) and could also explain why high trait anxious individuals were less likely to want to exercise in this study.

Participants were college-aged (*M*=21.14, *SD*=2.13) individuals, many who were kinesiology majors and/or exercised on a regular basis, which may have resulted in a biased sample. Overall, the individuals who participated in this study had $VO_{2\ peaks}$ averaging (*M*=54.06, *SD*=8.44) and (*M*=44.06, *SD*=9.23), for low-trait and high-trait anxious individuals, respectively. The participants in this study placed in the 90^{th} percentile based on normative VO_{2max} values for men (51.4 $mL \bullet kg^{-1} \bullet min^{-1}$) and women (44.2 $mL \bullet kg^{-1} \bullet min^{-1}$) between the ages of 20 and 29 (The Physical Fitness Specialist Certification Manual as cited in "Predicting your…", 2007; refer to Table 1). Through talking with participants before and after their testing sessions, it became apparent that many enjoyed exercising (many were kinesiology majors, had friends in kinesiology, or played sports). Thus, these individuals were mostly regular exercisers with high levels of aerobic fitness. It is possible that acute aerobic exercise would have greater capacity for enhancing cognitive function in individuals who do not perform regular aerobic exercise and/or have lower fitness levels. This concern is diminished by previous research, which has shown that fitness level does not mediate the way in which trait anxiety influences physical responses (i.e., HR) to cognitive stressors post-exercise (Sedlock & Duda, 1994). Thus, inherent anxiety levels may also be responsible for an individual's psychological responses to a cognitive stressor post-exercise.

There were a few group-specific differences between those considered high-trait anxious and those considered low-trait anxious. Of all participants (*N*=30) who completed the study. 53% were male (*n*=16) and 47% were female (*n*=14), but the percentage of females in the high-trait anxious group (67%) was slightly greater than in the low-trait anxious group (62%) (refer to Table 3). This was expected, as a prior meta-analysis of gender differences in personality found that females report slightly higher scores on anxiety scales than men (Feingold, 1994). The high-trait group was also less fit (in terms of VO_{2peak} and VT) than the low-trait anxious group. This was expected, as those with higher trait anxiety tend to report less physical activity (Kavussanu & McAuley, 1995) than low-trait anxious individuals, and would most likely be less fit.

High-trait anxious individuals had lower average GPAs than the low-trait anxious individuals (refer to Table 3); yet, both average GPAs were above 3.0, and representative of above average college students, who characteristically have had to hold and maintain high academic achievement levels to attain such a level of education. It is possible that a subset of the high-trait anxious group may have test anxiety, as high-trait anxious individuals had the two lowest and two highest GPAs of the entire sample, but this is merely speculation. It is interesting that although high-trait anxious individuals had lower GPAs, they did have higher average ACT scores (refer to Table 3).

STATE ANXIETY

Exercise did seem to effectively reduce SA for high-trait anxious individuals. As hypothesized, SA of the high-trait anxious group decreased significantly more from baseline to immediately post-exercise than it did for the low-trait anxious group (as the low-trait group had a very slight increase). Similar results have been shown in intervention studies of aerobic exercise and anxiety. Steptoe, Edwards, Moses, and Mathews (1989) found greater reductions in SA in high-trait individuals following an aerobic training program than following a strength and flexibility program for the same amount of time. Cronin (2005) found that high-trait anxious women had lower SA following weeks in which they participated in more aerobic exercise, while low-trait anxious women did not seem to show any significant pattern for SA change in relation to their aerobic exercise participation; their SA was relatively low on average. Overall, the high-trait anxious group had higher average SA than the low-trait anxious group. This makes sense, because "trait anxiety can be described as a susceptibility to respond to situations perceived as threatening with an increased level of state anxiety" (Bowers, Weaver, & Morgan, 1996, p. 173).

Not too surprisingly, SA in both groups increased during the cognitive testing portions of the testing sessions. It is interesting to note that on exercise days, SA in the high-trait anxious group dropped significantly more than it did for the low-trait anxious group between the 35 minute post-condition assessment and the end of the lab visit. It is possible that the anxiolytic effect of exercise was still present 70 minutes post-exercise, as it has been shown to last 120 minutes in previous studies (Raglin & WIlson, 1996). By introducing stressors such as the cognitive tests and SAT exams, anxiety reduction due to participation in exercise may have been blunted at the 35-minute post-exercise assessment. Testing them too early post-exercise could have been counterproductive to the anxiety-reduction process. Future research in this area may want to consider postponing any cognitive testing until this 70-minute post-exercise time point to see if SA still increases as much during testing, or if it remains at lower levels similar to low-trait anxious controls. This decrease in SA at the end of the testing session could also be contributed to participants' relief that testing was over for the day. Although this feeling of "relief" may or may not be the basis for the reductions seen at the end of the testing sessions, it is most likely not the cause for anxiety reductions seen immediately post-exercise (Petruzzello, 1995). Subjective responses from the participants reinforced this speculation. Regardless of group, most participants mentioned that they were relieved that testing was done for the day. This same relationship was not as profound for the low-trait anxious group, but that is mainly because their SA levels did not fluctuate much from assessment to assessment (refer to Figure 6). On the exercise days, SA showed a trend for being lower 70 minutes post-activity than on rest days. SA levels fluctuated much more for the high-trait anxious group than the low-trait anxious group.

It is possible that the 20-item SAI would have been more sensitive to subtle changes in SA for both groups, but due to the already lengthy testing sessions, it was in the best interests of both the participants and researchers to keep the assessments short, thus preventing negative attitudes from the participants and subsequent careless completion of the tasks due to loss of interest. As mentioned in the "Results" section, SA changes could have varied for individuals based on their experience with exercise on a treadmill (increased or decreased SA depending) or with how taking exams and doing computer tests affected them emotionally.

FLANKER TASK AND INHIBITION

FLANKER ACCURACY

Average accuracy on all trials combined was around 93%, for all participants. Accuracy on incongruent tasks was around 87% for low-trait anxious and 90% for high-trait anxious. Accuracy on congruent tasks was around 97% for all. On both congruent and incongruent trials, high-trait anxious individuals were slightly, but not significantly, more accurate than low-trait anxious individuals. On rest days, there was a trend for the low-trait anxious group to become less accurate from 0 to 50 minutes post-rest, while the high-trait anxious group showed a very slight increase. Accuracy showed an increasing trend from baseline to post-condition for both groups on exercise days.

FLANKER REACTION TIME

As expected, RT to incongruent stimuli was relatively slower than to congruent stimuli for both groups, presumably because incongruent flankers distract the individual from the task at hand resulting in decreased performance (Hommel, 2003). There was a trend for the high-trait anxious group to have faster average RT to both congruent and incongruent trials than the low-trait anxious group, but this occurred without respect to the exercise manipulation. Regardless of condition, both groups responded more quickly over time and average RT for congruent trials was significantly faster immediately post-condition than 50 minutes post-condition (refer to Figure 7; p=.006). Post-exercise, there was a trend for the high-trait anxious group to respond faster than post-rest on congruent trials, while the low-trait anxious group responded at about the same speed after both conditions. This reached significance for incongruent trials. In this case, exercise appeared to facilitate only the performance of high-trait, but not low-trait, anxious individuals. This could lend support to the idea that anxious individuals are cognitively impaired by their higher levels of anxiety (Gualtieri & Morgan, 2008) and that exercise may be the behavior that could diminish this impairment. RT on incongruent trials decreased significantly over time, as well (refer to Figure 8). This increase in speed could be explained by either a practice/learning effect or a desire to quickly finish the testing session. Although arousal has been postulated as one of the reasons for decreased RT post-exercise (Davranche, Hall, & McMorris, 2009), it did not appear to be the case here, as RT still decreased following rest. RT was faster for all individuals post-condition as compared to baseline (refer to Figure 9), suggesting that even though participants were given practice sessions prior to baseline assessment, they still were not performing to their best abilities on Day 1. High-trait anxious individuals showed a trend for having faster average RT for all Flanker trials. There was a trend for high-trait anxious individuals' RT to continuously decrease over time post-exercise, while low-trait individuals' RT began to return to baseline 50 minutes post.

FLANKER STANDARD DEVIATION OF REACTION TIME

There was a trend for high-trait anxious individuals to have slightly greater variability in response time than low-trait anxious individuals for all Flanker trials. In general, StdRT on congruent trials was significantly smaller post-condition and this same general pattern approached significance on incongruent trials. For incongruent trials, StdRT was smaller, especially after exercise as compared to rest, and this same trend appeared for congruent trials. The high-trait anxious group had a greater reduction in StdRT to congruent trials immediately following exercise (~8 ms more) and rest (~3 ms more) than the low-trait anxious group. The high-trait anxious group also had a slight increase in StdRT to incongruent trials immediately following rest (~3 ms) while the low-trait anxious group had a slight decrease (~3 ms); however, these differences were not statistically significant. Overall StdRT (a) decreased from baseline and was significantly different at all time points, and (b) was significantly lower after exercise than rest. Thus, exercise did appear to reduce response variability. This decrease in response variability following exercise could be attributed to increases in attentional control as this has been posited to be impaired by anxiety (Eysenck, Derakshan, Santos, & Calvo, 2007), and attentional resources appera to be enhanced through acute aerobic exercise (Tomporowski, 2003).

INHIBITION

Processing speed, attention, memory, and executive control processes have been examined in relation to acute exercise, and the most commonly studied executive control process in the acute exercise literature is inhibition (Hillman et al., 2009). Basten, Steizel, and Fiebach

(2011) found high-trait anxious individuals to have generally impaired attentional control and neural processing efficiency in relation to their low-anxious counterparts when performing a Stroop inhibition task. The Flanker task was chosen for this study to see how individuals could handle conflict created by the presence of distracters (incongruent stimuli). Previous work has shown the incongruent stimuli influence response inhibition in an unfavorable manner, ultimately making the response more difficult for the individual under such conditions (Takezawa & Miyatani, 2005). Researchers studying emotion and cognition have also discovered an additional level of conflict, that which arises from a person's anxiety levels (i.e., more anxiety, more conflict). It was thought that participation in a bout of acute aerobic exercise prior to confronting such a situation would help the individual to clear their mind, preparing them to handle the conflict more easily and enhance response performance (i.e., reduce RT without sacrificing accuracy).

Takezawa and Miyatani (2005) had similar results, as they found that RT to incongruent stimuli was longer than for congruent stimuli. They also found that RT to congruent trials was slower following incongruent trials and that incongruent trials were faster if they were following other incongruent trials, as the individual had become aware that conflict was present (Takezawa & Miyatani, 2005). The multiple choice questions of the SAT exams were meant to act as practical assessments of response inhibition, as each of these provided multiple distracting responses, as well as a correct answer. It would seem that multiple-choice questions with responses that are more alike would present greater conflict and result in worse response inhibition by the individual trying to answer that question. This was not analyzed in the current study, but would be a fruitful avenue for future research.

N-BACK TASK AND WORKING MEMORY

N-BACK ACCURACY

No differences in N0-back accuracy for target or nontarget trials were present in either group, and accuracy for target stimuli was worse than for nontarget stimuli. Based on the present results, it seemed as if the N0-back and N1-back tasks were too easy, resulting in a ceiling effect for performance on the nontarget trials, and was not sensitive enough to induce group differences in performance. Regarding N1-back target accuracy, high-trait anxious individuals performed worse after rest than exercise, while the opposite was seen in low-trait anxious individuals (but this relationship only approached significance; refer to Figure 10). For N2-back target trials, accuracy was worse than for N0-back and N1-back trials, and seemed to be worse over time post-condition, especially after exercise. Subjective responses from the participants suggested that the N2-back task was very difficult, to the point that some participants feared task completion. It is possible that the 2 shape N-back test was too difficult for both groups (high and low-trait anxious individuals); therefore, it was so difficult that it was impossible to see any significant differences in performance between the two. However, this seems unlikely, as accuracy was still in the upper 90th percentile for both groups and for N2-back nontarget trials, accuracy seemed to increase over time post-condition.

N-BACK REACTION TIME (RT)

In general, high trait anxious individuals had faster RTs to target and nontarget stimuli on the N0-back, N1-back, and N2-back tasks than low-trait anxious individuals, but the differences were not statistically significant. In general, RTs on target stimuli on the N0-back task increased (slowed) significantly over time from baseline at all time points, whereas, RTs to nontarget stimuli on the N0-back task remained relatively constant over time. The faster RT suggests that high-trait anxious individuals may have had greater motivation to complete the task or had experienced increased arousal, provoked by increased anxiety during the task, leading to the tendency for faster RTs. Conversely, there was a trend for average RT to both nontarget and target stimuli on the N1-back and N2-back tasks to become faster over time, although only significantly in some instances. Unexpectedly, average RT to both target and nontarget stimuli on the N1-back and N2-back tasks was slower after exercise than after rest, but these differences were not statistically significant.

N-BACK STANDARD DEVIATION OF REACTION TIME (StdRT)

In regards to response variability, the two anxiety groups had very different temporal responses to target stimuli on the N0-back task, (refer to Figure 12). Low-trait anxious individuals had increased response variability post-condition. Response variability was especially larger than baseline after the rest condition. High-trait anxious individuals also had increased response variability immediately post-rest, but this returned to baseline 50 minutes post-rest. Their response variability dropped below baseline (~15 ms) following exercise and then increased above baseline (~15 ms) at 50 minutes post-exercise.

On average, high trait anxious individuals had similar StdRT to target and nontarget stimuli on the N1-back task compared to low-trait anxious individuals. Average StdRT to target and nontarget stimuli on the N1-back task became larger immediately post-condition and then decreased 50 minutes post-condition. This decrease took the low-trait anxious individuals back towards baseline after both rest and exercise, while the decrease took high-trait anxious individuals down below baseline post-exercise (refer to Figure 13).

There was a trend for high-trait anxious individuals to have greater response variability to target and nontarget stimuli on the N2-back task than low-trait anxious individuals. Average response variability to target and nontarget stimuli on the N2-back task was significantly smaller post-condition than at baseline. The greater response variability could suggest that high-trait anxious individuals may have been distracted by conflicting thoughts during the task about issues completely unrelated to the task at hand or possible worries about how their ultimate performance would turn out (Wine, 1971).

WORKING MEMORY

Working memory deals with one's ability to use and manipulate available information to make needed decisions and both men and women with higher levels of anxiety seem to have decision-making impairments that may manifest differently (de Visser, van der Knaap, van de Loo, van der Weerd, & van den Bos, 2010). It is believed that performance on the N-back task will be better if working memory is functioning well because the individual will be able to hold information in short term memory for quick recall and be able to apply that knowledge reserve to make the appropriate choice. A meta-analysis of acute exercise and cognitive performance found exercise to be associated with generally improved performance, with larger weighted effect sizes for tasks involving memory than either executive function or information-processing time tasks (Lambourne & Tomporowski, 2010). These positive effects seem to occur for response speed but not accuracy on working memory tasks (for a meta-analytic review see McMorris, Sproule, Turner, & Hale, 2011).

In the current study, the N-back task relied on a simple right or left click on a keypad to demonstrate the much more profound cognitive paradigm of working memory. An impromptu essay about a video shown to a participant X minutes in the past may have been able to more thoroughly test differences in working memory between groups; however, such a test would also be much more difficult to assess.

The effects of trait anxiety may be fairly complicated. It appears that high trait-anxious individuals have differential working memory capacity depending on the stress level of the condition (Sorg & Whitney, 2004). Sorg and Whitney (2004) used a reading span task requiring memory storage and manipulation to assess performance in high- and low-trait anxious individuals. In the high-stress condition, high-trait anxious individuals performed worse than low-trait anxious individuals; however, the opposite occurred for the low-stress condition. Thus, it is plausible that the high-trait anxious individuals in the present study were experiencing transient levels of stress during the cognitive and academic assessments. Furthermore, these stress levels could have varied at the individual level. Since stress levels were not measured during this study, it is difficult to know how this may have played a role in the current experiment. The increased SA levels seen between round 1 and round 2 of cognitive testing do seem to reflect a worsening of mood, which could have been attributable to stress. With test anxiety, specifically, working memory capacity appears to be diminished on more difficult problems, as these individuals are distracted by thoughts unrelated to the task at hand, such as worrying about their final test grade (Shobe, Brewin, & Carmack, 2005).

SAT (MATH & READING)

Although many have looked at the relationships between fitness and academic achievement (Castelli, Hillman, Buck, & Erwin, 2007; Grissom, 2005) and physical activity patterns and academic achievement (for a review see Trudeau & Shephard, 2008), only a few studies have looked at the relationship between acute exercise and academic achievement (Mahar et al., 2006; Hillman et al., 2009). It was anticipated that students coming into the lab with higher state anxiety levels would receive higher scores on the academic achievement test following exercise, relative to their post-rest scores. Math scores were significantly higher after exercise than after rest for both groups. This result replicates other within-subjects studies of children in which academic math scores were higher post-physical activity than after no activity (Gabbard & Barton, 1979, McNaughten & Gabbard, 1993). Although not statistically significant, the mean difference in math score from post-rest to post-exercise was greater for high-trait anxious individuals than low-trait anxious individuals. There was a trend for high-trait anxious individuals to score higher on the reading exams than low-trait anxious individuals and previous research in children has associated acute aerobic treadmill walking with enhanced performance on a reading achievement test (Hillman et al., 2009). Although not statistically significant, the mean difference in reading score from post-rest to post-exercise was also greater for high-trait anxious individuals than low-trait anxious individuals. If there had been a more sensitive reading test or more participants, the current study may have also had significant results.

On average, most individuals performed well on the exams (better than chance). There are many possible explanations for why no significant group differences were seen. As all of the individuals had already taken collegiate entrance exams, these practice tests may have been familiar to them and they may have studied or recently taken courses on how to perform well on such exams. The practice tests were taken from year 2000 to avoid this problem (all but one or two of the participants would have been young enough that most would not have taken these exact exams for real, or in preparation for their own exams). Yet, there is always a possibility that these individuals had either seen these questions, or very similar ones, previously. If this is the case, the SAT practice tests may not have been sensitive enough to determine whether or not acute exercise could influence academic performance. The SAT practice exams were also very short and had a small range of scores, with many individuals receiving the same score for missing different types of questions. It may have been more practical to test these individuals on subject matter that they were currently studying. However, this would have complicated the comparison of results, as most participants had different areas of focus. It would have been quite difficult to normalize the scores across different participants and different tests, although *z*-scores could have been created.

It is possible that the SAT exams may have been too easy, as both groups were college students who had to perform well on such standardized exams in order to be accepted into the university in the first place, which could have led to a ceiling effect. An exercise session may have proven more effective in a group of younger individuals who had not yet been subjected to any college entrance exams. Subjective accounts by participants suggested that one of the versions of the SAT reading test was more interesting than the other. Maybe "how interesting" the SAT reading portion is helps or hinders performance on the questions. Katchmar, Ross, and Andrews (1958) found that high-trait anxious individuals took longer to complete a verbal coding task when under pressure; accuracy was also poorer for high-trait anxious individuals (as cited in Bowers, Weaver, & Morgan, 1996). In the present study, it would have been interesting to examine the length of time that it took individuals to complete the SAT exams to see if there were any group differences and to see if there was an inverse relationship between accuracy and completion time (they were given a maximum completion time of 15 minutes, with no minimum). It would also have been interesting to determine any differences in completion time in relation to condition. An important question to answer is what would happen in a test anxious population..

CORRELATIONS

Pearson product moment correlations were examined to see if reductions in state anxiety and/or improvements in cognition were significantly correlated with improvements in academic achievement. The whole premise on which this study was set was that by using exercise, one could reduce state anxiety and that if state anxiety was blocking people from being able to think clearly, it would make sense to see strong correlations between reduced SA and improved cognitive function (measures and SAT). However, it would have been beneficial to also analyze whether or not the relationships that were found were even stronger for high-trait anxious individuals than low-trait anxious individuals (meaning that this relationship would be more important for those individuals with high anxiety; exercise would be more effective for them because they would theoretically have more room for improvement due to anxiety-driven impairments). Since SA did not change much over time for the low-trait anxious group, one could assume that the significant relationships seen did relate more to high-trait anxious individuals (as their SA did change after exercise). Only significant relationships will be discussed in this section.

RELATIONSHIPS BETWEEN CHANGES IN STATE ANXIETY (SA) & ACCURACY

Accuracy on nontarget trials of the N0-back task, during the first round of cognitive testing was greater when SA increased from immediately post-rest to 35 minutes post-rest (r= .37, p=.042; refer to Table 36). Accuracy on target trials of the N0-back task, during the first round of cognitive testing, was greater when SA decreased from baseline to immediately post-exercise (r= -.38, p=.039; refer to Table 37). After rest, accuracy on target and nontarget (r= .40 p=.024; r= .52, p=.003; refer to Table 38) trials of the N1-back task was better during the second round of cognitive testing, when SA increased from 35 minutes post- to 70 minutes post-rest. Thus, when SA was at a relatively lower point on the continuum and this corresponded to the time at which an individual was completing the N-back task, performance was better. Accuracy on the N2-back task, during the second round of cognitive testing, was better when SA decreased from baseline to immediately post-rest (*r*= -.37, *p*=.041; refer to Table 40). It is plausible that if there was a large enough decrease in SA immediately post-condition, SA may have gradually approached an optimal level for N2-back task performance by the second round of cognitive testing.

RELATIONSHIPS BETWEEN CHANGES IN SA & REACTION TIME (RT)

RT on the incongruent trials of the Flanker task, during the second round of cognitive testing, was faster when SA decreased from baseline to immediately post-exercise (*r*=0.40, *p*=.032; refer to Table 43). RT on the N0-Back task during the second round of cognitive testing was faster when SA decreased following exercise (*r*=0.38, *p*=.036; refer to Table 45). RT to nontarget stimuli on the N1-Back task, during both rounds of cognitive testing, was faster when SA decreased following exercise (refer to Table 47 for Pearson product moment correlations and p-values). After exercise, RT to nontarget stimuli on the N2-back task was faster when SA decreased during the second round of cognitive testing (*r*=0.37, *p*=.043; refer to Table 49). Overall, RT appeared to be facilitated when SA decreased prior to cognitive testing. However, these correlations were not high strength, possibly because both decreased RT and decreased SA were artifacts of aerobic exercise participation. It is possible that decreases in RT were a result of increased movement time and closely associated to increases in arousal following exercise (Chang, Etnier, & Barella, 2009), possibly creating the illusion that SA changes contributed to changes in RT.

RELATIONSHIPS BETWEEN CHANGES IN SA & STANDARD DEVIATION OF RT

As SA decreased immediately post-exercise, N1-back StdRT to Nontarget stimuli decreased during the first round of cognitive tests (*r*=0.38, *p*=.040; refer to Table 55).

As SA decreased from immediately post-exercise to 35 minutes post-exercise, N1-back StdRT to nontarget stimuli also decreased during the first round of cognitive tests (r=0.43, p=.017; refer to Table 55) and N1-back StdRT to target stimuli during the second round of cognitive tests (r=0.39, p=.033; refer to Table 55). Thus, greater decreases in SA post-exercise were associated with greater decreases in N1-back response variability.

RELATIONSHIPS BETWEEN CHANGES IN SA & SCHOLASTIC APTITUDE TEST

When SA increased from immediately post-exercise to 35 minutes post-exercise, Math SAT scores improved, (r=0.39, p=.035; refer to Table 58). When SA increased from 35- minutes post-exercise to 70 minutes post-exercise, Math SAT scores improved (r=0.43, p=.019). These increases in SA appear to signify that SA had decreased significantly enough immediately post-exercise to have room to increase. Therefore, the important message that these positive correlations may provide is that SA was significantly low enough post-exercise, and that this may be the reason that enhanced math performance was seen. This could place the individual at their optimal level of SA for performance. If they had not been given the opportunity to reduce their anxiety in the first place it may have remained high and not had room to increase anymore.

RELATIONSHIPS BETWEEN COGNITIVE BEHAVIORAL MEASURES & SAT SCORES

After exercise, a significant moderate negative correlation was found between change in response variability to Incongruent stimuli on the Flanker Task during the second round of cognitive testing and change in Reading SAT score (r= -0.56, p=.002; refer to Table 59). This seems reasonable, because the Reading SAT exam was taken just prior to the second round of cognitive testing. Lower response variability was present around the time at which the individual took the Reading SAT exam, and may represent facilitated cognitive function, resulting in a greater Reading SAT score.

That being said, controversial results were seen in relation to response variability after exercise. Response variability increased for N0-back target stimuli during the second round of cognitive tests as Reading SAT scores increased (r=0.40, p=.027). As N0-back RT to target and nontarget stimuli slowed during the second round of cognitive tests and Reading SAT scores increased (r=0.39, p=.031; r=0.36, p=.049; refer to Table 60). The same occurred for N1-back RT to target stimuli and Reading SAT scores (r=0.47, p=.008; refer to Table 61). It could be that when RT slows following exercise, it is because the individual is more focused and paying more close attention to the task at hand (Barnes et al., 2010).

Larger changes in cognitive behavioral measures and SAT scores were expected for the high-trait anxious group. Some lack of significance could have been due to the small sample size (n=9). Many other factors could also have contributed to the absence of large changes. Unrecorded, subjective assessments of the participants' attitudes during the testing sessions suggested that the participants became tired over the course of the testing session, on both days. Comments made by participants indicated that individuals were feeling as if the session was "dragging on". Other comments made suggested that the participants were irritated about having a second round of cognitive tests post-condition. The lights being off during computer tests and the warmth and humidity of the room could also have contributed to some of the lethargy and lack of motivation to perform to their best abilities. Observation indicated that participants looked and acted physically tired towards the end of the session on both days. This may or may not have influenced performance during the second round of cognitive analyses. The testing sessions were indirectly designed to be long for one reason. It was necessary to see if any cognitive changes that may have occurred immediately post-condition were still present after a longer period of time post-activity. The second round of cognitive testing was used to assess this.

If cognitive enhancement does exist post-exercise, it is important to know how long such effects will last. If the individual is choosing to exercise specifically to reduce anxiety and perform better on an exam, do they have time to shower before going to take their test? Such questions help apply the basic results of this research to daily human practice.

CHAPTER 6

CONCLUSIONS

This study was an attempt to understand the relationships between exercise, anxiety, and cognition. Greater accuracy, faster RT, and smaller response variability have been assumed to be superior to their possible inverse cognitive responses (i.e., slower RT) to acute exercise. Clearly, these may not always be the most advantageous, in terms of superior cognitive performance, in all situations. However, such responses are commonly cited as reflective of facilitated cognition (Tomporowski, 2003). Reductions in state anxiety were seen in high-trait anxious individuals for both conditions. In the present study, high-trait anxious individuals had decreased state anxiety (SA) immediately post-condition, increased SA during the cognitive tests, and decreased SA at the end of the session. As hypothesized, SA of the high-trait anxious group decreased significantly more from baseline to immediately post-exercise than it did for the low-trait anxious group (in fact, the low-trait group had a very slight increase). Low-trait anxious individuals had less profound fluctuations in SA over time than high-trait anxious individuals. Overall, accuracy was fairly high for all tasks except for the N2-back task. RT was slower for tasks that were more difficult (i.e., incongruent and nontarget trials). Findings revealed generally greater accuracy, faster RT, and greater response variability for high-trait anxious individuals than low-trait anxious individuals on all tasks. However, these responses varied greatly depending on the condition and time of assessment. Exercise did show a trend towards facilitating cognitive performance, but failed to reach statistical significance on many accounts. However, this trend was not seen for N1-back and N2-back RT, because these were slower post-exercise for both groups. Thus, results are very inconclusive. Such results were not completely unexpected, as a recent meta-regression analysis determined that although acute exercise had a mean overall positive effect size of 0.20 in facilitating cognitive performance, the types of exercise and cognitive tasks used have variable results (Lambourne & Tomporowski, 2010). Math SAT scores were higher after exercise than rest, for both groups. A similar trend was seen for Reading SAT scores.

IMPLICATIONS

From the results of this study, and related research, aerobic exercise could be used as an economical therapy to help alleviate anxiety, improve cognitive function and academic achievement, and increase opportunities for individuals to advance in school and the work force, particularly for those burdened with high trait and state anxiety, along with other psychological impairments. Higher fitness, not performance of a bout of acute aerobic exercise, has been postulated as the primary reason for enhanced cognition (Stroth, Kubesch, Dieterle, Ruchsow, Heim, & Keifer, 2009). However, the present results demonstrate differential changes in cognitive performance variables in relatively high-fit individuals, on the basis of trait anxiety level. Clearly fitness has been shown to play a role in cognitive processing ability, but acute exercise participation should not be ruled out as a mechanism for cognitive enhancement.

Although aerobic exercise was studied in this experiment, the mode, duration, and temporal execution of acute exercise (in relation to the time of assessment) that will be associated with most dramatic changes in cognition is yet to be determined. It may be that acute aerobic exercise is not the best choice for cognitive enhancement. Anxiety does seem to be reduced by aerobic exercise participation. The anxiolytic effects of acute exercise appear to last 30-120 min post-activity (Bahrke & Morgan, 1978; Raglin & Wilson, 1996; Cox, Thomas, & Davis, 2000). However, it may be the case that anxiety reduction prior to cognitive examination has no effect on performance. It could also be the case that post-exercise assessment is not the best time to see positive changes in cognitive functioning. Exercising while learning or studying may produce different results depending on the intensity of exercise and the type of cognitive task; however, information processing tasks did seem to improve during steady-state exercise (Lambourne & Tomporowski, 2010).

Anxiety reduction does seem to be an effective strategy for enhancement of cognitive performance. Current approaches for anxiety reduction in testing situations involve pharmacological and cognitive-behavioral therapy approaches (Bekker & van Mens-Verhulst, 2007), or through altered environmental settings for students to take their tests. Anxiety-reduction in test anxious individuals has been positively correlated with academic performance enhancement; however, this is a moderate relationship and should be further investigated in terms of general state anxiety (Driscoll, 2007), and aerobic exercise was not previously used as the means of anxiety reduction. If anxiety is the sole moderator of cognitive impairment, then no additive effect will be seen. However, if the two (anxiety reduction and participation in aerobic exercise) act separately upon cognition, there may be an additive effect. Since both of these areas have conflicting opinions for how each independent variable influences cognitive performance, it is quite unclear whether additive enhancements, additive impairments, or neutralizing counterbalances would occur.

If additive enhancement of cognitive functioning can be determined in anxious individuals, it may serve as a source of motivation for individuals to exercise before important school exams or other cognitively taxing activities. If behavior begins to change so that acute bouts of exercise are performed more regularly, some may become chronic exercisers, which could result in ultimate reductions in their trait anxiety levels as chronic exercise has been associated with a 0.34 standard deviation reduction in trait anxiety (Petruzzello et al., 1991).

STRENGTHS

According to the meta-analysis by Lambourne and Tomporowski (2010) only 41% of studies involving post-exercise cognitive assessment have reported fitness (e.g., VO_{2max}) values for their participants. By reporting VO_{2peak}, the importance of physical fitness as a variable in acute exercise studies has been reaffirmed. This same meta-analysis also mentioned the lack of research on how cognitive performance changes over time in response to acute exercise and in comparison to a control condition, both of which were done in the current study. Although current attempts are being made to investigate aerobic exercise, cognition, and academic achievement, the area is still relatively new, leaving unanswered questions about whether or not acute bouts of activity can be used therapeutically, and if so, which populations would benefit most. The results from this study add to the knowledge base in these respects. The project was also novel in a broad sense, as it aimed to develop a new theoretical framework spanning multiple fields of study.

LIMITATIONS

The results presented here only describe how the populations of high- and low-trait anxious fit, young adults studied in this experiment would respond to acute aerobic exercise, and needs further exploration in individuals with test anxiety. According to Bowers, Weaver, and Morgan (1996), the emotional state of anxiety only occurs when the individual interprets that the stressful situation or stimulus needs to be avoided (p. 173). This leads one to question the motivations and study ethic that each group may have had when it came to standardized testing. It also leads to question whether or not this type of acute exercise intervention would have any profound effects in a high-trait anxious population, as compared to a test anxious population.

Participants were from a specific population (college students, mostly kinesiology majors) making generalization of results difficult. Future research should attempt to examine this relationship in youth, older adults, and individuals of different education levels. Since participants in this study may or may not have had any situation-specific state anxiety changes directly caused by “testing”, it would still be beneficial to perform this research in test-anxious individuals. An additional flaw may have been present in the research design, as the same versions of N-back and Flanker tasks were used during both cognitive testing rounds 1 and 2 on any given day. Even though versions were randomized by day, they were exactly the same within sessions, potentially allowing too much practice and corrupting results for the second round of testing on visits 2 and 3. Therefore, some time effects seen here may not be accurate.

Attrition Issues

A total of five individuals dropped out of the study. All were low-trait anxious. Four volunteers dropped out of the study after Visit 1: one female had overestimated the amount of time she could commit to the study before the end of the spring semester, and three (1 male, 2 females) never responded to follow-up e-mails or phone calls. One female made numerous cancellations and finally dropped out of the study after Visit 2 (resting condition), because she said she was too busy with finals and was a little worried about exercising for 34 minutes. If this study is to be replicated in the future, it is suggested that more time be set aside for recruitment, and if possible, money should be set aside for participant reimbursement. These two changes would be expected to increase sample sizes for both groups, high- and low-trait anxious.

FUTURE DIRECTIONS

From review of the literature, there appears to be a lack of anxiety research in testing situations. Few have attempted to explain the association between cognition and emotion. A meta-analysis discovered impaired long- and short-term visual and verbal memory and learning, executive function, attention, and processing speed in individuals with OCD, PTSD, Social Phobia, and Panic Disorder (Castaneda, Tuulio-Henriksson, Marttunen, Suvisaari, & Lönnqvist, 2008), but there appears to be a paucity of research on Generalized Anxiety Disorder (GAD) and cognitive impairment. It would be recommended that the current study be replicated in test-anxious individuals.

This exploratory work can hopefully serve as a pilot study for future research in individuals suffering from test anxiety. As the current study looked at general trait anxiety, it would be beneficial to determine whether or not similar or even more favorable changes in cognitive and academic performance are yielded in these individuals. It would also be beneficial to compare aerobic exercise to current standards for test anxiety intervention. This research area could also benefit from the formation of a well-established theoretical model of relationships between cognition, academic performance, exercise, and anxiety. It is the hope of this author that the proposed hypothetical model may spur interest in creating such a cumulative model. Many of these dual relationships have been investigated, but having an all-inclusive model could provide guidance to individuals studying other emotional-cognitive paradigms, elderly adults, children, and individuals with psychological disorders.

REFERENCES

Almeida, L., Kashdan, T. B., Nunes, T., Coelho, R., Albino-Teixeira, A., & Soares-da-Silva, P. (2008). Who volunteers for phase I clinical trials? Influences of anxiety, social anxiety and depressive symptoms on self-selection and the reporting of adverse events. *European Journal of Clinical Pharmacology, 64*(6), 575-582.

anxiety. (2010). In *Merriam-Webster Online Dictionary*. Retrieved May 6, 2010, from http://www.merriam-webster.com/dictionary/anxiety

Anxiety linked with a higher risk for certain chronic conditions. (July 2008). *Harvard Women's Health Watch*, © 2000-2011 Harvard University. Retrieved from https://www.health.harvard.edu/press_releases/Anxiety-linked-with-a-higher-risk-for-certain-chronic-conditions

Audiffren, M., Tomporowski, P. D., Zagrodnik, J. (2009). Acute aerobic exercise and information processing: Modulation of executive control in a Random Number Generation task. *Acta Psychologica, 132*, 85-95.

Augustine, A. A., & Hemenover, S. H. (2009). On the relative effectiveness of affect regulation strategies: A meta-analysis. *Cognition and Emotion, 23*(6), 1181-1220.

Backhouse, S. H., Ekkekakis, P., Biddle, S. J. H., Foskett, A., & Williams, C. (2007). Exercise makes people feel better but people are inactive: Paradox or artifact? *Exercise Psychology, 29*, 498-517.

Bahrke, M. S., & Morgan, W. P. (1978). Anxiety reduction following exercise and meditation. *Cognitive Therapy and Research, 2*(4), 323-333.

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 Science, 28(10), 1065-1076.

Basten, U., Steizel, C., & Fiebach, C. J. (2011). Trait anxiety modulates the neural efficiency of inhibitory control. *Journal of Cognitive Neuroscience*, 1-14. Early Access, posted Online March 10, 2011.(doi:10.1162/jocn_a_00003). © Massachusetts Institute of Technology.

Bekker, M. H. J., & van Mens-Verhulst, J. (2007). Anxiety disorders: Sex differences in prevalence, degree, and background, but gender-neutral treatment. *Gender Medicine, 4B*, S178-S193.

Borg, G. *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics, 1998.

Bowers, C. A., Weaver, J. L., & Morgan, B. B., Jr. (1996). Moderating the performance effects of stressors. In J. E. Driskell & E. Salas (Eds.), *Stress and human performance* (pp. 163-192). Mahwah, NJ: Erlbaum.

Castaneda, A. E., Tuulio-Henriksson, A., Marttunen, M., Suvisaari, J., & Lönnqvist, J. (2008). A review on cognitive impairments in depressive and anxiety disorders with a focus on young adults. *Journal of Affective Disorders, 106*, 1-27.

Castelli, D. M., Hillman, C. H., Buck, S. M., & Erwin, H. E. (2007). Physical fitness and academic achievement in third- and fifth-grade students. *Journal of Sport & Exercise Psychology, 29*, 239-252.

Chang, Y., & Etnier, J. L. (2009). Exploring the dose-response relationship between resistance exercise intensity and cognitive function. *Journal of Sport and Exercise Psychology, 31*, 640-656.

Chang, Y., Etnier, J. L., & Barella, L. A. (2009). Exploring the relationship between exercise-induced arousal and cognition using fractionated response time. *Research Quarterly for Exercise and Sport, 80*(1), 78-86.

Chisholm, D.M., Collis, M.L., Kulak, L.L., Davenport, W., Gruber, N., & Stewart, G. (1978). *PAR-Q Validation Report: The evaluation of a self-administered pre-exercise screening questionnaire for adults.* Vancouver, BC: Ministry of Health.

Claman, C. (Ed.). (2003). *10 Real SATs: Third Edition*. New York: College Entrance Examination Board.

Coe, D. P., Pivarnik, J. M., Womack, C. J., Reeves, M. J., & Malina, R. M. (2006). Effect of physical education and activity levels on academic achievement in children. *Medicine & Science in Sports & Exercise, 38*(8), 1515-1519.

Colcombe, S. J., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science*,*14*, 125-13

College Board. (2009). SAT. Retrieved from [http://www.collegeboard.com/student/testing/sat/about/SATI.html]

Cox, R. H., Thomas, T. R., & Davis, J. E. (2000). Delayed anxiolytic effect associated with an acute bout of aerobic exercise. *Journal of Exercise Physiology online, 3*(4) 59-66.

Cronin, L. (2005, December 7). Aerobic exercise and state anxiety: The moderating role of trait anxiety. *Clemson University-Psychology, Community of Undergraduate Journals Online.* Retrieved from http://cujo.clemson.edu/publication/show/16

Davranche, K., Hall, B., & McMorris, T. (2009). Effect of acute exercise on cognitive control required during Eriksen flanker task. *Journal of Sport and Exercise Psychology, 31*, 628-639.

De Moor, M. H., Boomsma, D. I., Stubbe, J. H., Willemsen, G., & de Gues, J. C. (August, 2008). Testing causality in the association between regular exercise and symptoms of anxiety and depression*. Archives of General Psychiatry, 65*(8), 897-905.

de Visser, van der Knaap, van de Loo, van der Weerd, & van den Bos. (2010). Trait anxiety affects decision-making differently in healthy men and women: Towards gender-specific endophenotypes of anxiety. *Neuropsychologia, 48*(6), 1598-1606.

Dennis, T. A., & Chen, C. (2008). Trait anxiety and conflict monitoring following threat: An ERP study. *Psychophysiology, 46*(1), 122-131.

Donner, E. (October, 2009). Definition of trait anxiety. Retrieved on May 1, 2010 from http://www.ehow.com/facts_5674194_definition-trait-anxiety.html

Driscoll, R. (2007) Westside Test Anxiety Scale Validation. Education Resources Information Center, pp. 1-5. Retrieved on April 18, 2010 from http://www.amtaa.org/res/svtxt.html

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (1999). Measuring state anxiety in the context of acute exercise using the state anxiety inventory: An attempt to resolve the brouhaha. *Journal of Sport & Exercise Psychology, 21*, 205-229.

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J (2005). Some like it vigorous: Measuring individual differences in preference for and tolerance of exercise intensity. *Journal of Sport & Exercise Psychology, 27*, 350-374.

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2008). The relationship between exercise intensity and affective responses demystified: To crack the 40-year-old nut, replace the 40-year-old nutcracker! *Annals of Behavioral Medicine, 35*, 136-149.

Etnier, J. L., Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., & Nowell, P. (1997). The influence of physical fitness and exercise upon cognitive functioning: A meta-analysis. *Journal of Sport & Exercise Psychology, 19*, 249-277.

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

Feingold, A. (1994). Gender differences in personality: A meta-analysis. *Psychological Bulletin, 116*(3), 429-456.

Gabbard, C., & Barton, J. (1979). Effects of physical activity on mathematical computation among young children. *The Journal of Psychology, 103*, 287-288.

Goldman-Rakic, P. S. (September, 1992). Working memory and the mind. *Scientific American*, pp. 11-117.

Gorfein, D. S., & MacLeod, C.M. "Chapter 1: The concept of inhibition in cognition." *Inhibition in Cognition.* World Composition Services, Sterling: VA, 2007.

Grissom, J. B. (2005). Physical fitness and academic achievement. *Journal of Exercise Physiology Online, 8*(1), 11-25.

Gualtieri, C. T., & Morgan, D. W. (2008). The frequency of cognitive impairment in patients with anxiety, depression, and bipolar disorder: An unaccounted source of variance in clinical trials. *Journal of Clinical Psychology, 69*(7), 1122-1130.

Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: the measurement of affect during exercise. *Journal of Sport & Exercise Psychology, 11*(3), 304-317.

Health & PA History Form (2010). Department of Kinesiology & Community Health, University of Illinois at Urbana-Champaign.

Hillman, C. H., Snook, E. M., & Jerome, G. J. (2003). Acute cardiovascular exercise and executive control function. *International Journal of Psychophysiology, 48*, 307-314.

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience, 159*, 1044-1054.

Hommel, B. (2003). Spatial asymmetries in the flanker-congruency effect: Attentional scanning is biased by flanker orientation. *Psychology Science, 45*(1), 63-77.

Howley, E. T., & Frakes, B. D. (2003). *Health fitness instructor's handbook: Fourth edition.* Champaign, IL: Human Kinetics.

http://www.amtaa.org/index.html

Humara, M. (September, 1999). The relationship between anxiety and performance: A cognitive-behavioral perspective. *Athletic Insight: The Online Journal of Sport Psychology, 1*(2), 1-14.

Kavussanu, M., & McAuley, E. (1995). Exercise and optimism: Are highly active individuals more optimistic? *Journal of Sport & Exercise Psychology, 17*(3), 246-258.

Kennedy, C. A., & Yoke, M. M. (2005). Methods of group exercise instruction. Champaign, IL: Human Kinetics.

Koltyn, K.F., & Morgan, W.P. (1997). Influence of west suit wear on anxiety responses to underwater exercise. *Undersea and Hyperbaric Medical Society,* 23-28.

Kramer, A. F., Erickson, K. I., & Colcombe, S. J. (2006). Exercise, cognition, and the aging brain. *Journal of Applied Physiol*ogy, *101*, 1237–1242.

Kyizom, T., Singh, S., Singh, K. P., Tandon, O. P., & Kumar, R. (2010). Effect of pranayama & yoga-asana on cognitive brain functions in type 2 diabetes-P3 event related evoked potential (ERP). *The Indian Journal of Medical Research* 131. 636-640.

Lambourne, K., & Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research, 1341*(23), 12-24.

Mathews, A., & Mackintosh, B. (1998). A cognitive model of selective processing in anxiety. *Cognitive Therapy and Research, 22*(6), 539-560.

Mahar, M. T., Murphy, S. K., Row, D. A., Golden, J., Shields, A. T., & Raedeke, T. D. (2006). Effects of a classroom-based program on physical activity and on-task behavior. *Medicine & Science in Sports & Exercise, 38*(12), 2086-2094.

McMorris, T., Sproule, J., Turner, A., & Hale, B. J. (2011). Acute, intermediate intensity exercise, and speed and accuracy in working memory tasks: A meta-analytical comparison of effects. *Physiological Behavior, 102*(3-4), 421-428.

McNaughten, D., & Gabbard, C. (1993). Physical exertion and immediate mental performance of sixth-grade children. *Perceptual & Motor Skills, 77*(3), 1155-1159.

Miller, G. (1995). How we think about cognition, emotion, and biology in psychopathology. *Psychophysiology, 33*, 615-628.

Moriya, J. M., & Tanno, Y. (2009). Dysfunction of attentional networks for non-emotional processing in negative affect. *Cognition and Emotion, 23*(6), 1090-1105.

Motl, O'Connor, & Dishman. (2003). Effects of cycling exercise on the soleus H-reflex and state anxiety among men with low or high trait anxiety. *Psychophysiology, 41*(1), 96-105.

National Institute of Mental Health. (2008). *The Numbers Count: Mental Disorders in America*. Online. Retrieved from http://www.nimh.nih.gov/health/publications/the-numbers-count-mental-disorders-in-america/index.shtml#Anxiety

Owen, A. M., McMillan, K. M., Laird, A. R., & Bullmore, E. (2005). N-back working memory paradigm: A meta-analysis of normative functional neuroimaging studies. *Human Brain Mapping, 25*(46), 46-59.

PAR-10-137: Behavioral and Social Science Research on Understanding and Reducing Health Disparities (R21). Retrieved from http://grants.nih.gov/grants/guide/pa-files/PAR-10-137.html#SectionIV1

Parvomedics TrueOne 2400. Sandy, UT, USA

Pellegrini, R. J., Hicks, R. A., & Lopez, J. C. (2008). Is there a multiple chance effect in human performance? A preliminary study of expected opportunity. *Current Research in Social Psychology, 13*(13), 154-160.

Peterson, P. (1977). Interactive effects of student anxiety, achievement orientation, and teach behavior on student achievement and attitude. Journal of Educational Psychology, 69(6), 779-792.

Petruzzello, S. J. (1995). Anxiety reduction following exercise: Methodological artifact or "real" phenomenon? *Journal of Sport and Exercise Psychology, 17*, 105-111.

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

Polar Electro. Polar Heart Rate Monitor, model Vantage XL, Finland. Copyright © Polar Electro Oy 2010. Retrieved from http://www.polar.fi/en

Pontifex, M. B., Hillman, C. H., Fernhall, B., Thompson, K. M., & Valentini, T. A. (2009). The effect of acute aerobic and resistance exercise on working memory. *Medicine & Science in Sports & Exercise, 41*(4), 927-934.

Post, D. (2003). CASE TEACHING NOTES for *The 2000 Meter Row: A Case Study in Performance Anxiety*. Retrieved on May 5, 2010 from http://www.sciencecases.org/crew_anxiety/crew_anxiety_notes.asp

Predicting your cardiorespiratory fitness level. (2007, July 27). McKinley Health Center. © The Board of Trustees of the University of Illinois. Retrieved from http://www.mckinley.illinois.edu/handouts/pdfs/cardiorespiratory_fitness.pdf

Raglin, J. S., & Wilson, M. (1996). State anxiety following 20 minutes of bicycle ergometer exercise at selected intensities. *International Journal of Sports Medicine, 17*(6), 467-471.

Ross, D. B., & Driscoll, R. 2006. *Test Anxiety: Age Appropriate Interventions.* Presentation made at the American Counseling Association Southern Region Leadership Conference: October 26th, 2006 in Huntsville, Alabama .

Sedlock, D. A., & Duda, J. L. (1994). The effect of trait anxiety and fitness level on heart rate and state anxiety responses to a mental arithmetic stressor among college-age women. *International Journal of Sport Psychology, 25*(2), 218-229.

Shobe, E., Brewin, A., & Carmack, S. (2005). A simple visualization exercise for reducing test anxiety and improving performance on difficult math tests. *Journal of Worry and Affective Experience, 1*(1), 34-52.

Slosman et al. (2004). Negative neurofunctional effects of frequency, depth, and environment in recreational scuba diving: the Geneva “memory dive” study. *British Journal of Sports Medicine, 38*, 108-114.

Sorg, B. A., & Whitney, P. (1992). The effect of trait anxiety and situational stress on working memory capacity. *Journal of Research in Personality, 26*(3), 235-241.

Spielberger, C. D. (1983). *Manual for the State-Trait Anxiety Inventory (Form Y).* Palo Alto, CA: Consulting Psychologists Press.

Spirduso, W. W. (2009). The influence of exercise on cognition in older adults. *Revista de Investigacion en Educacion, 6*, 195-198.

Spirduso, W. W., Poon, L. W., & Chodzko-Zajko, W. (2008). Exercise and its mediating effects on cognition. Champaign, IL: Human Kinetics.

Steptoe, A., Edwards, S., Moses, J., & Mathews, A. (1989). The effects of exercise training on mood and perceived coping ability in anxious adults from the general population. *Journal of Psychometric Research, 33*(5), 537-547.

Stroth, S., Kubesch, S., Dieterle, K., Ruchsow, M., Heim, R., & Keifer, M. (2009). Physical fitness, but not acute exercise modulates event-related potential indices for executive control in healthy adolescents. *Brain Research, 1269*, 114-124.

Surgeon General, 2000. http://www.surgeongeneral.gov/library/mentalhealth/chapter4/sec2.html

Takezawa, T., & Miyatani, M. (2005, October). Quantitative relation between conflict and response inhibition in the Flanker task. *Psychological Reports, 97*(2), 515-526.

Themanson, J. R., & Hillman, C. H. (2006). Cardiorespiratory fitness and acute aerobic exercise effects on neuroelectric and behavioral measures of action monitoring. *Neuroscience, 141*, 757-767.

Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta Pscyhologica, 112*(3), 297-324.

Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity, 5*(10), 1-12.

Wine, J. (1971). Test anxiety and direction of attention. *Psychological Bulletin, 76*(2), 92-104.

Appendix A: Informed Consent Document

The Informed Consent Document contains the information about the study and risks, benefits, and rights of participants. It may be found in a supplemental file named ICD.pdf.

Appendix B: Flyer

The Flyer was passed out and hung on bulletin boards during participant recruitment and can be found in a supplemental file named flyer.pdf.

Appendix C: Mass e-mail

The Mass e-mail was sent out to various departmental advisors on campus during participant recruitment and can be found in a supplemental file named email.pdf.

Appendix D: Physical Activity Readiness-Questionnaire (PAR-Q)

The PAR-Q was a questionnaire used to determine eligibility and safety of the participants in the study and can be found in a supplemental file named PAR-Q.pdf.

Appendix E: Health & Physical Activity History Inventory

The Health & Physical Activity History Inventory was a questionnaire used to collect data from the participants in the study and can be found in a supplemental file named HPAHI.pdf.

Appendix F: Feeling Scale (FS)

The Feeling Scale was a scale used to assess how participants were feeling during exercise and rest and can be found in the middle column of a supplemental file named FS.pdf.

Appendix G: Felt Arousal Scale (FAS)

The Felt Arousal Scale was a scale used to determine how aroused participants were during the study and can be found in the right column of a supplemental file named FAS.pdf.

Appendix H: Preference and Tolerance for Intensity of Exercise Questionnaire (PRETIE-Q)

The PRETIE-Q was a questionnaire used to determine participants' exercise habits and can be found in a supplemental file named PRETIE-Q.pdf.

Appendix I: Rating of Perceived Exertion (RPE) Scale

The Rating of Perceived Exertion Scale was a used to determine how hard participants felt that they were working during the study and can be found in the left column of a supplemental file named RPE.pdf.

Appendix J: State Anxiety Inventory (SAI)

The State Anxiety Inventory was a questionnaire used to assess state anxiety during the study and can be found in a supplemental file named SAI.pdf.

Appendix K: Trait Anxiety Inventory (TAI)

The Trait Anxiety Inventory was a questionnaire used to assess trait anxiety at the beginning of the study and can be found in a supplemental file named TAI.pdf.

Appendix L: Modified Flanker Task (Image & Instructions)

The Modified Flanker Task was used as a cognitive measure in the study. The Image was shown to participants to explain the task. The Instructions were used to describe the task. All can be found in supplemental file Flanker.pdf.

Appendix M: N-back Task (Image & Instructions)

The N-back Task was used as a cognitive measure in the study. The Image was shown to participants to explain the task. The Instructions were used to describe the task. All can be found in supplemental file Nback.pdf.

Appendix N: Practice Reading Scholastic Aptitude Test (SAT) (Versions 1 & 2)

The Practice Reading SAT test was used as a measure of academic performance in the study. Versions 1 and 2 can be found in supplemental file Read.pdf.

Appendix O: Practice Math Scholastic Aptitude Test (SAT) (Versions 1 & 2)

The Practice Math SAT test was used as a measure of academic performance in the study. Versions 1 and 2 can be found in supplemental file Math.pdf.